# INFLUENCE OF TUTOR BEHAVIOURS ON THE PROCESS OF PROBLEM-BASED LEARNING

ESTHER CHNG

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**Esther Chng**

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# Influence of Tutor Behaviours on the Process of Problem-Based Learning

Invloed van tutorgedrag op het proces van probleemgestuurd onderwijs

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**by**

**Chng Xue Li, Esther**
**Born in Singapore**

ERASMUS UNIVERSITEIT ROTTERDAM

**Doctoral Committee**

| | |
|---|---|
| Promotor: | Prof. dr. H.G. Schmidt |
| Co-Promotor: | Dr. E. H. J. Yew |
| Other members: | Prof. dr. H.T. van der Molen |
| | Prof. dr. D.H.J.M. Dolmans |
| | Prof. dr. T.A.J.M. van Gog |

*Dedicated to my parents and family*

# Contents


| | | |
|---|---|---|
| **Acknowledgements** | | 9 |
| **Chapter 1:** | Introduction | 11 |
| **Chapter 2:** | Is learning in Problem-based learning cumulative? | 27 |
| **Chapter 3:** | Effects of tutor-related behaviours on the process of problem-based learning | 55 |
| **Chapter 4:** | To what extent do tutor-related behaviours influence student learning in PBL? | 77 |
| **Chapter 5:** | Does social congruent behaviour contribute to the effectiveness of a PBL tutor? | 101 |
| **Chapter 6:** | Summary and conclusions | 123 |
| **References** | | 149 |
| **Appendices** | | 159 |
| **Propositions** | | 165 |
| **Curriculum Vitae** | | 167 |

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# Chapter 1: Introduction

The theme of this thesis revolves around the behaviours of the tutor in problem-based learning (PBL) and its effects on the learning in this approach. Although a substantial amount of research on PBL has been conducted over the years, it is still relatively unclear how learning takes place during the PBL process. In addition, factors that influence the learning process such as the quality of problems, the tutor and the use of scaffolds are areas that require greater investigation (Schmidt, Rotgans and Yew, 2011). With these considerations in mind, the research conducted in this thesis aims to deepen the understanding of what occurs during the actual learning process of PBL and in particular, the impact PBL tutors have on student learning.

Unlike the typical view of a teacher in the conventional classroom, students under the tutelage of a PBL tutor are taught not to be passive recipients of knowledge but are individuals who make their own decisions about the nature and structure of their learning (Barell, 2010). PBL tutors are expected to facilitate the learning process and to promote collaborative learning by encouraging students to actively participate in the classroom activities. Using a problem to trigger learning, students would tap on their prior knowledge to guide them in their investigations before applying the newly constructed knowledge to solve the problem. In addition, PBL tutors would aid in the scaffolding of learning, monitor the quality of learning and intervene when necessary (Schmidt *et al.*, 2011).

In view of the interactive nature between students and the PBL tutor, it can be hypothesized that what tutors do in the classrooms may have an effect on the learning process. There are three key behaviours of the PBL tutor that are often reviewed in the literature, namely, social congruence, subject-matter expertise, and cognitive congruence. These tutor-related behaviours and their influence on student learning would be studied in greater depth in this thesis.

In this chapter, a review of the current literature on PBL and the role of the PBL tutor will be examined before formulating a list of research questions that aid in guiding the investigation of this thesis. Towards the end of this chapter, an outline of what will be covered in the subsequent chapters will be presented.

## Why is there an interest in PBL?

As society continues to develop rapidly, organizations are forced to adapt to the environmental changes so as to remain competitive. For instance, globalization has created new opportunities for organizations to operate at an international level and advanced information technologies have improved the rate of information exchange. Ignoring such environmental changes would be destructive as they can affect the sustainability of an organization in the 21$^{st}$ century. Due to these developments, employers are constantly seeking to hire knowledge-based workers who are able to tackle these changes.

So what skills are necessary to handle these challenges in the 21$^{st}$ century? Living in the digital-age, it is unsurprising that there is greater demand for workers to possess technological literacy. However, besides being able to use multiple technologies, there is growing evidence that employers prefer workers who are proficient in critical thinking, problem solving, effective communication and team work (Paige, 2009). Creativity, leadership, adaptability and global awareness have also been cited as skills that are more crucial now than ever before as the challenges in the world today are increasing in complexity (Walser, 2008). This in turn has placed greater demand on educational institutions to develop individuals who are able to meet these expectations of a fast-changing global economy.

From a traditionalist viewpoint, educational institutions are designed for teaching students under the direction of teachers who imparted knowledge based on the agreed curriculum. However, over the years, educational research has indicated that possessing knowledge alone is insufficient as students may be unable to make appropriate use of what they have been taught (Schmidt, 1983). Together with the expectations to equip students with the 21$^{st}$ century skills, education policymakers are considering education reforms to address these issues. Although there is greater emphasis on these skills then before, it has been argued that these skills such as critical thinking and global awareness are not new skills, at least amongst the elites in the previous centuries. However, what is new is that success in the current day and age depends upon having such skills and therefore should not be confined to a group of individuals but they must become universal. In other words, these skills should be taught more intentionally and effectively in educational institutions (Rotherham and Willingham, 2010).

Student-centric methods have been favoured by advocators of the 21$^{st}$ century skills and PBL is a pedagogy that has become increasingly popular in developing workers for the 21$^{st}$ century. This is because PBL claims to provide a rigorous learning environment that not only allows learners to construct new knowledge but to train students how to apply the knowledge through the process of solving problems similar to those experienced at the workplace (Hmelo-Silver, 2004). In addition, the potential to develop social skills such as teamwork and communication through PBL supports its use and implementation in the classrooms as students have to work collaboratively to solve the problems. As the characteristics of PBL suggest that a rich learning environment that mirrors the workplace is provided for students, it is possible to conclude that PBL does help students develop skills that would prepare them to meet the demands of a changing workplace and society (Grabinger, Dunlap and Duffield, 1997).

## How do students learn in PBL?

Students in a PBL curriculum learn through the process of problem-solving as learning is driven by exposing students to real-life problems. This form of learning was developed in the late 1960's and has its roots in the medical field whereby students were tasked to solve real cases, conduct research and propose solutions for a wide variety of medical conditions. Despite remaining predominantly used in the medical and health science curriculum, PBL has since been adopted in other disciplines such as Business, Engineering and Law (Massa, 2008).

In a PBL classroom, students work in small collaborative groups to solve problems that are relevant to their domain of study. Through this problem-solving process, students would engage in discussions with their peers and build upon their prior knowledge to construct new knowledge. While working on these authentic problems, students will ask questions, conduct investigations, consider possible solutions, draw conclusions and reflect on their decisions (Barell, 2010). As these problems are often complex and without a single correct answer, it is believed that students would be able to learn both content and thinking strategies (Hmelo-Silver, 2004). Simultaneously, students learn to work in teams to achieve the common goal of solving the problem. Such a learning environment encourages learners to be active participants and an increased level of student engagement is believed to create a positive influence on learning. This can be supported by findings from a recent study where two groups of an undergraduate physics course were examined (Deslauriers, Schelew & Wieman, 2011). Students in the first group attended lectures conducted by a Noble Prize winning physicist while students in the second section were led by teaching assistants to solve real physics problems that they might encounter as a practicing physicist. The results indicated that students in the second section were more engaged and more likely to attend classes. In addition, their scores on a test averaged 74% as compared to an average score of 41% from students who attended the lectures, which suggests that learning is enhanced if students are engaged in the learning process (Deslauriers *et al.*, 2011).

Besides working in small collaborative groups, a significant amount of self-directed learning is usually involved with PBL (Prince, 2004). This is important because developing students as self-directed learners is essential so that they would be able to continue learning on their own for the rest of their lives (Das, Mpofu, Hasan & Stewart, 2002). These various components of PBL are weaved into the learning process comprising of three learning phases: problem analysis, self-directed learning and a reporting phase (Schmidt, 1983; Barrows, 1988; Hmelo-Silver, 2004). As students work in their small collaborative groups to examine the problem in the problem analysis phase, they utilize prior knowledge to identify learning issues and generate questions to help in the problem-solving process. In the self-directed learning phase, students refer to a variety of resources to search for relevant information that can be used to answer the questions raised. While students try to make sense of the gathered information, they share their views amongst their team and it forms the basis of brainstorming for possible solutions. By the reporting phase, the collaborative groups would have had sufficient time to synthesize and evaluate information, resulting in a proposed solution to the problem. As the groups share their findings, their peers are encouraged to raise questions and this helps the students to refine their original idea and hypotheses.

Through PBL, it can be expected that graduating students would have the domain knowledge and be more skilled in interpersonal communication, problem-solving and self-directed learning as compared to those from a conventional lecture-based environment (Schmidt, Vermeulen & Van Der Molen, 2006). Research has also shown that PBL is effective in equipping students with skills such as having the ability to work independently, possess good planning skills and ability to work under pressure, which are skills needed to prepare students for the workforce (Schmidt *et al.*, 2006; Vaatstra & De Vries, 2007). For these aforementioned reasons and more, it can be expected that interest in adopting the PBL pedagogy in educational institutions will continue to rise as it develops learners holistically.

Based on the description of the PBL process, it is evident that learning in a PBL curriculum is mainly student-centric. However, it is essential to note that a tutor is also present during the PBL process and their existence may have an influence on the learning process.

## What is the role of the tutor in PBL?

The role of the PBL tutor is qualitatively different from a teacher in a conventional classroom. As compared to teachers in a traditional curriculum, PBL tutors are often less content-driven and they view the process of learning as equally important to gaining knowledge. In view of this, PBL tutors must control their desire to impart knowledge and focus on the learning process instead in order to be effective (Wetzel, 1996). Rather than simply passing on information and providing direct instructions to students, the role of the PBL tutor is to model good strategies for learning and thinking so that learners can apply these strategies when they encounter similar situations in future (Hmelo-Silver, 2004).

During the learning process, the PBL tutor is present at the problem analysis and reporting phase. They are expected to play active roles in the scaffolding of student learning by assisting them in developing a framework that can be used to construct knowledge on their own. This allows students to foster the skills of critical thinking and habits of life-long learning (Das *et al.*, 2002). For students who are new to PBL, the tutor takes on more responsibility to aid students in developing learning scaffolds until they are able to create their own scaffolds. After which, the guidance provided by the tutor would begin to fade but the tutor continues to monitor the progress of the students (Hmelo-Silver, 2004).

To assist students in constructing learning scaffolds, the PBL tutor would ask questions to stimulate elaboration of concepts and encourage knowledge integration as well as interactions between students (De Grave, Dolmans & Van Der Vleuten, 1999). In addition, the tutor would probe students to think of possible solutions to the problem and model for them the kinds of questions that they should be asking themselves during problem-solving. As such, the relationship between the tutor and students can be viewed as a type of cognitive apprenticeship (Hmelo-Silver & Barrows, 2006; Schmidt & Moust, 2000; Collins et al., 1989). Therefore, in order to be effective in managing this cognitive learning process, it can be argued that the tutor should not only possess the relevant content knowledge, but also be skilled in facilitation, active listening, motivating learning, and critical reflection (Maudsley, 1999). In order to assess if a PBL tutor is able to perform their role effectively, it is necessary to examine their behaviours demonstrated in the classroom and how they influence students' learning.

## What kind of behaviours should tutors exhibit?

As mentioned previously, social congruence, subject-matter expertise and cognitive congruence are three key tutor-related behaviours that are often reviewed in the literature. In terms of social congruence, it is believed that this behaviour plays a key role in building a non-threatening learning environment as social congruence refers to the tutor's ability to interact informally with students. This in turn allows students to feel comfortable in voicing their views, which may ultimately enhance the learning process and result in better academic achievement (Schmidt & Moust, 1995).

The need for PBL tutors to be socially congruent can be supported by a study that explored students' perceptions on what makes a PBL tutor effective. The findings indicated that tutors, who respected the opinions of students, were able to establish good communications, understand students' feelings and advised them on how to learn, were deemed as effective tutors (Kassab, Al-Shboul, Abu-Hijleh & Hamdy, 2006). This indicates that possessing subject-matter knowledge alone is insufficient. Without a genuine interest in the lives and learning process of the students, the tutor would lack sensitivity to the difficulties faced by students, thus hindering their ability to guide students' learning. Furthermore, a study by Schmidt & Moust (1995) indicated that social congruence directly influenced group functioning during the problem-solving process and this may result in better student performance.

Besides social congruence, Schmidt and Moust (1995) also found that subject-matter expertise of tutors had a slightly direct positive impact on student achievement. Based on the common perception of the role of a teacher, it is natural to assume that effective PBL tutors should possess the relevant domain knowledge so that they are able to provide students with the necessary content knowledge and correct the misconceptions that are constructed. As a result of the guidance provided by a subject-matter expert, students are expected to have a better grasp of the concepts and in turn perform better academically. However, past studies focusing on the behaviours of tutors with subject-matter expertise and its effects on student performance remain debatable (Silver & Wilkerson, 1991; Schmidt, Van Der Arend, Moust, Kokx & Boon, 1993; Davis, Nairn, Paine, Anderson & Oh, 1992; Dolmans, Wolfhagen & Schmidt, 1996). For instance, Davis *et al.* (1992) found differences in the performance of students in favour of subject-matter experts, Dolmans *et al.* (1996) found that tutor expertise did not influence student achievement.

As a result of the conflicting findings on subject-matter expertise, other studies have shifted their focus to observe the behaviours of subject-matter experts in attempts to better understand the influence of a PBL tutor with relevant content knowledge. However, reports from various studies were also contradictory. A study conducted by Silver and Wilkerson (1991) suggested that tutors with subject-matter expertise took a more directive role in the PBL process, provided more direct answers to questions and contributed more during the discussions. In addition, a study by Schmidt *et al.* (1993) indicated that students guided by tutors with subject-matter expertise spent significantly more time on self-directed learning as compared to those guided by non-subject-matter experts, which indirectly may lead to better academic performance. However, Davis *et al.* (1992) could not identify behavioural differences in tutors with subject-matter expertise and those with lesser subject-matter knowledge.

Other than social congruence and subject-matter expertise, the study by Schmidt and Moust (1995) examined a third tutor-related behaviour termed as cognitive congruence. This behaviour can be defined as 'the ability to express oneself in the language of the students, using the concepts they use, and explaining things in ways easily grasped by students' (Schmidt & Moust, 1995, p.709). As such, cognitive congruence can also be viewed as a combination of subject-matter expertise and social congruence. Schmidt and Moust (1995) found that cognitive congruence was able to influence tutorial group functioning and this indirectly affected the level of student achievement through an increase in time spent on self-study. As a result, the authors concluded that a higher level of achievement can be attained through effective tutoring that requires not only the tutors' content knowledge but an ability to interact with students on a personal level as well as to utilize language that is easily understood by students (Schmidt & Moust, 1995). In another study that compared between faculty tutors and student tutors, the results indicated that faculty tutors used their subject-matter knowledge more extensively while student tutors were better able to identify with the difficulties students experience while dealing with the problem at hand (Schmidt, Van Der Arend, Kokx & Boon, 1994). This suggests that the student tutors were more cognitively congruent as compared to the faculty tutors, which allows them to better understand the nature of the problems faced by students and to respond more appropriately by using prompts that are more easily understood (Dolmans, Gijselaers, Moust, De Grave, Wolfhagen & Van Der Vleuten, 2002).

Using the structural equations modelling approach, Schmidt and Moust (1995) proposed that tutors who are more cognitively congruent would utilize subject-matter knowledge in a better way and be more socially congruent, which ultimately translates into higher student performance. This is because the problem-solving process would function better resulting in students being more interested in the subject matter and spending more time on self-directed learning (Schmidt & Moust, 2000). However, if the content expert is also able to guide students back onto the right track by discovering and learning from their own mistakes as well as reasoning their way to the desirable conclusions, then the PBL tutor would be more effective in developing students as self-directed learners. This is because a lack of the domain knowledge can make it difficult for the tutor to follow student discussions as well as to actively contribute to it and without an interest in the students the tutor would not be stimulated to encourage students to complete the problem-solving process (Schmidt & Moust, 2000).

The findings on the effect of the tutor's social congruence, subject-matter expertise and cognitive congruence on student achievement remain ambiguous. However, there is a general consensus that these behaviours do have an effect on students achieving the curricular outcomes. Yet, their influence on the PBL process remains unclear.

## What are my research questions?

A review of the current literature has indicated that tutor-related behaviours appear to have an effect on student achievement. However, little is known about how learning takes place as a student progresses through the different PBL phases and how the behaviours of the PBL tutor affects their effectiveness in facilitating the learning process. Hence, the following research questions were designed and used to guide the development of the investigation in this thesis.

- As student progress through the different learning phases of the PBL process, is learning dependent on what was learnt in the previous phase?
- How can learning at each PBL phase be measured?
- What behaviours make a PBL tutor effective in facilitating the learning process?
- Do the behaviours of the tutor influence learning at each PBL phase? If so, to what extent do the tutor-related behaviours influence learning during the PBL process?
- Amongst subject-matter expertise, social congruence and cognitive congruence, is there a particular tutor-related behaviour that has a greater influence on the learning process?

## Outline of thesis

The subsequent chapters in this thesis aim to address the research questions listed above and a concluding chapter would consolidate the findings from the studies that were conducted. All of the studies were conducted at the same tertiary educational institution in Singapore where PBL is used as the baseline pedagogy for all of its diploma courses. However, unlike other institutions, the implementation of PBL at this polytechnic is somewhat different whereby the entire PBL process is completed within a day (Yew and O'Grady, 2012). Students are introduced to a problem at the start of the day and are expected to report their proposed solution to the problem by the end of the day. Within the day and under the guidance of a tutor, students would engage in peer learning and self-study to grapple the concepts related to the problem.

In Chapter 2, the main focus was to examine how students learn during the PBL process. Learning is believed to be a cumulative process where new learning builds upon what was learnt previously. As such, this study investigated each learning phase and sought to understand if learning was dependent on the previous phase or if there was a particular learning phase that was more important than another. In order to do so, a method to measure student learning at each of the PBL phases was developed and the measurement tool was termed as the *concept recall test*. These tests required students to recall keywords that were related to the topic for the day. Besides measuring student learning at each PBL phase, an essay test was conducted at the end of the reporting phase to measure student achievement. As students were asked to elaborate on their understanding of the topic, it was possible to assess if students had understood the concepts they had learnt. Using the structural equations modelling approach, the data was analysed and the findings indicated that learning in PBL was cumulative whereby learning in one phase is influenced by what was learnt in the previous phase. In addition, the results proved that the methodology used to measure students' learning process and achievement was efficient and valid.

Following the successful development of the methodology described in Chapter 2, the remaining studies in Chapters 3, 4 and 5 utilized this method to explore the effect of the tutor's subject-matter expertise, cognitive congruence and social congruence on student learning during the PBL process. In Chapter 3, the aim of the study was to explore the effects of the tutor-related behaviours on student learning and to identify if there was a particular behaviour that had a greater influence on learning as compared to another. Tutors were randomly selected to be part of the study and the effects of their behaviours on the PBL process were examined. Although all three tutor-related behaviours were found to have a significant effect on student achievement, the findings indicated that the social congruent behaviour of the tutor had a significant influence on learning during the PBL process.

Based on the findings from the study in Chapter 3, further investigation on the effects of the tutor's social congruent behaviour were examined in Chapters 4 and 5. In attempts to ensure that a more distinct difference between the tutor-related behaviours was studied, tutors were handpicked to participate in the study instead of being randomly selected. In Chapter 4, tutors were chosen based on their student ratings from a questionnaire that measured tutor behaviours. The ratings either indicated that the tutors exhibit high levels of subject-matter expertise, cognitive congruence and social congruence or they exhibit low levels of these behaviours based on the students' perceptions. Therefore, the study involved exploring if the tutors exhibiting high levels of these behaviours, particularly social congruence, were more effective in tutoring the learning process. However, a change in the behaviours of the tutors was observed when they tutored a different group of students, resulting in a smaller difference between the tutor-related behaviours from both group of tutors. Hence, this led to findings that were not as straightforward as those obtained in Chapter 3.

The study in Chapter 5 was a continuation of Chapter 4 to further examine the effects of tutors exhibiting high or low levels of social congruence. However, instead of selecting different tutors to form the high and low groups, tutors who are known to display high levels of social congruence were asked to mimic the behaviours displayed by tutors in the low social congruence group by controlling their behaviours. This minimized the amount of natural variations that may occur when different tutors are used and it was an attempt to conduct a controlled experiment in a natural educational setting.

The final chapter provides an overview of the findings from the research conducted for this thesis. It highlights how each of the studies has attempted to answer the research questions raised and also suggests possible areas for future research. Through these studies, more insights will be gained about the PBL process and to what extent the PBL tutor influences the learning process. This would ultimately provide a better understanding on the PBL process so as to seek ways to enhance learning and develop learners in a PBL curriculum more effectively.

# Chapter 2: Is Learning in Problem-based learning Cumulative?[1]

## Abstract

Problem-based learning (PBL) is generally organized in three phases, involving collaborative and self-directed learning processes. The hypothesis tested here is whether learning in the different phases of PBL is cumulative, with learning in each phase depending on that of the previous phase. The scientific concepts recalled by 218 students at the end of each PBL phase were used to estimate the extent of students' learning. The data were then analyzed using structural equation modeling. Results show that our hypothesized model fits the data well. Alternative hypotheses according to which achievement is predicted either by collaborative learning alone or by self-directed learning alone did not fit the data. We conclude that the learning in each PBL phase is cumulative, and strongly influenced by the earlier phase, thus providing support for the PBL cycle of problem analysis, self-directed learning, and a subsequent reporting phase. We also demonstrate an efficient method to capture and quantify students' learning during the PBL process.

## Introduction

Educators have long been advocating 'active' learning whereby students are engaged in meaningful activities as part of their learning process. Active learning has been generally defined as any instructional strategy that involves "students in doing things and

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thinking about what they are doing" (Bonwell & Eison, 1991, p. 2). Given such a broad definition, active learning can be viewed as encompassing a wide variety of instructional methods. Although various studies have demonstrated the effectiveness of promoting student engagement using interactive-engagement methods compared to those in traditional courses (reviewed by Michael, 2006; Prince, 2004), questions about *how* students learn while being actively engaged, both individually and when in collaborative small groups, remain to be further investigated.

Generally learning is thought to be a cumulative process where new learning builds upon knowledge acquired in a previous phase. In the case of active learning, it is assumed that both collaborative learning episodes and individual self-directed study phases play important roles in students' learning. Although the idea that new learning is dependent on what has been learned previously is almost universally accepted, demonstrations of its truth have been largely confined to the psychological laboratory, particularly in the field of text processing (e.g., Bransford & Johnson, 1972; Kintsch & Van Dijk, 1978). To our knowledge, no natural classroom demonstration of the cumulative nature of learning exists to date. Moreover, since social constructivism suggests that knowledge is mainly constructed by means of collaborative interactions (e.g., Cobb, 1994; Driver, Asoko, Leach, Mortimer, & Scott, 1994), it is possible that the effects of active learning on achievement are really only due to the group interactions and co-construction of knowledge. Alternatively, since research on self-regulated learning has shown that the use of self-regulated learning strategies strongly influences academic achievement (Zimmerman, 1990), it can be argued that it is the individual self-directed learning phase that is most important to students' learning.

The purpose of this paper therefore is find the extent to which active learning is cumulative and whether it involves both collaborative and self-directed learning, in the context of problem-based learning (PBL). PBL is an example of an active-learning approach in which students are given the opportunity to learn independently as well as collaboratively, while understanding an ill-structured problem. It was originally developed in medical schools to help students integrate basic science and clinical knowledge, as well as to develop clinical reasoning and lifelong learning skills (Barrows, 1986). However it is now of increasing interest to educators of various levels and disciplines (Gallagher, Stepien, & Rosenthal, 1992; Kolodner et al., 2003) as it provides a structured framework of active and collaborative learning, in line with current understanding of learning as a constructive and co-constructive activity involving social interactions (Glaser & Bassok, 1989; Palincsar, 1998). As will be described in greater detail later on, PBL involves a sequential series of learning phases that emphasizes collaborative and individual self-directed learning at different points in time. The assumption underlying PBL is that learning in the PBL process is cumulative − learning in one phase is dependent on the previous, and also that both co-construction with peers and individual construction of concepts during self-directed study contribute to student learning (Schmidt, 1983). We therefore seek to test the assumptions regarding the nature of learning in PBL, by tracing the learning process of students throughout all the phases of PBL. The central thesis to be tested is whether learning in the different phases of PBL is cumulative − does the learning in each phase depend on the previous phase? Or are some phases of the PBL process more (or less) important than others? Secondly, we also seek to understand how students learn in the different phases of PBL in terms of concept acquisition and elaboration. A third objective is to devise an efficient and valid method to track students' learning as it unfolds in the course of the PBL process.

*The PBL Process*

PBL always starts with a problem, for which students do not prepare beforehand. After the description of the problem is given to small groups of students, they first analyse the problem, generate possible explanatory hypotheses, build on one another's ideas, as well as identify key issues to be studied further. These activities allow students to construct a shared initial explanatory theory or model explaining the problem-at-hand based on their prior knowledge (Schmidt, 1983). After this period of teamwork, they disperse for a period of individual study to work on learning issues they have identified as a group. When they next meet as a team during what is called the "reporting phase", they are expected to share and discuss their findings, as well as refine their initial explanations based on what they have learned. Students would then move on to analyse a new problem, or if new learning issues requiring further study are identified during this phase, the process described above would be repeated. Thus, PBL can be seen as a cyclical process consisting of three phases: initial problem analysis, self-directed individual learning, and a subsequent reporting phase (Barrows, 1988; Hmelo-Silver, 2004; Schmidt, Van der Molen, Te Winkel, & Wijnen, 2009). A tutor is present to guide students' learning in the problem analysis and reporting phases. The tutor's role is to facilitate the processes involved when students co-construct knowledge through discussions and sharing of ideas (Hmelo-Silver & Barrows, 2006). In PBL, both group and individual learning processes are recognized to play important supplementary roles in students' learning (Schmidt & Moust, 2000; Van den Hurk, Dolmans, Wolfhagen, & Van der Vleuten, 2001).

*How Students Learn in the Process of PBL*

Various studies have focused on how students learn in the different phases of the PBL cycle. The initial problem analysis activates students' prior knowledge and allows them to relate new information in the problem to their existing knowledge. Hearing what other students elaborate upon could also serve to activate or uncover the less accessible prior knowledge in the listeners. Studies by De Grave, Schmidt, & Boshuizen (2001) and Schmidt, De Volder, De Grave, Moust and Patel (1989) have demonstrated that elaboration during problem analysis in a small group prior to studying problem-relevant new information resulted in increased knowledge acquisition and recall. As argued by De Grave, Boshuizen and Schmidt (1996), such elaboration and activation of existing knowledge are instrumental in restructuring and transferring concepts resulting in the construction of new knowledge and ideas. The process of discussion during the problem analysis phase would also result in students realizing the gaps between their existing knowledge and what they are required to know in order to respond to the problem. Thus students would identify these gaps as learning issues to be studied further during the self-directed learning phase. This individual study phase is a key feature in PBL, in line with its underlying "student-centered" philosophy of enabling students to take responsibility for their own learning by deciding what to study and to what extent. Through the self-directed learning phase, students learn important skills such as goal setting, planning and self-control in terms of time and task-management (Zimmerman, 2002). As students implement their course of actions to achieve their goals, they would also have to monitor and reflect on their own progress, thus exhibiting a kind of feedback loop in the process (Hmelo-Silver, 2004; Zimmerman, 1990).

When the tutorial group reconvenes to report their findings and the results of their individual study, opportunities are given to students to present, explain and defend their ideas, and in the process, to restructure or refine their own knowledge networks (Schmidt & Moust, 2000). The discussions during the reporting phase are centered on students' response to the problem statement given in the problem analysis phase. Studies have shown that group interactions such as elaborations and co-constructions take place during this phase, allowing for collaborative knowledge construction (Hmelo-Silver & Barrows, 2008; Visschers-Pleijers, Dolmans, Wolfhagen, & Van der Vleuten, 2004; Yew & Schmidt, 2008).

*Factors Influencing Students' Learning in PBL*

A few studies have examined and tested how the variables thought to be active in PBL influence and relate with one another and students' learning outcomes. Gijselaers and Schmidt (1990) tested a path model relating input variables such as the quality of problems, tutor performance and students' existing knowledge, process variables such as group functioning and time spent on self-directed study, and the outcomes of learning. They demonstrated that problem quality influences tutorial group functioning, which in turn had an influence on the amount of time spent in individual study. More time put into individual study led to increased academic achievement. This model was further refined by Van der Hurk, Dolmans, Wolfhagen, & Van der Vleuten (2001). They investigated in more detail what actually happens to learners during problem analysis, individual study and reporting. They found that the quality of learning issues generated during the problem analysis phase had an impact on the extent to which the learning issues were used during individual study. Increased usage of learning issues during self-directed study also influenced students' research to be more explanation-oriented, which in turn led to a "deeper discussion" during the reporting phase. Finally the depth of reporting led to a higher score on an achievement test.

Both of these tests of a causal model provide insight into the relationships between the variables important in the PBL process and hence into how students learn in PBL. In particular, the study by Van der Hurk et al. suggests that learning in PBL is indeed cumulative. Their study demonstrates that learning in the problem analysis phase influences individual study, which in turn influences the reporting phase, and finally achievement. However, as recognized by the authors, a limitation to both studies was that data were obtained based on students' perceptions and retrospective self-report rather than on their actual behaviors. As argued by Dolmans & Schmidt (2006), and Hak & Maguire (2000), the research required to uncover the relationships between aspects of the tutorial process and students' learning should be focused on the *actual* activities occurring in the various phases of PBL.

Some studies have used direct observational methods to examine how and what students learn during PBL. One observational study focusing on the content of the learning-oriented interactions of students was conducted by Yew and Schmidt (2008). Here the verbal interactions taking place in an entire PBL process were audio recorded and analyzed qualitatively. While the results demonstrated that PBL stimulates constructive, self-directed and collaborative learning processes, no relationships between the content of their interactions with subsequent learning were reported. In addition, due to the data- and time-intensive nature of the methodology involved, the sample size used in the study was limited, thus making statistical analysis difficult. A recent study by Hmelo-Silver and Barrows (2008) analyzed in detail the knowledge building process in a PBL tutorial by examining the discourse of students and facilitator throughout both the problem analysis and reporting phase of a PBL tutorial. This was carried out by videotaping five students as they worked on a problem for more than

5 hours in two separate sessions. The study demonstrated how an expert facilitator guided the group discourse with the use of open-ended metacognitive questions, and how students actively worked on enhancing and refining their collective knowledge throughout the group interaction portions of a PBL cycle. However this study again did not relate the quality of students' verbal contributions to outcomes of their learning.

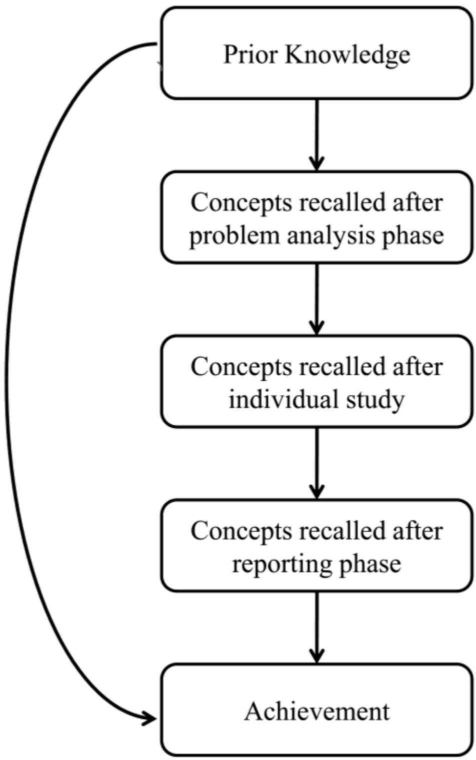
There have been several other attempts to trace the learning process in PBL. Visschers-Pleijers, Dolmans, de Leng, Wolfhagen, & Van der Vleuten (2006) made use of video recording while other researchers have made use of stimulated recall (De Grave et al., 1996), and thought sampling (Geerligs, 1995) to provide qualitative descriptions of the actual behaviors and activities in a PBL tutorial. The difficulty of such approaches is that they do not easily allow for the quantification of learning. In addition, they are so data-intensive that studying larger numbers of students becomes almost impossible. A case in point is our own previous attempt to study and identify the relationships between learning activities of students in PBL with their learning outcomes (Yew & Schmidt, 2008). We recorded all verbal interactions of two groups of students for an entire PBL cycle. In addition, we logged all their individual study activities, which were conducted through the use of computers. The resulting protocols, consisting of around 72 hours of material were segmented into 'idea units' consisting of the scientific ideas that were exchanged and studied (Meyer, 1985). The units of analysis selected were the relevant scientific concepts found in the protocols as expressed by the individual students during discussion and encountered during individual study on the internet (more about the relevance of scientific concepts for studying learning online in Method section). We identified and counted the relevant scientific concepts articulated by each student during the different PBL phases and those they studied individually while working on the problem-at-hand. By analyzing the number of concepts acquired over the different learning phases for the nine students two distinct phases in the PBL process were identified − an initial concept articulation phase, in which students are exposed to and articulate new ideas, and a later concept repetition phase, in which ideas acquired seem to be repeated and elaborated upon. Given the small number of students involved, however, further statistical analysis of the data proved impossible. A second study using the same methodology included a larger sample size of 35 students and thus enabled us to analyze the quantitative relationships between students' verbal interactions during different phases of the problem-based learning cycle, self-directed study, and achievement, using a structural equation modeling approach. Our results showed that students' verbal contributions through collaborative discussion during the initial problem analysis phase strongly influenced the extent of their verbal contributions in the reporting phase. Greater contribution of relevant concepts verbalized during the reporting phase also led to higher achievement at the end of the PBL cycle.

The methodology as used in these studies assumes that exposure to (from computer screen recordings of internet study resources) or the articulation of a concept during discussion can be considered a proxy of the learning taking place. However it is possible that students may not really understand the concepts they were verbalizing, or could be simply scanning the computer screens without seriously studying the material before them. In addition, the recording and transcription of all the learning activities throughout a PBL cycle turned out to be extremely time-consuming, thus limiting the sample size that could be utilized for each study.

To our knowledge, no natural classroom demonstration of the cumulative nature of learning exists to date. Moreover, since social constructivism suggests that knowledge is mainly constructed by means of collaborative interactions (e.g. Cobb, 1994; Driver et al., 1994), it is possible that the effects of active learning on achievement are really only due to the group interactions and co-construction of knowledge. Alternatively, since research on self-regulated learning has shown that the use of self-regulated learning strategies strongly influences academic achievement (Zimmerman, 1990), it can be argued that it is the individual self-directed learning phase that is most important to students' learning.

The purpose of this paper therefore is find the extent to which active learning is cumulative and whether it involves both collaborative and self-directed learning, in the context of problem-based learning (PBL). Figure 1 summarizes our hypothesized relations in terms of a causal model. We hypothesized that learning in PBL is a cumulative process where the learning in each new phase builds upon knowledge acquired in a previous phase. The process is initially driven by the prior knowledge that students bring with them to the classroom and the learning in each of the PBL phases influences student achievement.

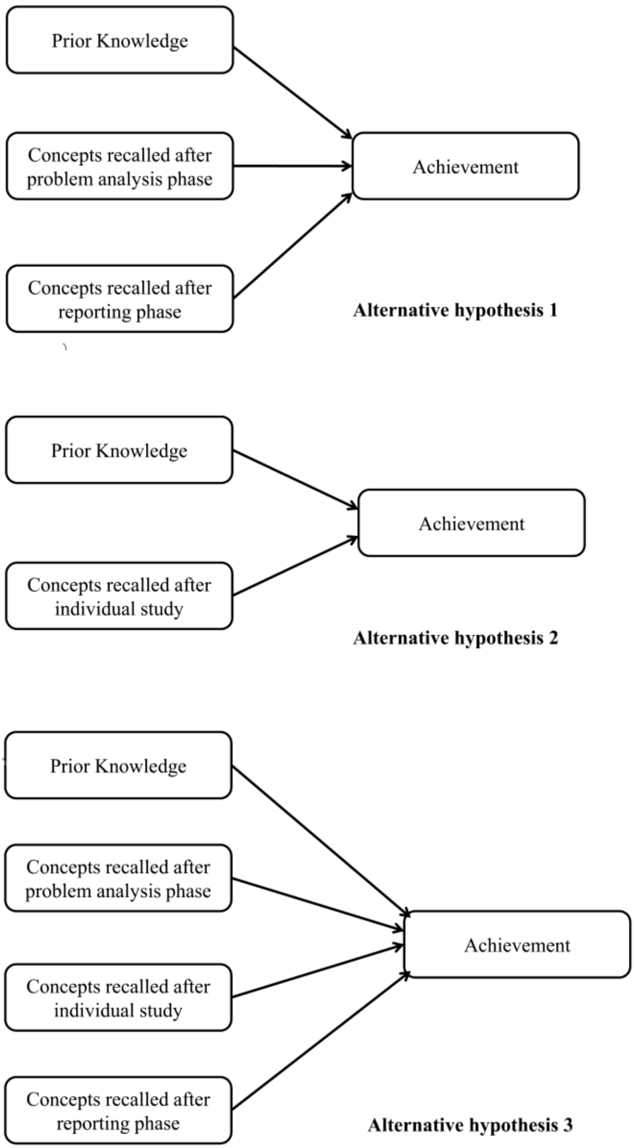
*Figure 1*. Hypothesized model on the relationships between the different learning phases of PBL



As mentioned earlier, it could be argued that the effects of active learning on achievement are mainly due to the group interactions and co-construction of knowledge or alternatively, that it is the individual self-directed learning phase that is most important to students' learning. We therefore test our hypothesis against these alternative hypotheses: (1) Learning in PBL is only influenced by phases involving collaborative learning and co-construction; (2) Learning in PBL is only influenced by self-directed study; and (3) Learning in PBL is influenced by both collaborative learning as well as self-directed study, but not in a sequential cumulative manner. These alternative models are summarized in Figure 2.

Secondly, we hypothesize that the different PBL phases would involve the acquisition of new ideas (concepts) and the elaboration of previously acquired concepts to different extents. In an earlier preliminary study involving only nine students, we have shown that two different phases of the PBL process could be observed: an initial *terminology articulation* phase − consisting mainly of the problem analysis phase and initial SDL period, and characterized by the emergence of new concepts articulated and studied online, and secondly, a *terminology repetition phase* (mainly the later part of the SDL phase) where relevant concepts are repeated (Yew & Schmidt, 2008). Here we aim to test this "acquisition-elaboration theory" of learning in PBL again, this time using a larger sample size. Finally, an important auxiliary issue is: How can students' learning be recorded as it unfolds? Through this study, we also aimed to develop and evaluate an efficient method to capture and quantify students' learning during the PBL process so that causal relationships in the PBL process can be identified through path analysis.

*Figure 2.* Alternative models on the relationships between the different learning phases of PBL



## Method

*Participants*

Participants were 218 students from 11 randomly selected classes. The students were in their second year in the School of Applied Science at a polytechnic in Singapore. Data were collected from these students during the third week of their Molecular Cell Biology class. As they had already completed one year of study in the polytechnic, students were not new to the PBL approach described below. Students and facilitators gave informed consent.

*Educational context*

The PBL process adopted at this polytechnic is somewhat unique in its “One-day-one-problem” approach. Here students work on one problem per day. Each class has a maximum of 25 students working together in teams of five. A brief description of the day’s process is described below:

- Problem analysis phase (approximately 1 hour): The facilitator presents the problem for the day. Students work in teams of five to identify their prior knowledge and learning issues.

- Self-directed learning (SDL) period (approximately 4 hours): Students do individual study or work with their teams on worksheets and other resources provided. They are also able to access other resources from the internet or textbooks. Time is spent helping one another within the team when necessary. Students meet with their facilitator for about 20 minutes in between this period to share their learning progress and strategy of understanding the problem.

- Reporting phase (approximately 2 hours): Each team presents their consolidated findings and response to the problem, defending and elaborating based on questions raised by peers and the facilitator. The team presentation is usually in the form of powerpoint slides and the facilitator would also clarify key ideas if necessary.

Although the PBL process in this institution was adapted to suit the learning needs of the students and is completed within one day, it remains classified as PBL based on the "six core characteristics of PBL" described by Barrows (1996). The characteristics include student-centred learning whereby students work in small groups under the guidance of a tutor who facilitates the learning process. Problems are used as the stimulus for students' learning with no opportunities to prepare beforehand. Furthermore, facilitators do not provide direct instruction. Instead, students construct their own understanding through self-directed learning (Hmelo-Silver, 2004). An additional feature of the PBL approach in this context is that instead of only individual study during the self-directed learning phase, peer consultation and collaboration also takes place during this time.

*Procedure*

A concept recall exercise was designed to estimate the number of relevant concepts that students were able to recall at the end of each PBL phase: problem analysis, self-directed learning and reporting. Our assumption is that as students engage in problem analysis, self-directed learning, group discussions, and/or peer teaching, they would be building networks of concepts related to the different learning issues as well as making relations between their prior knowledge and new ideas (Glaser & Bassok, 1989). A beginner's initial network would consist of a few isolated concepts or ideas that are poorly connected. Therefore, if asked to retrieve relevant concepts from these cognitive structures, his or her memory will be limited. The more students have learned about a topic, the richer, more coherent, and more detailed this particular network would be (Glaser & Bassok, 1989). As learning progresses, more linkages and integration between new and existing ideas are constructed. Therefore, students who have learned more effectively would be able to recall more concepts and would do that more easily (Collins & Quillian, 1969; Rumelhart & Norman, 1978). Hence, measuring the number of relevant concepts students were able to recall in regards to the problem-at-hand at the end of each learning phase gives an indication of the quality of students' learning, as well as the concepts they were exposed to either from what they had read or discussed during that phase.

The concept recall exercise was given to the students three times in the day − at the end of the problem analysis phase, self-directed learning and reporting phase. It consisted of the following instruction: "List all the keywords or terminologies that are related to DNA and/or RNA." (Understanding the structure of DNA and RNA was the focus of the particular day's learning.) Students were instructed to only list concepts or keywords 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.

*Materials*

The problem statement for the day was entitled "Made for the Job" and it introduced students to concepts related to the structures and functions of DNA and RNA. A week prior to the problem, students were given an essay pre-test consisting of the following instruction:

"Describe and explain as much as you know about the structure of DNA and RNA." This was to measure students' prior knowledge in regards to the topic. The same essay question was administered as a post-test immediately after the day's problem to measure students' learning achievement. No time limit was set but students were instructed to complete the test on their own without referring to any resources. The problem statement is presented in Appendix A.

The "idea unit" was used as the entity for scoring the free recall essay tests for accuracy (Meyer, 1985; Schiefele & Krapp, 1996). Answers were segmented into idea units, which was defined as a statement ending with a comma, period, or "and". A score of 2, 1 or 0 was awarded to each idea unit. A score of 2 was given for a completely correct idea unit, 1 for a partially correct idea unit and 0 when the idea unit was completely incorrect. The first and second authors independently scored about 20% of the tests with inter-rater correlation of $r$ = .91. The remaining tests were scored by the first author.

*Analysis*

Students' answers to the concept recall procedure were analyzed by awarding 1 point to each relevant concept given by the student. These concepts (keywords and terminologies related to DNA and RNA) were agreed upon by the first and second authors before rating. Both authors have expertise in the field of molecular and cell biology. All the concepts were then rated by both authors and checked for differences. As the keywords and terminologies related to DNA and RNA were not ambiguous, they were scored with only one discussion between the two raters to establish consistency. Total scores of each student for each PBL phase were then further analysed.

The relevant concepts listed were counted for each student for each learning phase (i.e. problem analysis, self-directed learning and reporting). The *total* number of concepts refers to the total number of relevant concepts recalled, including those that were repeated in one session. *Newly emerged* concepts were those that were not previously mentioned by the individual in any prior learning phase of the day. *Repeated* concepts were those that were previously recalled in an earlier learning phase. For the problem analysis phase, newly emerged and repeated concepts were deduced by comparing concepts listed at the end of the phase during the concept recall exercise with the concepts written in the pre-test answers.

T-tests were used to compare differences in pre- and post-test results. One-way ANOVA was used to find out if there were significant differences in the mean number of relevant concepts recalled at the end of each learning phase. The data were also analysed using structural equation modelling (SEM), a method that is able to test causal hypotheses among multivariate data. The pre- and post-test results as well as the total number of relevant concepts recalled by the students at the end of each PBL phase were analysed for this structural equation modelling analysis. The method generates several statistics that enable the investigators to assess how well the empirical data fit the theoretical model and to estimate the strengths of the causal relations hypothesized. Four indicators suggested in the literature were used to evaluate the goodness-of-fit of the models to the sample data, namely, the Chi-square/df index of fit, Chi-square, the Comparative Fit Index (CFI), and the Root Mean Square Error of Approximation (RMSEA) (Arbuckle, 2006; Browne & Cudeck, 1993; Hu & Bentler, 1999). The level of significance ($p$) computed from Chi-square and degrees of freedom should be higher than 0.05. The Chi-square/df index of fit yielded by dividing the minimum discrepancy (C) by its degrees of freedom should be lower than 3 and preferably close to 1 (Arbuckle, 2006). CFI values larger than 0.95 and RMSEA scores below 0.06 can be considered as indicators of good fit (Browne & Cudeck, 1993).

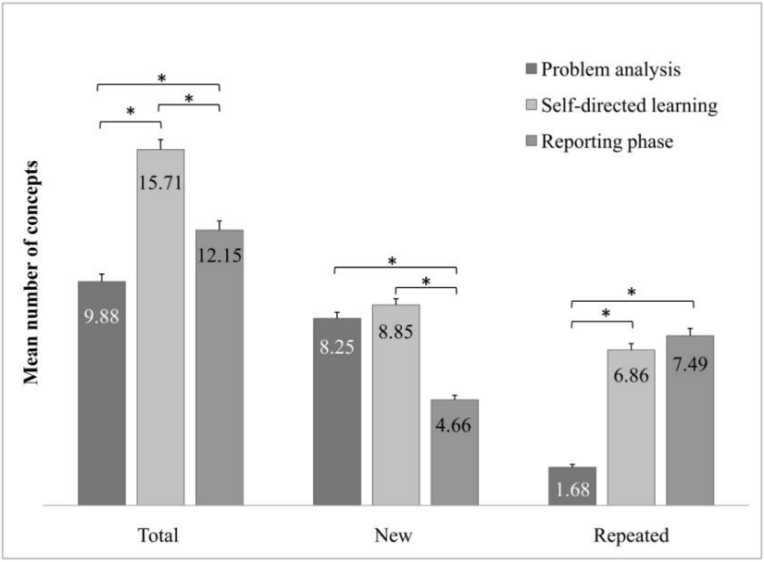
## Results

Results of mean student performance for the free recall essay pre- and post-tests showed improved scores for the post-test. The average difference between the post-test and pre-test scores for the free recall essay questions was 4.88 ($SD$ = 3.88), indicating a significant increase in achievement at the end of the learning process, $t$ (217) = 21.31, $p < .01$. The pre- and post-tests were significantly correlated at $r = .44$, $p < .01$.

The relevant concepts recalled by students at the end of each learning phase during the concept recall exercise were counted in three different ways − the total number of relevant concepts including those which were repeated, newly emerged concepts as well as repeated concepts. The distribution of the average number of these relevant concepts is shown in Figure 3.

The one-way ANOVA revealed that the concepts verbalized differed significantly as a function of the different learning phases. The assumption of homogeneity of variance was violated so the Brown-Forsythe F-ratio is reported. There was a significant effect of the learning phase on the total number of concepts, $F(2, 618.13) = 55.59$, $p < .01$; number of newly emerged concepts, $F(2, 609.93) = 79.32$, $p < .01$ and repeated concepts, $F(2, 497.73) = 156.06$, $p < .01$.

*Figure 3.* Distribution of the mean number (+ SE) of total, new and repeated relevant concepts recalled at the end of the different learning phases of the PBL process (N = 218)




Post-hoc analyses using the Games-Howell test showed that the total number of relevant concepts recalled was significantly higher after the self-directed learning phase (*M* = 9.88, *SD* = 4.86) as compared to after the problem analysis phase (*M* = 15.71, *SD* = 6.52) ($p < .05$) and the reporting phase (*M* = 12.15, *SD* = 5.94). The total number of relevant concepts recalled after the reporting phase was also significantly higher compared to after the problem analysis phase. For the number of newly emerging concepts, these were significantly higher in the problem analysis phase (*M* = 8.25, *SD* = 4.10) and self-directed learning phase (*M* = 8.85, *SD* = 4.06) compared to the reporting phase (*M* = 4.66, *SD* = 2.99), while for the repeated concepts, these were significantly higher in the self-directed learning phase (*M* = 6.86, *SD* = 4.19) and reporting phase (*M* = 7.49, *SD* = 4.71) compared with the problem analysis phase ($M$ = 1.68, $SD$ = 1.85). These significant differences are indicated in Figure 3.

Table 1 shows the intercorrelations, means and standard deviations of the variables used in the structural equation model. Prior knowledge as measured by the essay pre-test is significantly correlated to students' learning achievement and the total number of concepts recalled after each of the PBL phases. Students' achievement is also significantly correlated to the concepts recalled at the end of each PBL phase. It can also be seen that the concepts recalled at the end of the different PBL phases are highly correlated with one another.

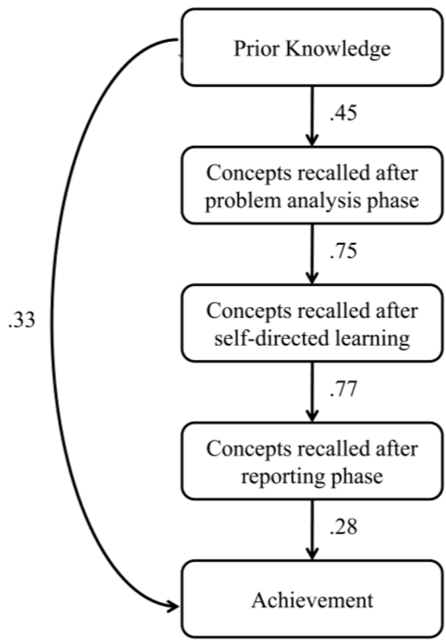
*Table* 1. Intercorrelations, Means and Standard Errors of the Variables ($N$ = 218)

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| 1. Pre-test results (Prior Knowledge) | – | | | | |
| 2. Total number of concepts recalled after problem analysis | .44** | – | | | |
| 3. Total number of concepts recalled after individual study | .37** | .74** | – | | |
| 4. Total number of concepts recalled after reporting phase | .26** | .59** | .75** | – | |
| 5. Post-test results (Achievement) | .41** | .34** | .40** | .34** | – |
| Mean | 2.02 | 9.88 | 15.71 | 12.15 | 6.90 |
| Standard deviation | 2.05 | 4.86 | 6.52 | 5.94 | 3.66 |

** significant at the 0.01 level

The hypothesized model displayed in Figure 1 was tested against the data, yielding the following results: Chi-square = 7.84, df = 5, *p* = .17; the minimum discrepancy, C, divided by the degrees of freedom, Chi-square/df = 1.57; the square root of the population discrepancy corrected by the complexity of the model RMSEA = .05; and the Comparative Fit Index (CFI) = .97. Figure 4 displays the path diagram of the model, showing the significant paths. The parameter estimates for the model were all statistically significant. These findings show that the model fits the data adequately.

*Figure 4*. Path model of the hypothesized model on relationships between different PBL phases



The following alternative hypotheses proposed in the introduction were also tested against the data: (1) Learning in PBL is only influenced by phases involving collaborative learning and co-construction; (2) Learning in PBL is only influenced by self-directed study; and (3) Learning in PBL is influenced by both collaborative learning as well as self-directed study, but not in a cumulative manner. Table 2 shows a comparison of the results of the indicators of goodness of fit for the different models tested.

*Table 2*. Comparison of Results for Different Models Tested Using Structural Equation Modeling

| Model\Indicators of goodness of fit | Cmin | df | Cmin/df | P value | CFI | RMSEA |
|---|---|---|---|---|---|---|
| Hypothesized model: learning in PBL is influenced by both collaborative learning and self-directed learning in a cumulative manner | 7.84 | 5 | 1.57 | .17 | .97 | .05 |
| Alternative model 1: learning in PBL influenced only by collaborative learning | 70.18 | 3 | 23.39 | .00 | .19 | .32 |
| Alternative model 2: learning in PBL influenced only by self-directed learning | 26.33 | 1 | 26.33 | .00 | .41 | .34 |
| Alternative model 3: learning in PBL is influenced by both collaborative and self-directed but not in a cumulative manner | 103.12 | 6 | 17.19 | .00 | .12 | .27 |

## Discussion

Our goals in this study were to understand how students learn in the different phases of PBL in terms of concept acquisition and elaboration as well as to investigate the extent to which active learning is cumulative and whether it involves both collaborative and self-directed learning, in the context of PBL. In addition, we sought to devise an efficient and valid method to track students' learning in the PBL process.

The results in Figure 3 indicate that the self-directed learning phase is rich both in the acquisition of new concepts as well as the reiteration and repetition of concepts previously exposed to. That there was a high number of new concepts at the end of the problem analysis phase (as compared to students' pre-test answers) suggests that the discussion during this phase helped to activate students' prior knowledge, as previous studies have suggested (De Grave et al., 2001; Schmidt et al., 1989). We also observe that the reporting phase is characterized more by repetition of concepts rather than being exposed to new ones. This result is similar to the findings by Yew and Schmidt (2008) who identified two distinct phases of initial terminology articulation and a later terminology repetition in the PBL process from a group of students' online research data and verbal interactions. Our results strengthen their findings, which were limited due to small sample size.

One surprising observation from the distribution of concepts in Figure 3 is that the total number of concept recalled during the reporting phase is less than that in the self-directed learning phase. One would expect that by the end of the whole PBL cycle, students would be able to recall more relevant concepts. Possible reasons for this observation could be due to students have already started to forget some of the concepts learned within the day, or they could also be mentally drained by the end of an intensive day's work.

Our hypothesis in this study is that learning in PBL is a cumulative process where the learning in each new phase builds upon knowledge acquired in a previous phase. Results from Table 2 clearly show that compared with the alternative hypotheses, our hypothesized model best fits the data obtained. This model shows that there was significant impact of students' prior knowledge on the concepts students were able to recall after the problem analysis phase (.45). Students' prior knowledge also influenced their achievement directly (.33). This finding is in line with a previous study by Gijselaers and Schmidt (1990) who found that amount of prior knowledge influenced students' achievement by .37. The number of relevant concepts recalled at the end of the problem analysis phase strongly influenced the number recalled at the end of the self-directed learning phase, which similarly influenced the number of concepts recalled at the end of the reporting phase. Finally being able to recall more relevant concepts at the end of the reporting phase influenced students' learning achievement significantly (.28). Results from the alternative hypotheses tested as tabulated in Table 2 also show that learning in PBL cannot be described only in terms of collaborative learning and teamwork, nor only in terms of self-directed learning. The lack of fit of the models with the data also demonstrates the importance of the sequential influence of learning from one phase to the next. This is important evidence showing that the three phases of PBL: problem analysis, self-directed learning, and reporting phase, play specific roles in influencing students' learning achievements.

Since our model enables us to predict student achievement very well, this also indicates the validity of our methodology as a means of keeping track of students’ learning in the course of the learning process. Thus our method appears to be a useful and efficient way to overcome the typical difficulties faced in data collection of large samples for naturalistic studies.

One limitation of this present study is that the units of analysis focused on individual scientific concepts students were able to associate with the topic-at-hand and to recall at the end of each PBL phase, without connecting propositions demonstrating how the different concepts were linked. This then limits the deductions we can draw about the depth and accuracies of students’ understanding of the different concepts. However despite this shortcoming, our findings from our model fit also show that this method does provide valid insight into students’ learning.

In conclusion, we have shown that all the phases in the PBL process are necessary to understand how students learn in PBL. The learning in each phase of the PBL process is shown to be strongly influenced by the earlier phase, thus providing support for the PBL cycle of initial problem analysis, followed by self-directed learning, and a subsequent reporting phase as described by various authors. Alternative hypotheses where students’ achievement is predicted only by collaborative learning or self-directed learning were shown to be insufficient to explain the data observed. Secondly, we have identified two distinct phases of initial terminology articulation and a later terminology repetition in the PBL process, thus providing further insight into the process of learning in PBL through a semi-naturalistic approach, instead of depending on student self-report. Lastly, we have described a useful and efficient method to keep track of students' learning throughout the PBL process.

# Chapter 3: Effects of tutor-related behaviours on the process of problem-based learning[2]

## Abstract

Tutors in a Problem-based learning (PBL) curriculum are thought to play active roles in guiding students to develop frameworks for use in the construction of knowledge. This implies that both subject-matter expertise and the ability of tutors to facilitate the learning process must be important in helping students learn. This study examines the behavioural effects of tutors in terms of subject-matter expertise, social congruence and cognitive congruence on students' learning process and on their final achievement. The extent of students' learning at each PBL phase was estimated by tracking the number of relevant concepts recalled at the end of each learning phase, while student achievement was based on students' ability to describe and elaborate upon the relationship between relevant concepts learned. By using Analysis of Covariance (ANCOVA), social congruence of the tutor was found to have a significant influence on learning in each PBL phase while all of the tutor-related behaviours had a significant impact on student achievement. The results suggest that the ability of tutors to communicate informally with students and hence create a less threatening learning environment that promotes a free flow exchange of ideas, has a greater impact on learning at each of the PBL phases as compared to tutors' subject-matter expertise and their ability to explain concepts in a way that is easily understood by students. The data presented indicates that these tutor-related

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[2] Published in: Chng, E., Yew, E. H. Y., & Schmidt, H. G. (2011) Effects of tutor-related behaviours on the process of problem-based learning. *Advances in Health Sciences Education*, 16 (4), pp. 491-503.

behaviours are determinants of learning in a PBL curriculum, with social congruence having a greater influence on learning in the different PBL phases.

## Introduction

Problem-based learning (PBL), as its name implies, is learning that is driven by problems. The PBL process typically consists of three phases, namely a problem analysis, a self-directed learning, and a reporting phase (Barrows, 1988; Hmelo-Silver, 2004). During problem analysis, students examine the problem together with peers, make inferences based on their prior knowledge and identify questions that need to be answered in order to understand or solve the problem. After this phase, students would engage in self-directed study to work on the learning issues previously identified. When the team reconvenes during the reporting phase, students would share their findings, refining their original ideas and hypotheses in the process. Thus, the construction of knowledge in the PBL process is a result of both collaborative learning while working with peers as well as through individual self-directed learning (Schmidt, 1983).

What then is the role of the tutor in PBL? A tutor is present during the problem analysis and reporting phase to facilitate and guide students' learning process. Tutors are expected to play active roles in the scaffolding of student learning in a PBL curriculum by providing a framework that students can use to construct knowledge on their own (De Grave, Dolmans, Van Der Vleuten, 1999). By probing students to think more deeply and modelling for them the kinds of questions that they should be asking themselves during problem-solving, the tutor-student relationship can be viewed as a type of cognitive apprenticeship (Hmelo-Silver & Barrows, 2006; Schmidt & Moust, 2000; Collins, Brown, & Newman, 1989).

As such, the behaviors of tutors in the PBL process may be expected to influence students' learning. Although various researchers have examined the effects of tutor-related behaviors (reviewed below), their impact on the PBL process and in students' knowledge construction remains unclear. Hence, the objective of this study was to investigate the influence of tutor-related behaviours on students' learning process in the different PBL phases as well as on their achievement.

Several studies have focused on the behaviours related to subject-matter expertise of the tutor (Silver & Wilkerson, 1991; Schmidt, Van Der Arend, Moust, Kokx & Boon, 1993). Findings from studies on the influence of tutors' subject-matter knowledge remain inconclusive (Davis, Nairn, Paine, Anderson & Oh, 1992; Dolmans, Wolfhagen & Schmidt, 1996). For instance, Davis *et al*. (1992) found differences in the performance of students favouring tutors with specific subject-matter expertise while Dolmans *et al*. (1996) found that tutor expertise did not influence student achievement. However, studies focusing on the differences between tutors with subject-matter knowledge and non-subject-matter knowledge from a process perspective have provided some further insights. A study conducted by Silver and Wilkerson (1991) suggested that tutors with subject-matter expertise were more inclined to play a directive role in the tutoring process, supplied more direct answers to questions posed by students, and suggested more points for discussion. Although achievement data of students were not reported, there is the suggestion that achievement can be influenced by the subject-matter expertise of the tutor, and that this expertise is expressed in particular through directing behaviours displayed in interaction with the students. In another study by Schmidt *et al*. (1993), findings indicated that students guided by tutors with subject-matter expertise spent significantly more time on self-directed learning as compared to those guided by non-subject-matter experts. On the other hand, despite finding effects of subject-matter experts, Davis *et al*. (1992) could not identify behavioural differences in tutors with subject-matter expertise and those with lesser subject-matter knowledge.

Besides subject-matter expertise, the ability of tutors to "facilitate" the learning process is believed to be important. As PBL is student-centred rather than teacher-centred, tutors avoid dispensing information, choosing to become a coach and focusing on guiding the learning process of the students instead. Tutors are required to closely follow the discussions generated amongst the students and consider when and how they might contribute to the learning process (Wetzel, 1996). This suggests the need for tutors to develop facilitative skills as they are involved in questioning, probing, suggesting and challenging ideas that are raised during discussion (Maudsley, 1999). Schmidt, Van Der Arend, Kokx and Boon (1994), for instance, compared between faculty tutors and student tutors and the results indicated that faculty tutors used their subject-matter knowledge more extensively while student tutors were better able to identify with the difficulties students experience while dealing with the problem at hand. This difference could be attributed to what was termed as 'cognitively congruent behaviour' that is exhibited more significantly by student tutors (Dolmans, Gijselaers, Moust, De Grave, Wolfhagen, Van Der Vleuten, 2002). Cognitive congruence can be defined as 'the ability to express oneself in the language of the students, using the concepts they use, and explaining things in ways easily grasped by students' (Schmidt & Moust, 1995, p.709). Thus, the student tutors are thought to be better able to understand the nature of the problems faced by students and to respond more appropriately using prompts that are more easily understood.

The concept of cognitive congruence was studied by Schmidt & Moust (1995). These authors suggested that the necessary conditions for cognitive congruence to occur included both subject-matter expertise and "social congruence." It was proposed that tutors who are more cognitively congruent would utilize subject-matter knowledge in a better way and be more socially congruent, which ultimately translates into higher student performance. Social congruence refers to the interpersonal qualities of the tutor such as the ability to communicate informally and empathically with students, and hence being able to create a learning environment that encourages open exchange of ideas (Schmidt & Moust, 1995). Subject-matter knowledge, on the other hand, would equip tutors with the ability to follow closely and contribute effectively to the discussions generated by students (Schmidt & Moust, 2000). A study conducted by Kassab, Al-Shboul, Abu-Hijleh & Hamdy (2006) found that effective tutors were perceived by students as those who respected their opinions, were able to establish good communications, understand their feelings and advise them on how to learn. This indicates that possessing subject-matter knowledge alone is insufficient. Without a genuine interest in the lives and learning process of the students, the tutor would lack sensitivity to the difficulties faced by students, thus hindering their ability to guide students' learning.

The data in the study by Schmidt & Moust (1995) was analysed using structural equations modelling, a statistical method that allows causal hypotheses to be tested by comparing the structure of correlational data with a theoretical model. Their findings indicated that social congruence directly influenced group functioning during the problem-solving process while subject-matter expertise of tutors had a slightly direct positive impact on student achievement. Furthermore, cognitive congruence, which is the combination of subject-matter expertise and social congruence, was found to influence tutorial group functioning and this indirectly affected the level of student achievement through an increase in time spent on self-study. Hence, by using structural equations modelling, Schmidt & Moust (1995) were able to establish that a higher level of achievement can be attained through effective tutoring that requires not only the tutors' content knowledge but an ability to interact with students on a personal level as well as to utilize language that is easily understood by students. However, how exactly do these interrelated qualities of tutors affect knowledge construction during the PBL process? Which of these tutor-related behaviours are most influential on student learning? And in which of the different learning phases within the PBL process do these behaviours most extensively influence student learning? In line with the initial findings of Schmidt & Moust (1995), we hypothesized that tutors exhibiting more cognitive congruent behaviours would influence knowledge construction and acquisition at each learning phase of the PBL process. As learning in a PBL curricular is considered to be cumulative where knowledge is built upon that which was learnt in the previous learning phase (Yew, Chng & Schmidt, 2010), students under the tutorship of such tutors should be more extensively involved in the construction of knowledge and would ultimately achieve better results at the end of the learning process. Therefore, rather than to relate tutor behaviours to the outcome of PBL, the aim of this study was to investigate the effects of tutor-related behaviours on student learning during the PBL *process*.

## Method

*Participants*

The participants were second-year students from 13 randomly selected classes from the Science faculty at a polytechnic in Singapore. Data were collected from the students during the third week of Semester Two in Immunology classes in the academic year of 2008 - 2009. Out of 262 students, data from 223 students were used in this study while the rest were removed due to incomplete sets of results. Having completed their first year of study, students were familiar with the PBL pedagogy. In total, seven tutors participated in this study and each tutor was rated by an average of 32 students. Students and tutors gave informed consent.

*Educational context*

The implementation of PBL at the polytechnic is based on a rather unique "One-day-one-problem" approach where students work on one problem per day. In the classroom, students are grouped into teams of less than or equal to five and one tutor to guide the learning process. A brief description of the day's process is described below:

- Problem analysis phase (approximately 1 hour): The problem for the day is presented to the students by the tutor. Students work in teams to identify the learning issues by utilizing their prior knowledge, assumptions and experiences. After spending some time to explore the problem on their own, the tutor will generate discussion amongst the teams and to encourage students to share their ideas and thoughts about the problem. The tutor also guides students in devising initial pathways for developing a response to the problem.

- Self-directed learning phase (approximately 4 hours): Students spend their time on individual study or helping their team members when necessary. Resources such as worksheets and suggested reading texts are commonly provided by the tutor but students are also encouraged to search and use information from the internet or textbooks. During this period, the tutor also spends approximately 20 minutes with each team to check on their progress and strategy aimed at understanding the problem. The tutor promotes interaction and evaluation of information found by the students during their individual study. Tutors also provide guidance in constructing new knowledge and encourage students to build on each other's ideas.

- Reporting phase (approximately 2 hours): Students are expected to connect their findings from their individual studies and demonstrate their ability to evaluate and synthesize information. Each team shares their consolidated findings and response to the problem. Students would take turns to present portions of their team's presentation as well as to assist one another in defending their points of view and elaborating based on questions raised by peers and the tutor. The tutor encourages critical thinking and creates opportunities for students to evaluate the information presented by their peers. Key ideas would also be clarified by the tutor if necessary.

The PBL approach adopted here is rather unique in that the entire PBL cycle is completed within one day. However, despite the modifications, this approach remains classified as PBL based on the 'six core characteristics of PBL': (1) the use of authentic problems for students to work on without prior preparation so as to achieve the required knowledge, (2) students initiate their own learning whereby students work in (3) small collaborative groups under the (4) flexible tutelage of a tutor who guides the learning process. As problems are used as the starting point for learning, (5) the number of lectures are limited and (6) students would have sufficient time for self-study (Barrows, 1996; Hmelo-Silver, 2004; Schmidt, van der Molen, Winkel, Wijnen, 2009). Furthermore, learning issues are generated by students and new information is acquired through self-study rather than direct instruction from the tutor (Hmelo-Silver, 2004).

*Materials*

Problem statement and subject matter to be mastered

The problem statement for the day was entitled "A Runny Issue" and it introduced students to concepts related to the structure and functions of antibodies. Students were to explore the biological properties of the different classes of antibodies in relation to their structure as well as antigen binding. The problem statement is presented in Appendix B.

Measurement

*Measurement of tutor behaviour*

Tutor behaviours were assessed by asking students to complete a questionnaire adapted from Schmidt & Moust (1995).

The questionnaire consists of 10 statements and students were required to indicate how much they agreed with each statement on a five-point Likert scale ranging from 'Not true at all' to 'Very true for me'. The questions were crafted with the intention of gauging three core tutor behaviours, namely, social congruence, subject expertise and cognitive congruence. Examples of the statements are 'The tutor helped us to understand the topic', 'The tutor showed interest in our personal lives' and 'The tutor used his/her content knowledge to help us'. Social congruence was measured by three items and subject expertise was measured by two while cognitive congruence was measured by five items. The questionnaire is presented in Appendix C.

The reliability of the questionnaire was determined by calculating Hancock's coefficient *H* for each scale as it is a construct reliability measure for latent variable systems. The recommended cut-off value by Hancock for the coefficient *H* is .70. For this particular questionnaire, the coefficient *H* values ranged from .70 (social congruence) to .80 (subject-matter expertise), with an average .75. In addition, the validity of the questionnaire was established in Schmidt & Moust (1995).

*Measurement of students' learning process*

The extent of students' learning at each PBL phase was estimated using a *concept recall test*. This was designed to estimate the number of relevant concepts that students were able to recall at the end of each PBL phase: problem analysis, self-directed learning and reporting (Yew *et al.*, 2010). The concept recall test consisted of the following instruction: "List all the keywords or terminologies that are related to antibodies that you are able to recall at this stage."

The same question was given to the students at the end of each PBL phase. Students were not allowed to discuss the question with their peers or to refer to any resources.

The assumption here is that as students engage in problem analysis, self-directed learning, group discussions, and/or peer teaching, they are in fact building semantic networks of concepts related to the problem as well as making relations between their prior knowledge and new ideas (Glaser & Bassok, 1989). As learning progresses, students would master more specific terminologies to articulate the newly acquired knowledge. Hence, as these networks of knowledge in their minds expand, reorganize, and become more tightly integrated, measuring the number of relevant keywords that can be recalled at any point in time can be considered an indication of the quality and progress of students' learning.

*Measurement of students' achievement*

Students' achievement at the end of the day was measured via the implementation of an essay test. The essay was used to estimate the depth of students' scientific knowledge by examining their ability to describe and elaborate upon the relationship between relevant concepts learned (Alao & Guthrie, 1999). It consisted of a response to the following instructions: "Describe and explain as much as you know about the structure and function of antibodies". No time limit was set for the test.

*Procedure*

In this study, the questionnaire that was used to measure tutor behaviours was administered at the end of the reporting phase.

The students were informed to answer the questions in relation to their tutor of that particular day and to reflect on their involvement with the tutor during all three learning phases. The concept recall test and essay test that were used to measure learning that takes place during the "one-day-one-problem" approach adopted by the institution were also administered on the same day but at different time points.

The concept recall test was administered immediately after each PBL phase – problem analysis, self-directed learning and reporting. The essay test was administered after students had completed the final concept recall test, which was at the end of the reporting phase. When the students were attempting the essay test, they were not allowed to refer back to what they had written for the concept recall test. The concept recall test and essay test were conducted independently of each other as they served a different purpose: The concept recall test was used as a measure of students' learning process while the essay test was used as a measure of students' achievement at the end of the PBL process.

No time limit was set for any of these tests. The results from the questionnaire, concept recall tests and essay test were aggregated for teams under the same tutor.

*Analysis*

The tutor behaviours were considered the independent variables; the learning process variables were the dependent variables. Scores for each of the core tutor behaviours, social congruence, subject expertise or cognitive congruence, were computed. It is standard practice to base indicators of teacher behaviours on class averages rather than on individual level data (Marsh, 1991). Hence, average scores reflecting ratings of the same tutor across different classes for the three tutor-related behaviours were used during analysis.

To examine the effects of tutor-related behaviours on the learning process, analysis of covariance (ANCOVA) was used to determine if differences were because of treatment effect or by chance. The covariate used in this study was the pre-existing grade point average (GPA) score and it equates to the average grades the students have achieved in the previous semesters of their course of study. The assumption made is that the GPA score equates to the level of prior knowledge, which may affect the results for the concept recall test and essay test. Yet, it is a measurable variable that is not affected by the experimental variables. By using ANCOVA, it is possible to reduce the error variance and provide a more accurate account of the impact made by the amount of prior knowledge on the students' learning process and achievement as ANCOVA removes the variability of the dependent variable that can be accounted for by the covariate. The average GPA score of the 223 students who participated in this study was 2.86 ($SD$ = 0.46).

Prior to performing ANCOVA, the data representing the tutor behaviours was divided equally into three groups for each independent variable. The purpose of categorizing the data into three groups was to rank the tutors according to their level of subject-matter expertise, cognitive congruence and social congruence. The tutors were split using the 33.4% percentile and the 66.7% percentile based on the range from the data set. The subject-matter expertise for the tutors involved in this study ranged from 3.70 to 4.29 ($M$ = 4.01, $SD$ = 0.22) and dividing the data into groups allowed the tutors to be ranked as having a high level, medium level or low level of subject-matter expertise. This ranking exercise was also conducted for cognitive congruence that had a range of 3.41 to 3.98 (*M* = 3.65, *SD* = 0.20) as well as for social congruence with a range of 2.92 to 4.02 (*M* = 3.27, *SD* = 0.37). For each of the independent variables, there were 2 tutors in the high and low groups and 3 tutors in the medium group.

The results of the concept recall tests were analysed by awarding 1 point to each relevant keyword listed by the student. Total scores from the concept recall tests completed after the problem analysis, self-directed learning and reporting phases were tabulated. A repetition of a keyword within each concept recall test was only counted once.

In the case of the essay tests, the "idea unit" was used as the entity for scoring (Meyer, 1985; Schiefele and Krapp, 1996). Answers were segmented into idea units that are defined as a statement ending with a comma, period, or 'and'. Each idea unit was awarded with a score of 2, 1 or 0. A score of 2 was given for a completely correct idea unit, 1 for a partially correct idea unit and 0 for a completely incorrect idea unit. Inter-rater correlation between two judges for the scoring of the essay tests was r = .77. Differences in judgment were resolved by discussion between the judges.

## Results

The means and standard deviations of the tutor-related behaviours are shown in Table 1. There were altogether seven tutors involved in this study and their level of subject-matter expertise (*M* = 4.01, *SD* = 0.22), cognitive congruence (*M* = 3.65, *SD* = 0.20) and social congruence (*M* = 3.27, *SD* = 0.37) were measured. As for the outcome measures, the scores from the concept recall tests and essay test from 223 students were used in the data analysis. The means and standard deviations of the concept recall test administered after the problem analysis phase (*M* = 5.63, *SD* = 3.35); self-directed learning phase (*M* = 9.64, *SD* = 4.08); reporting phase (*M* = 9.90, *SD* = 3.83) as well as the essay test (*M* = 3.57, *SD* = 1.94) are shown in Table 2. A correlation analysis indicated that there was a correlation between the two outcome measures ranging from .32 to .50 at a significance level of 0.01.

*Table* 1. Means and standard deviations of the independent variables

| **Tutor-related behaviours** | ***N*** | ***Mean* (*SD*)** |
|---|---|---|
| Subject-matter Expertise | 7 | 4.01 (0.22) |
| Cognitive Congruence | 7 | 3.65 (0.20) |
| Social Congruence | 7 | 3.27 (0.37) |

(Note: *N* refers to the number of tutors)

*Table 2*. Means and standard deviations of the dependent variables

| **Outcome Measures** | ***N*** | ***Mean* (*SD*)** |
|---|---|---|
| Concept recall test after problem analysis phase | 223 | 5.63 (3.35) |
| Concept recall test after self-directed learning phase | 223 | 9.64 (4.08) |
| Concept recall test after reporting phase | 223 | 9.90 (3.83) |
| Essay Test (Student achievement) | 223 | 3.57 (1.94) |

(Note: *N* refers to the number of students who completed the tests)

The ANCOVA revealed that the social congruence of tutors had the most influence on the learning process relative to cognitive congruence and subject-matter expertise. Social congruence was found to have a significant effect on the total number of concepts recalled at the end of the problem analysis phase, $F(2, 219) = 10.38$, $p < 0.01$; self-directed learning phase, $F(2, 219) = 9.83$, $p < 0.01$; and reporting phase, $F(2, 219) = 6.51$, $p < 0.01$. No significant effects were found of subject expertise and cognitive congruence of the tutor on each of the learning phases in the PBL process. Social congruence also had a significant effect on student achievement as measured by the essay, $F(2, 219) = 4.914$, $p < 0.01$. Similar effects were found for the subject-matter expertise, $F(2, 219) = 7.74$, $p < 0.01$, and cognitive congruence, $F(2, 219) = 7.74$, $p < 0.01$. The means and standard deviations from ANCOVA for relatively low, medium and high scoring tutors are shown in table 3.

## Discussion

The purpose of this study was to examine how the behaviours of tutors in a PBL curriculum would affect the students' learning process and outcome. The results have indicated that the social congruence of the tutor influences the learning process in a more significant way as compared to cognitive congruence and subject-matter expertise. This implies that the willingness of a tutor to establish an informal relationship with the students and display an attitude of genuine interest has the greatest impact on the progress made by students during the PBL process. Although a significant effect on the PBL process was not identified for cognitive congruence and subject-matter expertise, the impact for each of the independent variables on students' achievement mirror the findings made by Schmidt & Moust (1995), which concluded that these tutor-related behaviours are all determinants of learning in a PBL curricula.

*Table* 3. Means and standard deviations of test scores with respect to tutor behaviours

| Tutor Behaviours | *N* | Concept recall test score | | | Essay test score |
|---|---|---|---|---|---|
| | | After problem analysis | After self-directed learning | After reporting | |
| Social congruence (low) | 68 | 5.35 (3.25)* | 8.40 (3.98)* | 9.21 (3.22)* | 3.24 (1.73)* |
| Social congruence (medium) | 89 | 4.79 (2.90)* | 9.21 (3.48)* | 9.36 (3.75)* | 3.34 (1.92)* |
| Social congruence (high) | 66 | 7.04 (3.61)* | 11.50 (4.08)* | 11.35 (4.15)* | 4.21 (2.03)* |
| Cognitive congruence (low) | 74 | 6.05 (3.12) | 8.92 (3.90) | 9.76 (3.33) | 3.05 (1.93)* |
| Cognitive congruence (medium) | 86 | 5.45 (3.48) | 9.80 (4.01) | 10.05 (4.00) | 3.55 (1.80)* |
| Cognitive congruence (high) | 63 | 5.37 (3.44) | 10.27 (4.32) | 9.87 (4.19) | 4.20 (2.00)* |
| Subject-matter expertise (low) | 74 | 6.05 (3.12) | 8.92 (3.90) | 9.76 (3.33) | 3.05 (1.93)* |
| Subject-matter expertise (medium) | 86 | 5.45 (3.48) | 9.80 (4.01) | 10.05 (4.00) | 3.55 (1.80)* |
| Subject-matter expertise (high) | 63 | 5.37 (3.44) | 10.27 (4.32) | 9.87 (4.19) | 4.20 (2.00)* |

(Note: *significant at the 0.01 level; *N* refers to the number of students)

So, why is the impact of social congruence on the learning process so pervasive? During the process of constructing new knowledge and solving the problem, students would challenge and analyse possible solutions that are raised by peers while the tutor observes student interactions and encourage various kinds of cognitive activities, such as making connections between concepts and providing feedback (Dolmans *et al.*, 2002). In addition, tutors should allow students to propose their own hypotheses regardless of whether they are inaccurate or superficial. It has been demonstrated that through the process of expressing their own thoughts, students would be able to identify their misconceptions and see how it fits with the correct knowledge (Schmidt *et al.*, 2009). In order to create a learning environment where there is a free flow exchange of ideas, it is vital for students to feel comfortable in expressing their opinions openly. Therefore, the social congruence of the tutor can be anticipated to influence the learning process as a more socially congruent tutor would possess the interpersonal qualities to relate informally with students and this creates a non-threatening learning environment (Schmidt & Moust, 1995). Furthermore, as learning in a PBL environment is believed to be cumulative whereby knowledge is built upon that which was gained in the previous learning phase (Yew *et al.*, 2010), the amount of knowledge acquired during the learning process would in turn have an effect on students' achievement, which was observed during data analysis.

Although a significant influence on the PBL process of cognitive congruence and subject-matter expertise was not found in this study, it is unlikely that these tutor-related behaviours do not affect the PBL process but only the outcomes of the process. In addition, the essay test that measured students' achievement was administered immediately after the reporting phase, which did not give students extra time outside of the classroom for self-study. Thus, the knowledge gained must have been covered during the various learning phases of the PBL process within the same day, as also witnessed by the correlations between process and outcome which were highlighted in the results.

A possible reason that a statistically significant effect on the PBL process was not observed for cognitive congruence and subject-matter expertise could be due to the differential sensitivity of the measurement tools used in this study. The concept recall test required students to recall relevant keywords at the end of each learning phase and the number of keywords that could be easily recalled may have been limited. As students read and evaluate information from various resources, they may have understood the concepts but may not have paid close attention to the keywords used. On the other hand, the essay test required students to demonstrate their understanding of the topic and they were given the freedom to choose the words to describe what they have learnt. Hence, the essay test used to measure students' achievement may have been more sensitive in picking up differences as compared to the concept recall test that was used to measure students' learning process. Furthermore, the effects of cognitive congruence and subject-matter expertise on students' learning process may have been too small to be detected by the concept recall test. A limitation with the concept recall test was that it only required students to list as many keywords as possible that were related to the discussion topic at the end of each PBL phase without having to make connections with the different concepts. This may have affected the analysis of students' understanding about the concepts at each learning phase in terms of depth and accuracies (Yew *et al.*, 2010). Nevertheless, the concept recall test was adequate in capturing a significant effect made by social congruence on the PBL process, which may have been a larger effect as compared to the impact made by cognitive congruence and subject-matter expertise.

Another possible explanation could be due to the use of natural variations as the study was conducted in a real school setting. For instance, the tutors who participated in this study were randomly chosen instead of being selected based on their specific profiles. In addition, the tutors had to be tutoring students who were taking the same subject, which limited the sample size and resulted in a limited number of eligible tutors. This led to a situation in this particular sample of facilitators that the standard deviation for social congruence was almost twice as large as those of cognitive congruence and subject-matter expertise (see Table 1). Limited variability in combination with somewhat reduced sensitivity of the dependent variable may explain the absence of effects of cognitive congruence and subject-matter expertise on the PBL-process in this study. Therefore, a larger sample size of tutors with greater variation in the levels of cognitive congruence, social congruence and subject-matter expertise is required before a more definite conclusion on the tutor-related behaviours on students' learning process and achievement can be made.

The difference in PBL methodology practiced at this polytechnic as compared to other educational institutions limits the generalizability of the findings. Students at this polytechnic complete the PBL process from problem analysis to reporting phase within a day and students have close contact with their tutors throughout the day. However, the PBL process at other institutions may last for a longer period of time and the tutor may not be present at all times. These differences may influence the effect of tutor-related behaviours on the students' learning process and achievement. Additionally, there is an absence of a long-term perspective in this study as both outcome measurement tools were administered on the same day immediately after the learning process. Further studies to include longer term assessment would have been beneficial to provide insights on the long-term effects of the tutor-related behaviours on student learning.

## Conclusion

The effect of tutor-related behaviours on the PBL process and outcome was explored in this study. Our results indicated that social congruence had a significant influence on the learning process while social congruence, cognitive congruence and subject expertise all had significant effects on student achievement. These findings are not only supportive of work previously done by Schmidt & Moust (1995) that advocate the positive influence of tutor-related behaviours on student achievement but provide new insights on their effects on the PBL learning process. Therefore, this study concludes that an attempt to improve the learning process and achievement of students in a PBL curriculum can be based on the development of effective tutor behaviour.

Besides possessing the necessary subject-matter expertise, tutors should recognize the importance of developing the ability to establish informal communication with the students as well as utilizing language that is easily understood by the students in the classroom. These qualities of the tutor contribute to creating a learning environment where students feel liberated to share their ideas and in developing strong tutor-student relationships that aid in promoting student engagement in discussions, which translates into better student performance during the learning process and at the end of the PBL process.

# Chapter 4: To what extent do tutor-related behaviours influence student learning in PBL?

## Abstract

The purpose of this study was to investigate how tutor behaviours influence learning in Problem-Based Learning (PBL). A previous study had indicated that the tutor's social congruent behaviour has significant influence on the PBL process and this study further investigates this finding by examining two groups of tutors displaying large differences in social congruence. The participants were 77 students under the tutelage of four tutors and a self-report questionnaire completed by the students ranked two tutors to be more socially congruent as compared to the other two. Student learning was measured by a concept recall test and the results from the Analysis of Covariance (ANCOVA) indicated a significant impact of the tutor's social congruent behaviour on learning after the problem analysis phase. However, there was no significant influence on the self-directed learning and reporting phases. It was concluded that the academic abilities of students and the small number of tutors involved may have affected the results, which led to the second part of this study. A group of 11 tutors were selected and their behaviours on student achievement measured by the overall score from the "Understanding Tests" (UTs) conducted within a module was examined. One-Way Analysis of Variance (ANOVA) indicated that the tutor behaviours had a greater influence on average and academically weaker students as compared to the academically stronger students. This finding suggests that the academic abilities of students may affect the extent to which a tutor influences learning and proposes that students who are academically stronger are not as reliant on the tutor and would be able to perform well under any

tutor. On the other hand, academically weaker students may depend more on the tutor to guide and motivate them in order to achieve the learning goals.

## Introduction

Students in a Problem-Based Learning (PBL) curriculum learn through the process of problem-solving as problems are believed to help organize learning. Barrows (1985) claimed that problems would challenge students to utilize their reasoning and problem-solving skills as well as aid students in discovering what they already know (Dolmans & Schmidt, 1994). Thus, the PBL process begins with introducing students to a problem relevant to their subject domain and it comprises of three learning phases: problem analysis, self-directed learning and reporting phase (Barrows, 1988; Hmelo-Silver, 2004).

During the problem analysis phase, students gather in small collaborative groups and brainstorm for possible solutions to the problem. Without having an opportunity to prepare for the problem beforehand, students utilize their prior knowledge to analyse and identify learning issues. Prior knowledge may have been acquired through previous formal education, the mass media or through relevant personal experiences (Schmidt & Moust, 2000). As students move into the self-directed learning phase, they would use a range of resources to search for relevant information and answers to questions they had formulated as a guide towards a feasible solution. By the reporting phase, students would have had sufficient time to evaluate and synthesize information from various resources through self-study and collaborative learning. Hence, students are expected to share their proposed solution to the problem as well as clarify any misunderstanding of the concepts learnt during the PBL process.

Although learning in a PBL curriculum is mainly student-centred, a tutor is present to provide guidance by probing students to think more deeply and modelling for them the kinds of questions that they should be asking during problem-solving. This relationship between the tutor and students can be viewed as a type of cognitive apprenticeship (Hmelo-Silver & Barrows, 2006; Schmidt & Moust, 2000; Collins, Brown & Newman, 1989). In addition, Barrows (1988) has described an ideal PBL tutor to be one that plays a role in facilitating student learning rather than only conveying knowledge. Therefore, instead of receiving direct instructions from the tutor, students are responsible for their own learning and would work with their peers under the tutelage of the tutor to achieve the common goal of solving the problem (Hmelo-Silver, 2004). While students work in their collaborative groups, the tutor plays a key role in questioning, suggesting and challenging ideas raised (Maudsley, 1999). Thus, the role of the tutor in the learning process should not be ignored and there should be more emphasis in developing effective tutors as they would be able to enhance the learning process.

So what makes a PBL tutor effective? Similar to teachers in a conventional classroom where they are known to be the source of knowledge, it is unsurprising that subject-matter expertise of the PBL tutor has been thought to be crucial for tutors to be effective. There is a general agreement that tutors with the domain knowledge would be able to provide students with the necessary content knowledge and to correct the misconceptions that are constructed as they would know when to intervene in the discussions with statements or questions that evoke relevant ideas or reasoning processes (Hendry, Phan, Lyon & Gordon, 2002). By doing so, these tutors would be able to challenge the students’ level of understanding adequately, which in turn allows students to construct new knowledge and perform well academically (Gilkison, 2003). However, studies on the behaviours of tutors with subject-matter expertise and their impact on student learning have remained inconclusive (Schmidt & Moust, 2000). It has been found that subject-matter expertise may not necessarily produce desirable outcomes and may have a negative impact on student learning as these tutors are tempted to intervene too often in the PBL discussions. For instance, a study by Silver and Wilkerson (1991) showed that tutors with subject-matter expertise took a more directive role in the PBL process and provided more direct answers to questions that were raised by students as well as contributed more points for discussion. Furthermore, another study observed that tutors who were too instructional created tension and conflict amongst the students, which led to student absenteeism, sarcastic remarks or lack of commitment (Hendry, Ryan & Harris, 2003).

Although a clear relationship between the subject-matter expertise of tutors and student learning has not been established, these studies have highlighted the importance of developing good facilitative skills to guide students in the PBL process. Therefore, if the content expert is able to guide students back onto the right track by discovering and learning from their own mistakes as well as reasoning their way to the desirable conclusions, then the PBL tutor would be more effective as they would be developing students as self-directed learners who would continue learning on their own for the rest of their lives (Das, Mpofu, Hasan & Stewart, 2002). It was also observed that without an interest in the students, the tutor would not be stimulated to encourage students to complete the problem-solving process (Schmidt & Moust, 2000). Thus, it was concluded by Schmidt and Moust (2000) that effective tutors possess three key qualities: (1) appropriate domain knowledge, (2) empathic attitude toward students' learning and (3) an ability to express oneself in a way that is easily understood by students. Furthermore, these three qualities have been proposed to be inter-related (Schmidt & Moust, 1995).

A tutor with an empathic attitude toward students' learning can be described as one who displays a high level of social congruence, which refers to the interpersonal qualities of the tutor such as the ability to communicate informally and empathically with students. As tutors are constantly interacting with students during the PBL process, it is reasonable to expect tutors to be socially congruent as it would help to create a learning environment that encourages open exchange of ideas that in turn allows students to construct new knowledge (Schmidt & Moust, 1995). On the other hand, cognitive congruence can be used to describe the tutor's ability to express oneself in a manner easily understood by students. This quality can be deemed as a combination of subject-matter expertise and social congruence as it requires the tutor to have the ability to communicate in the language of the students so as to explain concepts in ways easily gasped by them (Schmidt & Moust, 1995). The effects of these behaviours on student achievement were studied by Schmidt and Moust (2000) who found that tutors who are more cognitively congruent would utilize more subject-matter knowledge and be more socially congruent. This ultimately translates into higher student performance as the problem-solving process would function better, resulting in students being more interested in the subject matter and spending more time on self-directed learning.

Past studies like Schmidt and Moust (2000) have focused on the influence of these three tutor-related behaviours on student achievement at the end of the PBL cycle. However, little is known about the impact of these behaviours on each learning phase of the PBL process. In a previous study by Chng, Yew and Schmidt (2011), the effect of the tutor's subject-matter expertise, social congruence and cognitive congruence on the PBL process was examined. It was found that the level of social congruence has a significant impact on learning at the problem-analysis, self-directed learning and reporting phases. Although subject-matter expertise and cognitive congruence were not found to have any significant influence on each learning phase, all three behaviours had a significant effect on student achievement. However, the outcome from the study may have been influenced by the random selection of the tutors as further analysis indicated that the standard deviation for social congruent behaviour was twice as large as subject-matter expertise and cognitive congruence. As the study was conducted in a real educational setting and the tutors were randomly selected, it was not possible to control the variation of the tutor's social congruence.

Thus, this study aims to further investigate the effect of social congruence on the students' learning process in a PBL context. Instead of randomly selecting the tutors, they would be selected based on their level of social congruence. One group of tutors would be more socially congruent as compared to another group of tutors and there should be a significant difference between both groups. Although the tutors in this study are selected based on their social congruent behaviours, the tutor's subject-matter expertise and cognitive congruence on student learning would also be examined. Through this study, it is hoped that more insights can be gained into the qualities that make a tutor effective in facilitating the PBL process.

## Study 1

## Method

*Educational context*

This study was conducted at a polytechnic in Singapore that utilizes PBL as its baseline pedagogy. The PBL approach adopted is unique as learning is driven by a different problem each day. Throughout the day, students work under the guidance of a tutor in teams of less than or equal to five. Although the PBL cycle is completed within a day, this unique approach maintains the 'six core characteristics of PBL': (1) the number of lectures is limited as (2) authentic problems are used for students to work on so as to achieve the required knowledge without prior preparation. (3) Learning is initiated by students who would have (4) sufficient time for self-study and would work in (5) small collaborative groups under the (6) flexible guidance of a tutor (Barrows, 1996; Hmelo-Silver, 2004; Schmidt, Van Der Molen, Te Winkel, & Wijnen, 2009).

The PBL process at the polytechnic is briefly described below:

- Problem analysis phase (approximately 1 hour): The tutor presents the problem for the day to the students. In their individual teams, students would analyse the problem and highlight learning issues based on their prior knowledge, assumptions and experiences. After spending approximately 15 – 20 minutes in their respective teams, the tutor will lead a class discussion so as to allow students to exchange their ideas and thoughts with the rest of the students in the class. Students are also guided by the tutor in generating possible routes to solving the problem.

- Self-directed learning phase (approximately 4 hours): During this period, students spend their time on individual study and would assist their team members if needed. Students are encouraged to search for their own resources either through the internet, textbooks or other means, however, there are several additional learning materials that often accompany the problem and these are provided by the tutor. These materials are in the form of worksheets and suggested reading texts that act as scaffolds to assist in the construction of new knowledge. Although majority of the time is spent on their own, the tutor spends approximately 20 minutes per team to check on their progress and the strategies that have been devised. The tutor also encourages students to discuss and evaluate information that have been collated individually with their peers. As they build on each other's ideas, new knowledge is constructed and guided by the tutor.

- Reporting phase (approximately 2 hours): As the name suggests, this phase requires each team to produce a possible response to the problem based on their consolidated findings. However, it is not simply to regurgitate information but to demonstrate the ability to evaluate and synthesize information so as to formulate a probable solution to the problem. Each team will be given time to present their ideas and to defend their views as their peers and tutor poses questions to them. Critical thinking is encouraged by the tutor who would also create opportunities for students to evaluate the presentations made by their peers. The tutor would also clarify and reinforce key ideas if necessary.

*Participants*

The participants in this study were 77 students in their second year of study at the polytechnic. Hence, these students were familiar with the PBL pedagogy practiced at the institution. The participants were from the Science faculty and data was collected during the eighth week of Semester One during the Immunology module. The students were under the tutelage of four tutors who were selected to be part of the study.

Tutors were selected based on their social congruent behaviour. One group comprises of two tutors with high level of social congruence while the other group comprises of two tutors displaying low social congruent behaviour. The tutor's level of social congruent was based on student ratings received through a student evaluation survey conducted in each semester at the institution. The same set of survey questions was used in this study.

*Materials*

Problem statement and subject matter to be mastered

The problem for the day introduces students to the concept of vaccination. It comprises of a debate between two individuals about the use of viral agents to develop defence mechanisms against the specific virus. Students are expected to explore how such pathogenic agents can be used as vaccines to develop immunity and what are the various types of vaccines available. The problem statement is presented in Appendix D.

Measurement

*Measurement of tutor behaviour*

A self-report questionnaire was used to measure the three key tutor-related behaviours: subject-matter expertise, social congruence and cognitive congruence. The questionnaire was adapted from Schmidt and Moust (1995) and it comprises of 10 statements. Using a five-point Likert scale ranging from 'Not true at all' to 'Very true for me', students were asked to indicate how much they agreed with each statement. There were two items that measured the tutor's subject-matter expertise, four items that assessed social congruence and another four items measured cognitive congruence. The questionnaire is presented in Appendix E.

*Measurement of students' learning process*

As a tool to measure students' learning at each phase of the PBL cycle, a concept recall test was designed and administered (Yew, Chng & Schmidt, 2011). The concept recall test required students to list relevant concepts related to the topic for the day. The test was utilized as the ability of the students to recall relevant concepts would provide an estimation of how much students have learnt. This was based on an assumption that when students construct new knowledge, they would build semantic networks that link their prior knowledge with newly learnt concepts (Glaser & Bassok, 1989). As these semantic networks continue to expand and reorganize, students would utilize specific terminologies to help them articulate their new knowledge. Therefore, as a student progresses through the different learning phases in the PBL cycle, it is assumed that the number of relevant concepts recalled at the end of each phase continues to increase.

*Procedure*

As mentioned previously, the tutors (n = 4) involved in this study were selected based on their social congruent behaviour. Two of the tutors formed the group of tutors who displayed a high level of social congruence while the other two formed another group of tutors with low level of social congruence. The average ratings of the tutor's subject-matter expertise, social congruence and cognitive congruence are shown in Table 1. The ratings were extracted from the student evaluation survey conducted in the previous academic year comprising of two semesters. The data clearly indicates the difference in the level of subject-matter expertise, social congruence and cognitive congruence between the two groups of tutors. Furthermore, it can be observed that when tutors were low in social congruence, their ratings for subject-matter expertise and cognitive congruence are also ranked lower as compared to those in the other group.

*Table 1*. Mean scores of the tutors' behaviours based on student evaluation survey conducted in previous academic year

| **Grouping of tutors** | **Tutor-related behaviours** | | |
|---|---|---|---|
| | **Subject-matter expertise** | **Social congruence** | **Cognitive Congruence** |
| High Social Congruence | 4.66 | 4.14 | 4.04 |
| Low Social Congruence | 4.13 | 3.43 | 3.46 |

The tools used to measure tutor-related behaviours and student learning were administered at different intervals of the PBL process. The self-report questionnaire measuring tutor-related behaviours was administered at the end of the reporting phase. The results were used as a means of cross-checking that the behaviours of the tutors had not changed dramatically in the current semester that the study was conducted as compared to the previous ratings. Before the students completed the questionnaire, they were encouraged to reflect on their interaction with the PBL tutor for the day and to honestly rate each statement.

As for the concept recall test, they were administered three times at different time intervals. The same concept recall was distributed immediately after each PBL phase: problem analysis, self-directed learning and reporting phase. While working on the concept recall tests, the students were informed to complete the assignments independently and without making reference to resources. No time limit was given to complete the self-report questionnaire and concept recall tests.

*Analysis*

The self-report questionnaires were analysed by calculating the average scores based on the ratings given by students for the same tutor. An average rating for subject-matter expertise, social congruence and cognitive congruence was computed. These tutor-related behaviours were the independent variables while the learning process variables were the dependent variables in this study.

Analysis of covariance (ANCOVA) was the statistical test used to examine the effects of tutor-related behaviours on the learning process as ANCOVA is able to determine if differences were because of treatment effect or by chance. The covariate used in this study was the pre-existing grade point average (GPA) score and it equates to the average grades the students have achieved in the previous semesters of their course of study. GPA was used as the covariate based on the assumption that the score is an indication of the students' level of prior knowledge, which may affect the results for the concept recall test. Yet, it is a measurable variable that is not affected by the experimental variables. As ANCOVA removes the variability of the dependent variable that can be accounted for by the covariate, it reduces the error variance and provides a more accurate account of the impact made by the amount of prior knowledge on the students' learning process. The average GPA score of the 77 students who participated in this study was 2.61 (*SD* = 0.55). Students under the tutelage of tutors with high social congruence (n = 38) had an average GPA score of 2.54 (*SD* = 0.56) while the students under the guidance of tutors with low social congruent behaviour (n = 39) had an average GPA score of 2.67 (*SD* = 0.55).

As for the concept recall tests, any repetition in the list of keywords for each concept recall test was only counted once. For each relevant concept that was listed, 1 point was awarded and the total score from the concept recall tests administered at the end of each PBL phase was tabulated for each student.

## Results and Discussion

The purpose of this study was to examine the tutor-related behaviours and their effect on student learning during the PBL process. In this study, emphasis was placed on the tutor's level of social congruence as a previous study by Chng *et al.* (2011) had found a significant influence of social congruence on each learning phase. Hence, tutors (n = 4) with contrasting social congruent behaviour were carefully selected to be part of the study with two tutors forming the group of tutors displaying a high level of social congruence while the other two displays low social congruent behaviours.

The tutor-related behaviours measured through the self-report questionnaire for both groups of tutors are shown in Table 2. The mean values indicate that tutors who were more socially congruent were not only high in the level of social congruence but were also rated higher in subject-matter expertise and cognitive congruence. An independent t-test that compared the mean scores between the two groups revealed that there was no significant difference in subject-matter expertise, $t\ (75) = 1.39$, $p = 0.17$. However, a significant difference in the level of cognitive congruence exhibited by tutors from the two groups was observed, $t\ (75) = 2.26$, $p = 0.02$, and a borderline significance was observed for social congruence, $t\ (75) = 1.77$, $p = 0.08$. As compared to ratings from the previous two semesters (refer to Table 1), it can be observed that there were variations in the ratings obtained in this study. More specifically, the variation of social congruence between the two groups of tutors narrowed as the mean values for social congruence of tutors in the high social congruence group had decreased slightly from 4.14 to 3.90 while the tutors in the low social congruence group had an increased average rating from 3.43 to 3.67. Nevertheless, the tutors in the high social congruence group still scored a higher rating as compared to the other group.

*Table 2*. Means and Standard Deviations of the Independent Variables

| Grouping of tutors | N | Tutor-related behaviours | | |
|---|---|---|---|---|
| | | Subject-matter expertise | Social congruence | Cognitive Congruence |
| High Social Congruence | 38 | 4.51 (0.51) | 3.90 (0.55) | 4.08 (0.48) |
| Low Social Congruence | 39 | 4.35 (0.54) | 3.67 (0.58) | 3.83 (0.45) |

The means and standard deviations of the dependent variables are shown in Table 3. Based on the results from ANCOVA, it was revealed that there was a significant effect of social congruence on the concept recall test after the problem analysis phase, $F (1, 74) = 10.56$, $p = 0.00$. However, no significant effect was found on the concept recall test after the self-directed learning phase, $F (1, 74) = 0.06$, $p = 0.80$. In addition, an inverse relationship was observed on the concept recall test after the reporting phase, $F (1, 74) = 6.70$, $p = 0.01$ as the students under the guidance of tutors with low social congruence performed better than those in the other group. The same results from ANCOVA would be obtained for subject-matter expertise and cognitive congruence as tutors high in social congruence were the same tutors who were high in subject-matter expertise and cognitive congruence. Nonetheless, it can be observed that learning was progressive during the PBL process as there was an increase in the number of concepts recalled after each learning phase with the exception of the concept recall test after the reporting phase for students in the high social congruence group. This may have been attributed to the fatigue that students in this group may have experienced as the test was administered at the end of the day.

*Table 3*. Means and standard deviations of the dependent variables

| Tutor Behaviour | *N* | Concept recall test score | | |
|---|---|---|---|---|
| | | After problem analysis | After self-directed learning | After reporting |
| High Social Congruence | 38 | 4.32 (2.71) | 6.39 (3.22) | 4.84 (3.54) |
| Low Social Congruence | 39 | 2.82 (1.68) | 6.38 (2.78) | 6.97 (3.18) |

Unlike the previous study by Chng *et al.* (2011), the outcome from this study does not indicate a clear relationship between social congruent behaviour and student learning and there could be a few reasons why similar findings were not observed. A possible reason could be because the social congruent behaviour displayed by both groups was not largely different from each other as indicated by the independent t-test. Further analysis of the student ratings for each tutor involved in this study indicated that one of the tutors belonging to the low social congruence group had improved student ratings whereby the mean score for social congruence increased from 3.37 to 3.90. Therefore, this change in tutor behaviour could have influenced students to perform better in the concept recall test, leading to an increase in the mean scores that was eventually comparable to the mean score obtained by students in the high social congruence group.

The improvement in student ratings suggests that tutor behaviours can change over time and it is possible for tutors to enhance their social congruent behaviour, which may ultimately influence student learning. Other than a more conscious effort made by the tutor to change their behaviour, it is also possible that social congruent behaviour may depend on the interactive nature of behaviours between the tutor and the students. In order to have informal communication and interaction in the classroom, it does not only depend on the tutor but it requires students to play a part in forming a rapport with the tutor. Therefore, if students are not interested to interact with the tutor, the level of social congruence expressed by the tutor may be affected. However, as this study was conducted in a real educational setting, it would be difficult to control what happens in the classrooms and the kind of interactions formed between the tutor and students.

Another possible reason for not observing a significant impact of the tutor behaviours on student learning may be attributed to the small number of tutors involved in this study as a small sample size would limit the variation in the tutor-related behaviours between the high and low groups. In addition, students' prior knowledge may have been a factor that could have influenced learning. It was noted that students in the high social congruence group generally had a lower GPA score as compared to their peers in the other group. Hence, students with lesser prior knowledge would have to take more time to catch up with their peers. Since the cumulative GPA is a combination of grades obtained from a range of modules, it may also be used as an indication of the students' academic abilities whereby a lower GPA score would suggest that students are academically weaker than students with a higher GPA score. As PBL requires students to play an active role in engaging and acquiring new knowledge, the academic abilities of students may have influenced the extent by which a tutor contributes to student learning. This is based on observations that students who are academically stronger are often able to cope with evaluating and synthesizing new knowledge on their own and may not require as much guidance from the tutor. For such students, the tutor may not be the main factor that affects their learning process and they would continue to perform well regardless of the tutor and their behaviours.

Based on the hypothesis that the academic abilities of students may affect the extent by which students are dependent on the tutor, a second study was proposed. Instead of examining the effect of tutor-related behaviours on learning at each PBL phase, the next study aimed to investigate the effects of the tutor-related behaviours on student achievement and to examine if these behaviours have the same influence on all students. A larger group of tutors would be involved and the academic profiles of the students under the guidance of the tutors would be examined.

## Study 2

## **Method**

### *Participants*

A total of 11 tutors from the same educational institution as the tutors in study 1 were selected. The tutors were selected based on their ratings obtained from the student evaluation survey, which comprises of the same questions found in the self-report questionnaire used in study 1 to measure tutor behaviours. The ratings for the 11 tutors in terms of their subject-matter expertise ranged from 3.77 to 4.72 (M = 4.41, SD = 0.28), social congruence ranged from 3.52 to 4.30 (M = 3.83, SD = 0.28), and cognitive congruence ranged from 3.53 to 4.17 (M = 3.94, SD = 0.19). The student ratings of these 11 tutors collated in the previous two semesters were also taken into consideration when selecting these tutors. The rationale for tracing the student ratings obtained over a period of time was to ensure that the behaviours exhibited by the tutors were consistent so that any effect by the tutor could not be attributed to the change in behaviours like what was observed in study 1.

## Measurement

### *Measurement of student achievement*

Student achievement was measured by the overall score obtained from three "Understanding Tests" (UTs) conducted during the semester. At the polytechnic, for each module that students are enrolled in, a UT is conducted once every five weeks over the 15-week semester period. These tests are used to assess the students' ability to recall and demonstrate what they have learnt. The format of these UTs is typically in the form of short-answer questions that require students to elaborate and apply a particular concept. The first and second UTs carry the same weightage while the final UT has double the weightage.

Based on the guidelines by the polytechnic, the raw numerical score for each UT will be converted into a grade (i.e: A, B, C, D or F). An A grade is awarded to students who achieve at least 80% and above. On the other hand, an F grade is awarded to students who have failed the test and have scored less than 50%. For the purpose of this study, each of the UT grades obtained by a student would be converted into a whole number whereby A = 4, B = 3, C = 2, D = 1, F = 0. Using this conversion system, the total score from the first, second and third UTs will be used and the appropriate weightage will be applied when calculating the overall UT score.

*Procedure*

The overall UT score is a measurement of student achievement but it can also be used as an indication of the students' academic abilities as a high score for UTs would suggest that students are academically stronger than those who obtain a low UT score. Therefore, instead of using cumulative GPA as a measurement of students' academic abilities, the students under the tutelage of the 11 tutors were grouped into three categories based on their overall UT score from the three UTs. The first group consisted of students who scored an overall average of A or B+ for their understanding tests and they were known as the group who were academically stronger. The next group was made up of students who scored an overall average of B to D+ and they represented the average students. The final group had students who scored an overall average of D and below and they were classified as the group who were weaker academically.

*Analysis*

In this study, the independent variables were the tutor-related behaviours and the dependent variable was the overall UT score achieved. The statistical test used to analyse the effect of the tutor's subject-matter expertise, social congruence and cognitive congruence on student achievement was One-Way ANOVA (Analysis of Variance) as the means from three groups of students were being compared. Other than the *F*-value and *p*-value, eta-squared was used as a measure of the effect-size.

## Results and Discussion

This study examined if the effect of tutor-related behaviours was the same for all students by considering the academic abilities of the students. The overall UT score was used to categorize students into three groups: academically stronger, average and academically weaker. Students in the academically stronger group scored an average of A to B+ and students in the average group scored an average of B to D+ while those in the academically weaker group scored an average of D and below for their UTs.

The results from the One-Way ANOVA revealed that the subject-matter expertise, social congruence and cognitive congruence of the tutor had differing effects on different groups of students. For students who were academically stronger, no significant effect of the tutor-related behaviours on student achievement was found, $F (10, 63) = 1.903$, $p > 0.05$. However, there was a significant effect of subject-matter expertise, social congruence and cognitive congruence on the average students, $F (10, 443) = 7.740$, $p < 0.01$ and those who were academically weaker, $F (10, 99) = 2.081$, $p < 0.05$. In addition, there was a larger effect size of 0.42 on students who were academically weaker as compared to the effect size of 0.24 on students in the average group.

The data suggests that the extent of which the tutor-related behaviours affect student achievement is influenced by the students' academic abilities. For students who are academically stronger, the tutor seems to have a lesser effect on learning as compared to those who are academically weaker. Besides the tutor, there are other factors in a PBL curriculum that may have helped these students scaffold their learning. One such factor could be the peer group discussions that students are expected to engage in during the PBL process. Past studies have indicated that if students are engaged in their small group discussions, there will be positive cognitive effects such as activation of prior knowledge, recall of information and causal reasoning (Dolmans and Schmidt, 2006; Hmelo, 1998). As a result, this may increase students' interest in the subject, which indirectly leads to an increase in motivation to learn (Dolmans and Schmidt, 2006). Based on observations, students who are academically stronger are more likely to engage in small group discussions and more willing to participate in peer teaching. By doing so, these students appear to be less dependent on the tutor as they would work collaboratively with their peers to achieve the learning objectives. Hence, this may account for the insignificant effect of the tutor-related behaviours on the overall UT score for this group of students.

On the other hand, students who are academically weaker are generally less motivated to perform well and may be uninterested in the subject. These students may also face more difficulty in constructing new knowledge and engaging in meaningful discussions. Therefore, these students often rely more on the tutor to guide their thought processes and to motivate them, which is indicated by the greater influence of the tutor-related behaviours on student achievement as observed for the average and academically weaker students. As compared to those who are academically stronger, these students would require tutors with subject-matter expertise and who are more socially as well as cognitively congruent. This is because tutors with the relevant domain knowledge would be able to identify learning gaps and help these students in bridging those gaps. In addition, tutors who are more socially congruent are often more approachable and they would be able to create a learning environment that allows these groups of students to feel comfortable in exchanging ideas with one another. Tutors that display more cognitive congruent behaviour would also be more effective in explaining the concepts in a manner that is easily understood by the students.

## Conclusion

The findings from this study have provided insights on the qualities that make a PBL tutor effective as well as highlight a possible factor that may influence the extent of which tutor behaviours would affect student learning. Although a consistent significant effect of the tutor behaviours was not observed in the first study due to various reasons discussed previously, it is possible to conclude that the behaviours of tutors does affect student learning to a certain extent. This can be supported by the significant effect of the tutor behaviours in the problem analysis phase observed in the first study and the significant effect of the tutor behaviours on the average and academically weaker students in the second study.

The academic abilities of the students have also been found to influence the effect of the tutor behaviours on student learning. The results from the second study suggest that tutors do not necessarily exert the same influence on all students and seem to have a greater influence on average and academically weaker students. In other words, students who are performing well academically will continue to perform well even if there is a change in the tutor. However, those who are not performing well may rely more on the tutor and the behaviours of the tutors would determine how much a student learns. For these students, the exact role played by the tutor and which behaviour has a greater influence on learning remains to be established. Nonetheless, this finding suggests that these students require tutors, who are able to provide more guidance, generate interest in the subject and deliver the subject matter in a way that is easily understood.

In conclusion, this study supports previous studies that subject-matter expertise, social congruence and cognitive congruence are key qualities that make a PBL tutor effective. These tutor-related behaviours would allow tutors to develop a positive partnership with their students as effective tutoring is not only dependent on the tutor but the willingness of the students to engage in constructing new knowledge. In addition, such behaviours aid in creating conducive learning environments for students, which ultimately affects student learning.

# Chapter 5: Does social congruent behaviour contribute to the effectiveness of a PBL tutor?

## Abstract

The aim of this study is to investigate the effects of the tutor's social congruent behaviour on the learning process in a problem-based learning (PBL) curriculum. As PBL tutors are actively involved in engaging students in discussion and guiding them in the process of constructing new knowledge, it is believed that a more socially congruent tutor (e.g., a friendly tutor who shows interest in the students) would have a greater influence on learning as they are able to create a non-threatening learning environment that promotes an exchange of ideas. In this study, students from four randomly selected PBL classes (N = 81) formed a control and an experimental group. In the control group, the students were under the tutelage of tutors who were known to be more socially congruent. The experimental group was guided by the same tutors but they controlled their behaviours to exhibit characteristics of tutors with low levels of social congruence. A concept recall test measured students' learning at the end of each PBL phase while pre- and post-essay tests were used to measure prior knowledge and student achievement respectively. Results indicated that there were no significant differences between the control and experimental groups. However, it was observed that the decrease of social congruence affected the ratings for tutor's subject-matter expertise and cognitive congruence, which suggests that tutor behaviours are strongly intertwined.

## Introduction

A teacher is central to the development of the perceptions learners have of learning, the learning strategies they adopt, and the academic outcomes they achieve. However, in comparison to a teacher in a conventional classroom, the role of the problem-based learning (PBL) tutor is qualitatively different. Teachers in a traditional curriculum are often likely to be more content-driven while PBL tutors view the process of learning as equally important to knowledge acquisition and are expected to model good strategies for learning and thinking for the students (Hmelo-Silver, 2004).

The PBL process consists of three phases: a problem analysis, a self-directed learning and a reporting phase (Barrows, 1988; Schmidt, 1983). Students are introduced to a problem relevant to their subject domain at the beginning of the instruction cycle and would work in small groups to solve the problem. The students would use their prior knowledge to identify learning issues and ask questions that remain to be answered in the learning process. A range of resources will be utilized to search for relevant information in the self-directed learning phase, which would be shared amongst the team members and form the basis of brainstorming about possible solutions. Once the team has decided on the most appropriate solution, they would present their idea to the tutor and the rest of the class. This process of problem solving is believed to allow students to learn both content and thinking strategies as the problems are often complex and without a single correct answer (Hmelo-Silver, 2004). In addition, PBL is said to impart better and deeper learning such that knowledge is well-organized, structured and more readily accessible to recall (Norman and Schmidt, 1992).

Thus in a PBL curriculum, there is a strong emphasis in active participation from the learners as the responsibility of learning belongs largely to the students (Massa, 2008). The learning process requires students to work in small collaborative groups and learn through the experience of solving problems that are relevant to their domain of study. Besides collaborative learning, significant amounts of self-directed learning are usually involved, which encourages students to develop self-directed learning skills so that they would be able to continue learning on their own for the rest of their lives (Das, Mpofu, Hasan & Stewart, 2002).

Although learning appears to be mainly student-directed, the role of the PBL tutor should not be ignored. In a study by Choo, Rotgans, Yew & Schmidt (2011), a survey was conducted amongst students that required them to rank factors they thought influences their learning the most in a PBL environment. Although other factors that may influence learning such as the team dynamics and problems used were identified, students ranked the tutor as the strongest factor influencing their learning. This suggests that in this educational context, from a student's perspective the tutor plays a crucial role in engaging them in learning and constructing new knowledge.

What then is the role of a PBL tutor? During the PBL process, the tutor is present in the different learning phases and is expected to facilitate discussions and to probe students to think of possible solutions to the problem. They are expected to stimulate elaboration of concepts, knowledge integration and interactions between students by asking questions, seeking clarifications on how the newly constructed knowledge can be applied (De Grave, Dolmans, & Van Der Vleuten, 1999). Rather than a question and answer session, the tutor would need to follow the discussions that are occurring amongst the students and to decide when to contribute and when to hold back during the discussions (Wetzel, 1996). Thus tutors must make a professional judgement on when and how to impart knowledge as they guide students in refining their learning process and assist them in developing a framework that can be used to construct knowledge on their own (Wetzel, 1996). This allows students to foster the skills of critical thinking and habits of life-long learning (Das *et al.*, 2002). Once the students are able to create their own learning scaffolds, the guidance provided by the tutor would begin to fade and students would start to take greater ownership of their learning. However, the tutor continues to monitor the progress of the students and to ensure that every student is involved in the problem-solving process (Hmelo-Silver, 2004).

Thus, in order to be effective in such a learning environment, the tutor is not only expected to possess relevant subject-matter expertise but to be skilled in facilitation, active listening, motivating learning, and critical reflection as well (Maudsley, 1999). As a result, it has been suggested that the level of cognitive and social congruence of the tutor may significantly influence the tutor's ability to engage students in the discussions and ultimately have an impact on their performance. Cognitive congruence refers to the tutors' ability to utilize appropriate language to express and explain concepts in a way that students can easily understand (Schmidt & Moust, 1995). Through structural equation modelling, Schmidt and Moust (1995) identified that cognitive congruence is a combination of the tutor's subject-matter expertise and social congruence. A tutor who is more cognitively congruent would be more socially congruent and uses more of his subject-matter expertise. Social congruence refers to the interpersonal qualities of the tutor such as the ability to communicate informally and empathically with students. Hence, a tutor with high social congruence is believed to be able to create a learning environment that encourages open exchange of ideas that in turn allows students to construct new knowledge (Schmidt & Moust, 1995).

Previous studies have supported the notion that social congruence enables tutors to empathize with students and guide them in the learning process, leading to better student performance. In a study conducted by Kassab, Al-shboul, Abu-Hijleh and Hamdy (2006), students shared that tutors who respected their opinions, were able to establish good communication, understood their feelings and advised them on how to learn were the most effective tutors. Steinert (2004) made a similar observation whereby students were more inclined in commenting about their tutors' interest in teaching and their ability to create an environment that was conducive for learning as compared to the subject expertise of the tutor. In the study by Schmidt and Moust (1995), social congruence was found to directly influence group functioning during the problem-solving process, which in turn ultimately affected student performance. These findings are in line with our previous argument that possessing subject-matter knowledge alone is insufficient for a PBL tutor.

A study that further examined the effect of a tutor's subject-matter expertise, level of social and cognitive congruence on the PBL was carried out by Chng, Yew and Schmidt (2011). They found that while all three behaviours influence student *achievement* at the end of the PBL process, social congruence had a significant impact on the learning *process* at each PBL phase. However, some limitations of the study were that the standard deviation for social congruent behaviour of the tutors was almost twice as large as those of cognitive congruence and subject-matter expertise. This made it difficult to conclude if social congruence alone influences learning at each PBL phase as the tutors had a greater variation in their level of social congruence that could have accounted for the significant effect. In addition, there was a general observation that tutors who exhibit a low level of social congruence tend to be low in the areas of cognitive congruence and subject-matter expertise as well. Therefore, even though educators have agreed that the tutor's ability to interact well with the students influences the learning environment and student performance, it is difficult to identify if it was only social congruent behaviour that affected student learning or was it a combination of the tutor's subject expertise, cognitive and social congruence behaviours.

In view of this, this study aims to investigate the effects of social congruence on student learning in the PBL process by using the same tutors whereby social congruent behaviour will be controlled when tutoring a group of students while maintaining a high level of social congruence with another group. By doing so, it is hoped that the level of cognitive congruence and subject-matter expertise would remain consistent and leaving social congruence to be the only factor that varies between the two groups of students. Based on the studies conducted previously, it is hypothesized that tutors exhibiting more social congruent behaviours would influence student learning positively. This in turn would ultimately impact student achievement positively as learning in a PBL curriculum has been found to be cumulative whereby knowledge from the previous learning phase is built upon during the PBL cycle (Yew, Chng, & Schmidt, 2011).

## Method

### *Participants*

Data was collected from a sample of 81 students from a polytechnic in Singapore. The students were from four randomly selected classes from the Science faculty and they were under the tutelage of two tutors. The students were in the first week of Semester Two of the Psychology module, which is a module taken by students in their second or third year of their studies. Since they had completed at least the first year of their studies at the polytechnic, the students were familiar with the PBL pedagogy practiced at the institution.

### *Educational Context*

The polytechnic uses PBL as its baseline pedagogy and has adapted it so that student learning is driven by one problem per day. Although modifications have been made for the PBL cycle to be completed within a day, this approach is still classified as PBL based on the 'six core characteristics of PBL': (1) authentic problems are used to drive student learning and the students work on these problems without prior preparation, (2) learning is initiated by students whereby they work in (3) small collaborative groups under the (4) tutelage of a tutor who guides the learning process, (5) a limited number of lectures are conducted and (6) students have sufficient time for self-directed learning (Barrows, 1996; Hmelo-Silver, 2004; Schmidt, van der Molen, Winkel, Wijnen, 2009). In addition, direct instructions from the tutor are limited as students are encouraged to generate learning issues and construct new knowledge (Hmelo-Silver, 2004).

In this approach of solving a problem within a day, students are introduced to a problem at the start of the PBL cycle and would work towards solving the problem in the teams of less than or equal to five by the end of the day. During the process of problem-solving, a tutor is present at different intervals of the day to guide the learning process. A brief description of the day's process is described below:

- Problem analysis phase (approximately 1 hour): A problem is presented by the tutor to the students at the start of the day. Students are given time to brainstorm with their peers to identify learning issues based on their prior knowledge, assumptions and experiences. Once the teams have had sufficient time to explore the problem on their own, the tutor would generate discussion to consolidate the learning issues raised by each team. The tutor would play an active role in encouraging students to share their ideas and views as well as to guide students in strategizing possible approaches to solving the problem.

- Self-directed learning phase (approximately 4 hours): During this phase, students have time to work independently and collaboratively with their peers. The tutor would provide some resources such as worksheets and suggested reading texts for the students as well as to encourage them to search from other sources of information such as the internet and textbooks. After spending some time to work through the resources, the tutor spends approximately 20 minutes with each team to check on their progress. As the students share what they have found, the tutor utilizes questions to promote interaction, check on the students' abilities to evaluate information and guides them in constructing new knowledge.

- Reporting phase (approximately 2 hours): Students from each team are expected to share their consolidated findings and proposed solution to the problem with the rest of the students in the class. During the presentations, students would demonstrate their ability to connect, evaluate and synthesize information gathered from different sources. Each team member plays a part in defending their points of views and answering questions raised by their peers and the tutor. Critical thinking is encouraged by the tutor who also ensures that students are given opportunities to assess the information presented by their peers. At the end of the reporting phase, the tutor would clarify key ideas if necessary.

*Materials*

The problem for the day introduced students to the concept of sensation. The problem statement described the phenomenon about how babies are able to make sense of the world around them such as recognizing different smells and distinguishing their mother's voice from other sounds from the time they are born. The learning objective for this problem was for students to understand the different sensory organs and explain how they function. When working on this problem, it is hoped that students would appreciate how information gathered by various sense organs are used in combination to make sense of the surroundings.

## Measurement

### *Measurement of tutor behaviour*

A questionnaire adapted from Schmidt & Moust (1995) was used to assess tutor behaviours. Students were asked to complete the questionnaire comprising of 10 statements by indicating how much they agreed with each statement based on a five-point Likert scale ranging from 'Not true at all' to 'Very true for me'. Although the main focus of this study was to observe the effects of the tutor's level of social congruence, the questionnaire included questions designed to assess all three core tutor behaviours, namely, social congruence, subject expertise and cognitive congruence, which gives a holistic assessment of the behaviours exhibited by the tutor in class. It also provides an indication if the tutor's subject-matter expertise and cognitive congruence remained consistent between the control and experimental groups with only the level of social congruence varying between groups. Four statements were used to measure the level of social congruence and two statements were measuring subject expertise while cognitive congruence was measured by four statements. Some examples of the statements are 'The tutor helped us to understand the topic', 'The tutor showed interest in our personal lives' and 'The tutor used his/her content knowledge to help us'. The questionnaire is presented in Appendix E.

### *Measurement of students' learning process*

A concept recall test was used to measure students' learning at each PBL phase. The test required students to recall relevant concepts at the end of each PBL phase: problem, analysis, self-directed learning and reporting phase (Yew *et al.*, 2011). The following instruction was given in the concept recall test: "List all the keywords or terminologies related to the different sense organs in the human body. Consider the structure, function and processes involved". Peer collaboration and reference to any resources was not allowed during the test.

The purpose of the concept recall test was to assess the ability of the students to recall relevant concepts as the number of concepts recalled would provide an estimation of how much the student has learnt in the PBL phase. This measurement tool is based on the assumption that students are building in their memory semantic networks consisting of prior knowledge and new concepts related to the problem during the learning process (Glaser & Bassok, 1989). As the networks continue to expand, reorganize and become tightly integrated, students would also acquire more specific terminologies that would help them to articulate their newfound knowledge. Therefore, measuring the number of relevant concepts recalled could provide an indication of the quality of students' learning and how it progresses through the different PBL phases.

*Measurement of students' prior knowledge and achievement*

An essay pre-test was used to measure students' prior knowledge at the start of the day and an essay post-test measured their achievement at the end of the day. The test consisted of the following instructions: "Describe and explain as much as you know about the structure and function of the human sense organs and how they are used to recognize changes in the surroundings." As students describe and elaborate upon the relationship between relevant concepts learned, an estimation of the depth of students' scientific knowledge can be obtained by examining their responses.

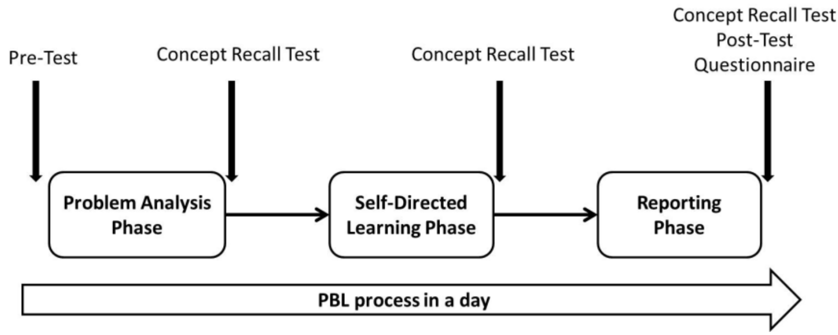
*Procedure*

The tutors involved in this study were selected due to their high level of social congruence based on a student evaluation survey conducted in the previous semester. The data gathered from the student evaluation survey was done by students different from those participating in this study. However, it was noted that both tutors have managed to maintain a constant high rating for social congruence over several semesters prior to this study. Based on a five-point Likert scale, the tutors' average scores for social congruence have consistently hovered over 4.09 and 4.27, respectively. These scores are higher than the average social congruence score for the entire institution, which stands at 3.81 (*SD* = 0.36). In addition, these tutors had been working at the institution for at least six academic semesters and were used to conducting PBL classes.

For each tutor, two classes were assigned and they were requested to demonstrate different levels of social congruence with one group being the control and the other being the experimental group. This study was carried out on the day the tutors met their classes for the first time in that semester – majority of the students were new to the tutors as they had not facilitated them before this. For the control group, the tutor was encouraged to communicate informally and to develop rapport with the students as what they have typically been doing. In the experimental group, the tutor was asked to demonstrate a low level of social congruence by avoiding informal communication and showing interest in the students' personal lives. Despite the differences in displaying social congruent behaviours, the tutors were still expected to ensure that the key learning objectives were delivered in both classes professionally and effectively – the only difference was to avoid personal interest in students and informal talk that was not directly related to students' understanding and learning of the subject matter. Both tutors resumed their usual their high social congruence behaviours in the subsequent lessons for the classes.

The measurement tools used to measure students learning throughout the PBL process were administered on the same day but at different time intervals. Figure 1 gives an overview of the time periods at which the various measurements tools were administered to the participants. As students completed the questionnaire used to measure tutor behaviours, they were asked to reflect on their interactions with the tutor during all three learning phases and to answer each question truthfully. For the concept recall tests, essay pre-test and post-test, the students were informed to complete the tests independently and no reference to resources was allowed. There was no time limit for students to complete the questionnaire, concept recall tests and essay tests.

*Figure 1.* Time intervals at which measurement tools were administered



*Analysis*

In this study, the independent variables were subject-matter expertise, cognitive and social congruent behaviour of the tutor while the dependent variables were the learning process variables and outcomes. As it is standard practice to base indicators of tutor behaviours on class averages rather than on individual data (Marsh, 1991), average scores reflecting ratings of the same tutor across different classes for social congruence, subject expertise and cognitive congruence was computed and used during analysis.

The data obtained from two classes whereby the tutors demonstrated high levels of social congruence was used to compare with the data obtained from the two classes whereby the tutor displayed low levels of social congruence. Analysis of covariance (ANCOVA) was used to examine the effects of social congruence on the learning process and to determine if differences were due to treatment effect or by chance. This statistical test was selected as it is possible to reduce the error variance and provide a more accurate account of the impact made by a measurable factor such as the amount of prior knowledge on the learning process. This is because ANCOVA removes the variability of the dependent variable that can be accounted for by the covariate. Therefore, the scores obtained from the essay pre-test were used as the covariate since the essay test was meant to measure students' prior knowledge. As the essay test is administered before any interaction with the tutor, the results will not be affected by the experimental variables. The average score for the essay pre-test obtained from 81 students was 4.46 ($SD$ = 3.17).

The concept recall tests were marked by awarding 1 point to each relevant concept listed. Computations of total scores from the concept recall tests administered at the end of each PBL phase were tabulated for each student. Any repetition in the list of keywords for each concept recall test was only counted once.

As for the essay test, they were marked based on the "idea unit" (Meyer, 1985; Schiefele and Krapp, 1996). An idea unit can be defined as a statement ending with a comma, period, or 'and'. The idea unit was awarded with a score of 2 if the idea unit was completely correct, 1 if it was partially correct and 0 for a completely incorrect idea unit.

## Results

The level of social congruence displayed by the tutors in their classrooms was determined based on ratings given by their students through the questionnaire used to measure tutor behaviours. The mean and standard deviation of the scores gathered from students under the tutelage of tutors with high level of social congruence were 3.81 and 0.58 respectively. On the other hand, students under the guidance of the same tutors who were instructed to avoid informal communication with their students scored lower ($M$ = 3.32, $SD$ = 0.47). An independent t-test compared the mean scores between the two groups and it indicated a significant difference, $t$ (79) = 4.15, $p < 0.01$. The results suggest that the tutors were successful in controlling their levels of social congruence in their respective classes. The mean and standard deviation of the three tutor-related behaviours are shown in Table 1.

*Table* 1. Means and Standard Deviations of the Independent variables

| **Tutor-related behaviours** | | **N** | **Mean (SD)** |
|---|---|---|---|
| Subject-matter expertise | Control | 40 | 4.38 (0.50) |
| | Experimental | 41 | 4.07 (0.54) |
| Cognitive Congruence | Control | 40 | 4.09 (0.51) |
| | Experimental | 41 | 3.90 (0.52) |
| Social Congruence | Control | 40 | 3.81 (0.58) |
| | Experimental | 41 | 3.32 (0.47) |

The intercorrelations, means and standard deviations of the dependent variables are displayed in Table 2. The results indicate that prior knowledge measured by the essay pre-test appears to be significantly correlated to the total number of concepts recalled after the problem analysis phase suggesting that the concept recall test is a valid indicator of knowledge that students acquire during learning. In addition, significant correlations can be observed amongst the concepts recalled at the different PBL phases, which are also correlated with student achievement measured by the essay post-test. The mean scores of the concept recall test administered after each PBL phase shows that students are performing better as they move into a different learning phase and this suggests that relevant knowledge is being acquired as the day progresses.

Although the data discussed above has shown that the tutors were able to control their social congruent behaviours and that learning was taking place during the day, unlike what we hypothesized, the ANCOVA results did not reveal any significant effects of social congruence on the learning process and student achievement. The mean and standard deviations of the concept recall tests and essay tests gathered from the control and experimental groups are tabulated in Table 3. Conversely, students who were under the guidance of the highly social congruent tutor did not seem to perform as well as those in the experimental group. Nevertheless, an increasing number of concepts recalled at the end of each PBL phase were observed, which indicates that new concepts were being learnt as the students progressed through the PBL cycle.

*Table* 2. Intercorrelations, means and standard deviations of the dependent variables (N = 81)

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| 1. Prior knowledge | 1.00 | | | | |
| 2. Concepts recalled after problem analysis phase | .29** | 1.00 | | | |
| 3. Concepts recalled after self-directed learning phase | .19 | .52** | 1.00 | | |
| 4. Concepts recalled after reporting phase | .09 | .40** | .67** | 1.00 | |
| 5. Student achievement | .18 | .24* | .27* | .37** | 1.00 |
| Mean | 4.46 | 7.91 | 10.00 | 11.51 | 6.36 |
| Standard deviation | 3.17 | 4.53 | 6.03 | 6.97 | 3.97 |

** significant at the 0.01 level
 * significant at the 0.05 level

*Table* 3. Means and standard deviations of test scores with respect to tutor's social congruent behaviour

| Tutor Behaviour | *N* | Concept recall test score | | | Essay | |
|---|---|---|---|---|---|---|
| | | After problem analysis | After self-directed learning | After reporting | Pre-test | Post-test |
| Control (High Social Congruence) | 40 | 6.98 (3.39) | 9.93 (5.40) | 11.25 (6.81) | 4.72 (3.32) | 6.25 (3.88) |
| Experimental (Low Social Congruence) | 41 | 8.83 (5.31) | 10.07 (6.66) | 11.76 (7.20) | 4.20 (3.03) | 6.46 (4.10) |

## Discussion

The effect of the tutor's social congruent behaviour on student learning and performance was examined in this study. In the control group, tutors who were known to be more socially congruent were encouraged to continue displaying a high level of social congruence. On the other hand, the students in the experimental group were guided by the same tutors (n = 2) but who were informed to avoid informal communication with the students so as to mimic tutors with low social congruence. The results indicate that tutors were able to control their social congruent behaviour successfully in the experimental group as there was a significant decrease in the level of social congruent behaviour displayed by the experimental groups as compared to the control groups. However, unlike in a previous study by Chng *et al.* (2011), the social congruent behaviour of the tutor was not found to have any significant impact on student learning process and achievement. The possible reasons for this are discussed below. Nevertheless, although a significant relationship between social congruent behaviour of the tutor and student learning was not found, the mean scores from the concept recall test show growth of knowledge over the day and that learning is cumulative (Yew *et al.*, 2011).

In order to account for a lack of evidence to support how a tutor's social congruent behaviour influences student learning and achievement, several factors may be considered. As the relationship between the tutor and students can be viewed as a type of cognitive apprenticeship (Hmelo-Silver & Barrows, 2006; Schmidt & Moust, 2000; Collins, Brown & Newman, 1989), it is necessary to consider the quality of student participants and how it may affect the findings. For the learning process to be beneficial it does not only depend on the capabilities of the tutor but also requires students to participate actively in the discussions and to constantly analyse possible solutions to the problem. In the context of this study, when the results of the control and experimental groups were compared, it can be observed that the mean test scores for the concept recall tests and post-essay test were generally higher in the experimental group when the tutor displayed low social congruent behaviour. One possible reason could be the time at which this study was conducted. This study was conducted at the start of the academic semester and it was the first day that the students met with their tutor. At this point of time, a rapport between the tutor and students had not been established. The first meeting with the tutor is often a time for students to adjust to their tutor's expectation and to make a good impression. For tutors who exhibit low social congruence, they often come across as unapproachable and strict as they show little interest in the students as well as avoid informal communication with them. Therefore, the students in the experimental group may have felt that they had to work harder to obtain approval from their tutor and ultimately obtain a better grade from the tutor. Hence, this could have been a motivation for them to perform well during the day.

On the other hand, students in the control group may have felt relaxed in their learning environment and it being the first week of the new semester, the students may not have felt a sense of urgency to learn as much as possible in the problem analysis phase as observed by a larger difference between the mean concept recall test scores between the control and experimental groups. Nevertheless, by the end of the reporting phase, students in the control and experimental groups had similar mean scores for the concept recall test. This may also indicate that the speed at which students learn new concepts may have differed between the two groups.

Another possible reason could be due to a lack of sensitivity of the measurement tools. For the concept recall tests, students were asked to write down keywords that were related to the topic. During the learning process, students may have been able to explain their understanding using simple language rather than the specific terminologies. Therefore, if they had not paid attention to the keywords, they would have scored lower in the concept recall tests. In addition, the final concept recall test and post essay test were conducted at the end of the day when students could have been feeling tired from completing the various tests during the day, which could have affected their performance in the tests and resulted in similar mean scores.

On another note, the tutors involved in this study noted their observations after tutoring both groups of students. They observed that students in the low social congruence group were less willing to complete the concept recall tests and essay tests. By the end of the day, these students seemed even more reluctant to attempt the post essay test and this could have accounted for the drop in their performance based on the calculated mean score despite scoring better than the control group in the concept recall tests. In addition, the tutors had a difficult time trying to engage the students from the experimental group in verbal discussion during the problem-solving process. The atmosphere in the classroom of the experimental group was also more tense and there were more students showing signs of disengagement and disinterest. In the following weeks after this study was conducted, the tutors resumed their usual style of tutoring and no longer controlled their level of social congruence. However, it was observed that it still took several weeks before the level of interest in the experimental group matched that of the control group. Eventually the learning attitudes of the students did improve and the students began to engage more actively and spontaneously in the discussions. The overall atmosphere in the classroom also became more congenial and students were more responsive to questions as well as to seek clarifications. Thus although the results from the study indicated a lack of influence of social congruence on students' achievement scores, the observations above show that in fact, tutors with low social congruence do impact students' learning process and motivation negatively. However due to ethical considerations, it would not be possible to continue the study to observe the effects on students on a longer term basis.

In addition to the level of social congruence, Table 1 shows the ratings for subject-matter expertise and cognitive congruence of the tutor as perceived by students in the control and experimental groups. It is evident that subject-matter expertise and cognitive congruent behaviours varied between the two groups based on the mean scores obtained. Although the tutors were the same and they were informed to only control their social congruent behaviour, the students perceived a change in their tutor's subject-matter expertise and cognitive congruence, resulting in lower ratings in the experimental group. This finding suggests that subject-matter expertise, cognitive congruence and social congruence are strongly interlinked and dependent on each other. Although the original intent of this study was to control for only one tutor behaviour, the results show that this atomistic approach is not viable and it is difficult to examine the influence of one aspect of a tutor's behaviour without considering other inter-related behaviours.

Understanding the effects of tutor-related behaviours on student learning has proven to be challenging and complex. The findings from this study indicates that learning does accumulate during the learning phases but a significant effect of the tutor's social congruent behaviour on students' learning was not observed possibly due to the factors discussed earlier. The results also indicate that it is hard to manipulate one variable in an experimental education setting without affecting another as shown by the interdependence of the three tutor-related behaviours. However, although there were no significant differences in the test scores, it can be observed that the attitudes of students were more positive when they were under the tutelage of a more socially congruent tutor and this is likely to have a greater impact on their performance in the long term.

# Chapter 6: Summary and Conclusions

In Problem-based Learning (PBL), knowledge and skills are developed as students work in small collaborative groups to solve authentic problems. A significant amount of self-directed learning is also usually involved with PBL and this process of problem-solving is guided by a tutor. A review of the literature indicates that in particular, three tutor-related behaviours – namely, subject-matter expertise, social congruence and cognitive congruence play a key role in students' learning process and achievement in the PBL classroom (Schmidt & Moust, 1995).

Several studies that examined the effects of subject-matter expertise have highlighted the need for PBL tutors to be content experts since they would have the domain knowledge to correct mistakes and pose more challenging questions (Schmidt & Moust, 2000). However, a study by Silver and Wilkerson (1991) has also suggested that content experts play a more directive role in the tutoring process by directly answering questions raised by students and suggesting points for discussion. By doing so, it may hinder students from discovering and learning from their mistakes as well as reasoning their way to the right conclusions (Schmidt & Moust, 2000). Hence, it has been argued that the facilitative skills of tutors are equally or are even more important for a PBL tutor to be effective as they are involved in questioning, probing and challenging ideas during the problem solving process (Maudsley, 1999).

These facilitative skills can be attributed to social congruence and cognitive congruence whereby socially congruent tutors would be able to communicate openly and build a good rapport with students, which may motivate students to learn. With an ability to communicate informally and empathically with students, a more socially congruent tutor would be able to create a learning environment where students feel comfortable to contribute to the discussions and this may result in better student performance. Furthermore, cognitive congruence, which is the combination of subject-matter expertise and social congruence, would enable tutors to understand the problems faced by students during the problem-solving process as well as possess the necessary domain knowledge to contribute actively in student learning (Schmidt & Moust, 1995). As such, a tutor who is more cognitively congruent would be able to deliver and explain concepts in a manner that is easily understood by students.

A study that examined the qualities of an effective tutor provided insights that tutors who are perceived by students to be effective are those who respected their opinions, able to establish communication and understand their feelings, which suggests that possessing the relevant domain expertise alone is insufficient (Kassab, Al-Shboul, Abu-Hijleh and Hamdy, 2006). Hence, the ideal situation would be for the PBL tutor to be skilled in facilitating the problem solving process as well as possess the relevant content knowledge (Schmidt & Moust, 2000). However, Barrows (1988) highlighted that if it is not possible for a tutor to be both a domain expert and skilled in tutoring, the next best tutor is one who is good at facilitating the learning process.

Although studies related to the behaviours of tutors have been conducted, a majority have focused on the effects of these tutor-related behaviours in achieving curricular outcomes and the influence of these behaviours on the learning *process* remains unclear. Therefore, the main objective of the research conducted for this thesis was to examine the effects of tutor-related behaviours on student learning during the PBL process. As the assumption underlying PBL is that learning is dependent upon what was learnt in the previous phase, it would be necessary to consider how learning takes place during the learning process before investigating the effects of tutor-related behaviours on the learning process. Furthermore, demonstration of the idea that the PBL process is cumulative in a natural classroom setting has yet to be established as most of the research have been mainly confined to the psychological laboratory. Hence, in the study described in Chapter 2, the findings provided insights as to how students learn during the PBL process. In addition, an attempt was made to develop an efficient and valid methodology to track students' learning from one learning phase to the next. As a result, this created an opportunity to investigate the effects of the PBL tutor's behaviours on the learning process in the subsequent chapters.

Before sharing an overview of the findings, it is necessary to understand the rather unique educational context in which the research was conducted. The PBL process is known as 'one-day, one-problem' where students work on one problem in a day (Yew and O'Grady, 2012). A brief description of the PBL process and the role of the tutor at each learning phase are described below:

- Problem analysis phase (approximately 1 hour): Students work in groups of less than or equal to five to identify learning issues based on a problem presented by the tutor. After spending some time to explore the problem, the tutor engages students in discussion and guides them in devising initial pathways for developing a response to the problem.

- Self-directed learning phase (approximately 4 hours): Students engage in self-study and collaborative learning while referring to various resources to gather relevant information. Some examples of resources include worksheets, textbooks, suggested reading texts and the internet. The tutor also spends approximately 20 minutes with each team to check on their progress and strategy to solve the problem. In addition, the tutor promotes interaction and evaluation of information as well as provides guidance in constructing new knowledge.

- Reporting phase (approximately 2 hours): Students present their findings and response to the problem. They are expected to connect their findings from their individual studies and demonstrate their ability to evaluate and synthesize information. The tutor encourages critical thinking and creates opportunities for students to evaluate the information presented by their peers. Key ideas would also be clarified by the tutor if necessary.

Although the learning process described above is rather different from how PBL is implemented in other institutions, it should be clarified that this PBL approach does possesses the six core characteristics of PBL as described by various authors: (1) students work to solve authentic problems without prior preparation so as to achieve the learning objectives, (2) learning is initiated by students and they work in (3) small collaborative groups under the (4) guidance of a tutor. As students learn through the process of problem solving, (5) students would engage in self-study and (6) the number of lectures are limited (Barrows, 1996; Hmelo-Silver, 2004; Schmidt, van der Molen, Winkel, Wijnen, 2009).

In this final chapter, an overview of the findings from each study will be given in hope to answer the following research questions as raised earlier in Chapter 1:

- As student progress through the different learning phases of the PBL process, is learning dependent on what was learnt in the previous phase?
- How can learning at each PBL phase be measured?
- What behaviours make a PBL tutor effective in facilitating the learning process?
- Do the behaviours of the tutor influence learning at each PBL phase? If so, to what extent do the tutor-related behaviours influence learning during the PBL process?
- Amongst subject-matter expertise, social congruence and cognitive congruence, is there a particular tutor-related behaviour that has a greater influence on the learning process?

Towards the end of the chapter, some reflections on the findings and possible areas for further research will be discussed before highlighting the implications of this research in the professional development of tutors.

## Main conclusions

The following segments in this section aim to provide a summary of the findings from each of the studies conducted in this thesis.

### Chapter 2

In the first study, we sought to have a better overview and understanding of how students learn in the process of PBL before focusing on the influence of tutor behaviours in the subsequent studies. Learning is generally viewed as a cumulative process whereby new learning is built upon knowledge that was obtained previously. Similarly, learning in a PBL setting is believed to depend upon what was learnt in the previous phase during the PBL process. In addition, the independent study and interactive nature of students during collaborative work is thought to contribute to student learning in PBL (Schmidt, 1983). However, this cumulative process has yet to be studied in a natural classroom setting. In view of this, the aim of this study was to test this assumption that learning in PBL is cumulative where learning in one phase is built upon the previous phase as well as to examine if the learning process is influenced by both collaborative and self-directed learning. However, being able to efficiently trace student learning throughout the PBL process would be difficult.

Several studies have tried to track student learning over the different learning phases in PBL. For instance, Visschers-Pleiers *et al.* (2006) took video recordings, De Grave *et al.* (1996) made use of stimulated recall and Geerligs (1995) used thought sampling in an attempt to describe the actual behaviours and activities in the PBL classroom. However, these approaches have proven that the data cannot be easily translated into quantification of learning. In addition, the collection and analysis of the data is time consuming, which makes it challenging to study larger numbers of students. Therefore, another objective of this study was to devise a valid method that could easily trace students' learning over the different learning phases.

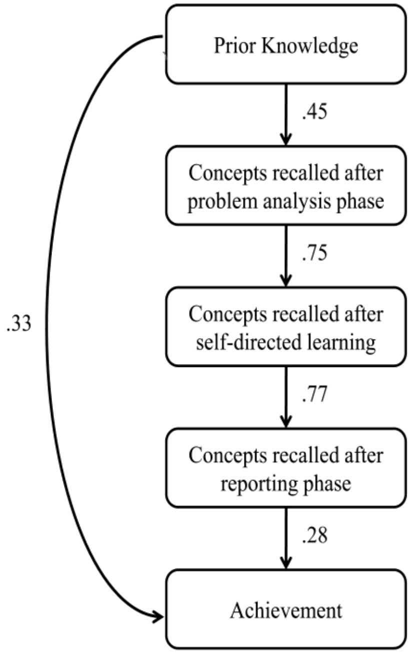
In view of the study objectives, a concept recall test was designed to estimate the number of relevant concepts that students were able to recall at the end of each PBL phase. The test was developed based on the assumption that engagement in the discussions during the PBL process would allow students to form a mental network of concepts related to the different learning issues as well as connecting them with knowledge learnt previously (Glaser and Bassok, 1989). It is believed that as students continue to learn more, the network would become more detailed and coherent. In addition, students who were able to learn effectively during the PBL process should be able to recall more concepts and recall them more easily (Collins and Quillian, 1969; Rumelhart and Norman, 1978). Besides the concept recall tests, the participants in this study were asked to complete an essay test before and after the PBL process so as to measure their level of prior knowledge and achievement, respectively. The essay test would allow students to freely demonstrate their understanding of the topic as they elaborate on the concepts that they have learnt.

Data collected from the concept recall tests indicated that it was during the self-directed learning phase where students are able to effectively recall new concepts and those learnt previously. In addition, when the scores from the essay test measuring prior knowledge was compared with the concept recall test from the problem analysis phase, the results suggest that the discussions in the problem analysis phase aid in activating their prior knowledge, which is similar to findings from previous studies (De Grave, Schmidt & Boshuizen, 2001; Schmidt, De Volder, De Grave, Moust & Patel, 1989). The findings also indicate that learning of new concepts appear to take place more often during the problem analysis and self-directed learning phase as the reporting phase was characterized more by the repetition of previously learnt concepts. Furthermore, there was a drop in the number of concepts recalled at the reporting phase as compared to the previous two phases. This was not expected as it is natural to assume that students would be able to recall more concepts after they have completed the entire PBL cycle. However, a drop in the number of recalled concepts could be due to fatigue from the intensive day of work or students may have forgotten some of the concepts learnt during the day.

Analysis of the concept recall tests shed insights into the events that take place during each PBL phase. However, the question as to whether learning in PBL is cumulative remained. Hence, a structural equation modelling approach was used to analyse if the results from the concept recall test and essay tests fit the hypothesized model. The data was also tested against three alternative hypotheses stating that learning in PBL is influenced (1) only by collaborative learning, (2) only by self-directed learning or (3) by both collaborative and self-directed but not in a cumulative manner. The results eventually indicated that the data fit the hypothesized model as shown in figure 1. Furthermore, the model demonstrated that there was a significant influence of prior knowledge on the concepts recalled after the problem analysis phase (.45) and there was a direct influence on achievement (.33). In addition, the results indicated that being able to recall more relevant concepts at the end of the reporting phase significantly influenced student achievement (.28).

As the data did not fit the models for the alternative hypotheses, it can also be concluded that learning PBL is not only cumulative over each PBL phase but it is influenced by both collaborative and self-directed learning. In addition, it highlights the importance of each PBL phase in influencing student achievement. Based on the results gathered through structural equation modelling, it is also evident that the use of concept recall tests and essay tests are efficient and valid tools in tracking student learning and predicting student achievement.

*Figure 1*. Path model of the hypothesized model on relationships between different PBL phases




## Chapter 3

Using the methodology developed in Chapter 2, it was possible to venture into exploring the effect of the tutor's subject-matter expertise, cognitive congruence and social congruence on student learning and achievement in Chapter 3. The study participants were students under the tutelage of randomly selected tutors ($n = 7$). Besides the concept recall tests and essay test to measure achievement, the students were expected to complete a questionnaire to measure their tutor's behaviours. Based on the student ratings, the tutors were categorised into three groups displaying either a low, medium or high level of subject-matter expertise, cognitive congruence and social congruence.

The statistical analysis using ANCOVA (Analysis of Covariance) indicated that there was a significant influence of the tutor's social congruent behaviour on student learning as measured by the concept recall test administered at the end of the problem analysis phase, $F (2, 219) = 10.38$, $p < 0.01$; self-directed learning phase, $F (2, 219) = 9.83$, $p < 0.01$; and reporting phase, $F (2, 219) = 6.51$, $p < 0.01$. However, no significant effect on the PBL process was observed for cognitive congruence and subject-matter expertise. With regards to student achievement, a significant effect was observed for social congruence, $F (2, 219) = 4.914$, $p < 0.01$; subject-matter expertise, $F (2, 219) = 7.74$, $p < 0.01$; and cognitive congruence, $F (2, 219) = 7.74$, $p < 0.01$, which emulates findings by Schmidt and Moust (1995) where all three tutor-related behaviours were found to be determinants of learning in a PBL curriculum.

The significant effect of social congruent behaviour on the PBL process suggests that effective PBL tutors are individuals who possess the willingness to establish an informal relationship with students and display an attitude of genuine interest. Through such behaviours, the tutor would be able to create a learning environment that students feel comfortable in expressing their views and tutors could do so by allowing students to freely propose their own hypotheses regardless of whether they are accurate or superficial.

Such an environment is necessary in a PBL classroom as students are encouraged to engage in active discussions. In addition, past research has demonstrated that as students voice their thoughts, they would be able to identify their misconceptions and establish connections with the various concepts, which would ultimately influence their academic performance (Schmidt et al., 2009).

Although cognitive congruence and subject-matter expertise displayed no significant influence on the PBL process, it is unlikely that these tutor-related behaviours do not affect the PBL process. This is because the findings in Chapter 2 had demonstrated that learning in a PBL environment is cumulative whereby knowledge is built upon that which was gained in the previous learning phase. Therefore, as a significant effect of cognitive congruence and subject-matter expertise on student achievement was observed, the knowledge gained must have been covered during the various learning phases of the PBL process within the same day. Furthermore, the essay test was administered on the same day as the concept recall tests so this rules out the possibility that knowledge was gained outside of the classroom as no extra time for self-study was given.

Several possible reasons to account for the absence of a statistically significant effect of subject-matter expertise and cognitive congruence on student learning were discussed in Chapter 3. One of the factors that may have had an influence on the results was the fact that the study was conducted in a real school setting where natural variations would occur. For instance, although the participating tutors were randomly selected, they had to be tutoring the same subject and this limited the number of eligible tutors for the study. As a result, it was not expected that the standard deviation of social congruence for this pool of selected tutors was almost twice as large as that of cognitive congruence and subject-matter expertise. Therefore, although the results from this study suggests that social congruence plays a greater role in enhancing student learning as compared to cognitive congruence and subject-matter expertise, it is also evident that a larger sample size of tutors with greater variation in their behaviours is required.

## Chapter 4

Based on the findings made in Chapter 3, the study in Chapter 4 continued to explore the effects of the tutor-related behaviours on the learning process and placed greater emphasis on the tutor's social congruent behaviour. Instead of randomly selecting tutors to participate in the study, tutors ($n = 4$) with contrasting social congruent behaviour were selected. Two of the tutors formed the group displaying a high level of social congruence while the other two tutors displayed low social congruence.

The tutors were selected based on student ratings obtained prior to the study via a questionnaire consisting of the same questions as that in Chapter 3. The same questionnaire was administered again to the current students under the tutelage of the selected tutors. Based on the mean ratings, the results indicated that tutors who were more socially congruent were also rated higher in the area of subject-matter expertise and cognitive congruence. Between the two groups of tutors, no significant difference in subject-matter expertise was detected based on an independent t-test, $t(75) = 1.39$, $p = 0.17$. However, a significant difference in the level of cognitive congruence exhibited by tutors from the two groups was observed, $t(75) = 2.26$, $p = 0.02$, and a borderline significance was observed for social congruence, t (75) = 1.77, p = 0.08.

Similar to Chapter 3, ANCOVA was used to analyse the effect of the tutor-related behaviours on the PBL process as measured via concept recall tests. The results revealed that there was a significant effect of social congruence on the concept recall test after the problem analysis phase, F (1, 74) = 10.56, p = 0.00. However, no significant effect was found on the concept recall test after the self-directed learning phase, F (1, 74) = 0.06, p = 0.80. In addition, an inverse relationship was observed on the concept recall test after the reporting phase, F (1, 74) = 6.70, p = 0.01 as the students under the guidance of tutors with low social congruence performed better than those in the other group. This trend was also seen when the effect of cognitive congruence and subject-matter expertise on the learning process was analysed. Nevertheless, there is a general pattern that mirrors the findings from Chapter 2 whereby learning is cumulative from one learning phase to the next. As seen in Table 1, there was an increase in the number of concepts recalled after each learning phase with the exception of the concept recall test after the reporting phase for students in the high social congruence group, which may account for the inverse relationship observed through ANCOVA. This drop in the number of concepts recalled after the reporting phase was also observed in Chapter 2.

In comparison to the findings in Chapter 3, the results in this study were not as straightforward due to the variations in the effect of social congruence on each learning phase. A possible reason could be because the social congruent behaviour displayed by both groups of tutors was not largely different from each other as indicated by the results from the independent t-test. An analysis comparing the student ratings obtained before and during this study revealed that the variation of social congruence between the two groups of tutors narrowed as the mean values for social congruence of tutors in the high social congruence group had decreased slightly from 4.14 to 3.90 while the tutors in the low social congruence group had an increased average rating from 3.43 to 3.67. This suggests that tutor-related behaviours may fluctuate either because a more conscious effort was made by the tutor to change their behaviour or it may be dependent on the tutor's interactive nature with the students in the classroom as it takes both the tutor and students to build a good rapport. As a result of an improvement in the behaviours of tutors in the low social congruence group, there is a possibility that it could have influenced students to perform better in the concept recall test. Once again, similar to Chapter 3, the natural variations that arise within the classroom make it difficult to control how the tutors interact with the students.

*Table 1*. Means and standard deviations of the dependent variables

| **Tutor Behaviour** | ***N*** | **Concept recall test score** | | |
|---|---|---|---|---|
| | | **After problem analysis** | **After self-directed learning** | **After reporting** |
| High Social Congruence | 38 | 4.32 (2.71) | 6.39 (3.22) | 4.84 (3.54) |
| Low Social Congruence | 39 | 2.82 (1.68) | 6.38 (2.78) | 6.97 (3.18) |

Another possible reason for not observing a larger significant effect of the tutor behaviours on student learning may be due to the students' level of prior knowledge. Further analysis indicated that students in the high social congruence group generally had a lower level of prior knowledge. As students in a PBL curriculum would build upon their prior knowledge to solve problems, students with lesser prior knowledge would spend more time catching up with their peers. In this study, the level of prior knowledge was indicated by the cumulative grade point average (GPA) score obtained by calculating the mean grade based on a range of modules that the students had taken in the previous semesters. Therefore, a student with a lower GPA would suggest that students have lesser prior knowledge and are academically weaker as compared to their peers with a higher GPA. In addition, students who are academically stronger are generally able to cope better on their own during the problem solving process and may not require much guidance from the tutor as compared to students who are academically weaker. Therefore, the academic abilities of students may be a determining factor that affects the extent by which a tutor contributes to the learning process.

With this hypothesis in mind and recognizing that a small number of tutors (n = 4) limits the variation in the tutor-related behaviours, a second study involving a larger group of tutors (n = 11) to examine if their behaviours have the same influence on all students was conducted. In addition, the effect of tutor-related behaviours on student achievement at the end of the learning process will be examined instead of their effects on the learning process. In order to categorize students based on their academic abilities, the overall Understanding Test (UT) score was used to group students into either the academically stronger, average or academically weaker group.

Analysis using the One-Way ANOVA (Analysis of Variance) revealed that the subject-matter expertise, cognitive congruence and social congruence of the tutor had differing effects on students with different academic abilities. No significant effect of the tutor-related behaviours on student achievement was found, $F(10, 63) = 1.903$, $p > 0.05$, for students in the academically strong group. However, there was a significant effect of subject-matter expertise, cognitive congruence and social congruence on the average students, $F(10, 443) = 7.740$, $p < 0.01$ and those who were academically weaker, $F(10, 99) = 2.081$, $p < 0.05$. In addition, there was a larger effect size of 0.42 on students who were academically weaker as compared to the effect size of 0.24 on students in the average group. The results suggest that the extent of which the tutor-related behaviours affect student achievement is influenced by the students' academic abilities whereby tutors do not influence the learning process of academically stronger students as much as their peers in the other groups.

Based on observations of how students behave in class and through informal discussions with other tutors, there seems to be a general trend whereby academically stronger students are more likely to take initiative to engage in small group discussions and are more willing to help other students in grasping the concepts. Such behaviours are encouraged as research has shown that if students are engaged in their small group discussions, there will be positive cognitive effects such as activation of prior knowledge, recall of information and causal reasoning (Dolmans and Schmidt, 2006; Hmelo, 1998). This in turn may increase students' interest in the subject, which indirectly leads to an increase in motivation to learn (Dolmans and Schmidt, 2006). With a positive attitude towards learning, these students may engage in more self-directed learning to satisfy their desire to learn.

On the other hand, academically weaker students are generally less motivated and may face more challenges in the problem solving process. Therefore, they may rely more on the tutor to motivate and guide their thought processes. All three tutor-related behaviours can be anticipated to have a positive effect on the learning process of academically weaker students as a tutor with subject-matter expertise would be able to identify learning gaps and help these students in bridging those gaps. In addition, a more socially congruent tutor would create a learning environment that allows students to feel at ease in raising their opinions and a more cognitively congruent tutor would be better at explaining concepts in a manner easily understood by the students.

Through the research in this chapter, it can be concluded that social congruent behaviour does have some effect on the learning process. The effect of tutor-related behaviours on student learning may also be affected by their academic abilities with the tutor exerting a greater influence on the learning process of academically weaker students. In addition, the findings from this study suggest that it is possible for tutors to exhibit different levels of their behaviours due to the interactive nature with their students or it may be due to a conscious effort by the tutor to change.

## Chapter 5

The previous chapters have highlighted that natural variations surrounding the tutor’s behaviours may influence the results. For instance, in Chapter 4, it was not expected that tutors who were previously rated low in social congruence could display more social congruence when they tutored a different group of students. Therefore, in an attempt to control the experiment and minimize natural variations, the tutors involved in this study were tasked to play both the role of a highly social congruent tutor and a tutor with lower social congruence.

Tutors who were known to be more socially congruent were encouraged to continue displaying a high level of social congruence and they formed the control group (n = 2). In the experimental group, the students were guided by the same tutors but they were briefed to control their social congruent behaviour by avoiding informal communication with the students. Based on an independent t-test, the results indicated that tutors were able to control their social congruent behaviour in the experimental group as the level of social congruence significantly decreased as compared to the control group, $t\ (79) = 4.15$, $p < 0.01$. However, unlike the findings in Chapter 2, the social congruent behaviour of the tutor was not found to have any significant impact on student learning process and achievement as measured by concept recall tests and an essay test. Nevertheless, the mean scores from the concept recall test continued to support the findings from Chapter 2 that learning in PBL is cumulative as there was a steady increase in the number of relevant keywords during the PBL process.

Amongst other possible reasons discussed in Chapter 5, the quality of the student participants could be one of the factors that contributed to the absence of a significant impact of social congruence on student learning and achievement. Meaningful discussion during the problem solving process is not solely dependent on the tutor but it requires students to be active participants in their own learning. Table 2 indicates the means and standard deviations of test scores obtained from both the control and experimental groups. Based on the mean test scores, it is evident that the students in the experimental group generally perform better in the concept recall tests and post-essay test.

*Table* 2. Means and standard deviations of test scores with respect to tutor's social congruent behaviour

| **Tutor Behaviour** | ***N*** | **Concept recall test score** | | | **Essay** | |
|---|---|---|---|---|---|---|
| | | **After problem analysis** | **After self-directed learning** | **After reporting** | **Pre-test** | **Post-test** |
| Control (High Social Congruence) | 40 | 6.98 (3.39) | 9.93 (5.40) | 11.25 (6.81) | 4.72 (3.32) | 6.25 (3.88) |
| Experimental (Low Social Congruence) | 41 | 8.83 (5.31) | 10.07 (6.66) | 11.76 (7.20) | 4.20 (3.03) | 6.46 (4.10) |

Although statistically significant differences between the performances of students in the control and experimental groups were not observed, the tutors were able to share some qualitative feedback about their experience in tutoring both groups of students. In the experimental group, it was observed that students were less willing to attempt the concept recall tests and essay tests, which resulted in the tutors placing more effort into persuading the students. Furthermore, the tutors faced more challenges in engaging students in verbal discussions during the PBL process and the atmosphere was not as relaxed as the control group. The number of students showing signs of detachment and listlessness was also greater. In the subsequent weeks after the study, the tutors resumed to their usual style of facilitation that involved a high level of social congruence in both groups of students. However, the tutors noted that it took several weeks for the students in the experimental group to match the level of engagement experienced in the control group. The overall atmosphere in the classroom also became friendlier and students were more proactive in asking questions and contributing to the discussions.

Based on the findings in Chapter 5, it can be concluded that the behaviours of a PBL tutor does have an impact on students' learning. Although the effect of social congruence was not measured quantitatively, the feedback from the tutors suggests that social congruent behaviour does influence students' attitude and level of engagement in the classroom. This in turn may ultimately affect the learning process and achievement as well as have a greater impact in the long term. Furthermore, despite having a more focus approach in attempting to control only one aspect of the tutor's behaviours, the findings in this study continued to support the notion that subject-matter expertise, cognitive congruence and social congruence are all strongly interlinked and dependent on each other. If a tutor is rated lower in the area of social congruence, the ratings for subject-matter expertise and cognitive congruence also seems to decrease. Therefore, this highlights the difficulty in identifying which particular tutor behaviour has a greater influence on the learning process.

## Critical reflections and directions for further studies

Understanding the effects of tutor-related behaviours on student learning during the PBL process has proven to be rather complex. Nevertheless, the findings have been somewhat consistent in supporting the belief that all three tutor-related behaviours outlined in the introductory chapter of this thesis contribute to student learning, with social congruent behaviours of PBL tutors appearing to exhibit a greater effect on the learning process. It is believed that more socially congruent tutors will be able to create a suitable learning environment that encourages an open exchange of ideas as they are able to establish information communication with students more easily (Schmidt & Moust, 1995). This in turn may provide students with a richer learning experience and ultimately translate into better academic performance as they are encouraged to actively engage in the learning process. Some of the studies in this thesis have provided quantitative data to support this notion that students learn more under the tutelage of socially congruent tutors while others have provided qualitative information on how social congruence can influence students' attitudes and motivation.

The conclusions derived from this research also highlight that a student's learning experience is not entirely dependent on the tutor but it requires students to voluntarily participate in the learning activities. Although the social congruent behaviour of the tutors may be the first steps towards fostering collaborative and self-directed learning during the PBL process, the immediate outcomes in terms of academic performance during the day would also rely on the quality of the students and their willingness to engage in constructing new knowledge.

Although some significant effects of tutor-related behaviours on student learning and achievement was observed in this research, the difference in PBL methodology practiced in this educational context as compared to other educational institutions limits the generalizability of the findings. In comparison to other PBL institutions, students at this institute complete the entire PBL process within a day and have close contact with their tutors whereas the PBL process at other institutions may last for a longer time period and have lesser time for tutor-student interaction. Therefore, it is necessary to examine if similar effects of tutor-related behaviours on student learning can be observed in a different educational context.

Enhancing the format of the concept recall test may also be advantageous. The concept recall test expected students to list as many relevant keywords that they could recall. However, as students gather information from various resources during the problem-solving process, they may have understood the concepts but they may not have mentally registered the keywords. As a result, the number of keywords that they could recall would be limited. Furthermore, being able to recall concepts and relevant keywords do not necessarily mean that the students understand the concepts. A possible solution may be to ask students to construct concept maps that require them to demonstrate their understanding by linking the concepts together.

The research in this thesis has an absence of a long-term perspective as the essay tests to measure student achievement were administered on the same day immediately after the learning process. Further studies to include longer term assessment would be beneficial to provide insights on the long-term effects of the tutor-related behaviours on student learning. In addition, studies examining a larger pool of tutors with wider variations in their tutor-related behaviours would be valuable.

Lastly, based on personal interaction with other PBL tutors, there appears to be a misconception that students view socially congruent tutors as those who are able to tell jokes and allows students to do whatever they like in the classroom. Although PBL tutors like conventional teachers have the responsibility of enforcing discipline in the classroom, it does not necessarily mean that the tutor should play the role of a stern disciplinarian and have a tight control over the students as there are other ways in instilling values related to discipline. In fact, it is often easier and more effective to address disciplinary issues when a good relationship between the tutor and the students has been established. To address this issue, another area for further research may be to examine what social congruent behaviour exactly entails so as to clearly identify the distinctive behaviours of a socially congruent tutor.

## Implications of the findings

The findings from this research have several implications. For instance, hiring managers at PBL institutions would have a better idea of the characteristics they could consider looking for when selecting suitable candidates to fulfil the roles of PBL tutors. In addition, more awareness about the effect of social congruent behaviour on student learning could be shared amongst individuals already employed as PBL tutors. Training courses on how to improve social congruence could also be developed to aid tutors who are less socially congruent in changing their behaviours. Furthermore, the research provides a better understanding of the tutor behaviours that would be required to reach out to students with different academic abilities whereby more attention and guidance could be given to students who are academically weaker. Hence, tutors could alter their behaviours to suit the needs of the students.

Although the findings have suggested that social congruence may have a greater effect on student learning during the PBL process, it is vital to recognize the common trend that subject-matter expertise, cognitive congruence and social congruence are not mutually exclusive but inter-related. Furthermore, all three tutor-related behaviours appear to play important roles in providing students with a rich learning experience that could translate into better academic achievements. The findings from this research are not only supportive of work previously done by Schmidt and Moust (1995) that advocate the positive influence of tutor-related behaviours on student achievement but provide new insights on their effects on the PBL learning process. Therefore, besides social congruence, PBL tutors should strive to demonstrate behaviours related to all three aspects in order to be effective in tutoring the PBL process.

In conclusion, this research has shown that PBL tutors play important roles in the development of learners and their behaviours may influence the learning process and achievement of curricular outcomes. Therefore, more time and effort should be spent in developing effective tutor behaviours. This in turn would ensure that students are receiving good quality guidance from an effective PBL tutor in an engaging learning environment so that they are well-trained and fully equipped to face challenges when they enter the workforce of a rapidly changing society.

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# Appendices

## Appendix A: Molecular Cell Biology problem that students worked on for the day

**Made for the job**

Living things use the DNA molecule to store their genetic information and to pass this information to their offspring.

Analyse the structure of DNA, and determine why it is suitable to assume this role.

## Appendix B: Problem Statement that was offered to students

**'A Runny Issue'**

Jason was sick with fever, sore throat and runny nose. He also felt very lethargic. On consultation with his doctor, Jason was told that he was suffering from an infection that has triggered the immune system. The doctor then prescribed some medicine to relieve the symptoms. However, Jason's condition did not improve after a few days. Upon a second visit to the clinic, the doctor took a sample of Jason's blood for clinical tests. Jason got his test results back from the clinic a week later. Looking at his results, he wondered what could have triggered the infection. Explain.

| | Normal Range<br>gram per liter (g/L) | Jay's Blood Sample<br>gram per liter (g/L) |
|---|---|---|
| *Antibody titer:* | | |
| IgG | 6.4 – 14.3 | 950 |
| IgM | 0.2 – 1.4 | 60 |
| IgE | 0.0001 – 0.0004 | 0.0002 |
| IgD | less than 0.08 | 0.04 |
| IgA | 0.7 – 3.0 | 180 |

(From the Immunology curriculum, Republic Polytechnic, 2008-2009)

## Appendix C: Tutor behaviours measured by a questionnaire involving the use of a five-point Likert scale

| Tutor Behaviour | Questions |
| --- | --- |
| Social Congruence | 1. The tutor showed that he/she liked informal contact with us.<br>2. I was not afraid to tell the tutor when I did not understand something.<br>3. The tutor showed interest in our personal lives. |
| Cognitive Congruence | 1. We could understand the questions asked by the tutor.<br>2. We were interrupted several times by the tutor, which disturbed the progress of the group discussion.<br>3. The tutor helped us to understand the topic.<br>4. Our efforts were appreciated by the tutor.<br>5. I had difficulty understanding the words/terminologies used by the tutor. |
| Subject-matter expertise | 1. The tutor used his/her content knowledge to help us.<br>2. The tutor has a lot of content knowledge. |

## Appendix D: Problem statement that was offered to students

**<u>'It's unbelievable'</u>**

**Jon:** "My friend told me that he was injected with the chicken pox virus to prevent chicken pox for life! I don't quite believe…"

**Lee:** "But I think there may be some truth in it. It makes sense, since I've had chicken pox before and…."

**Jon:** "Come on… How can it be? Common sense tells us that the injected virus will cause the disease, not prevent i! We also can't be sure that once injected, he's protected from the disease for his entire life!"

Discuss who do you think is right.

(From the Immunology curriculum, Republic Polytechnic, 2010-2011)

**Appendix E: Tutor behaviours measured by a questionnaire involving the use of a five-point Likert scale**

| **Tutor Behaviour** | **Questions** |
|---|---|
| Subject-matter expertise | 1. The tutor used his/her content knowledge to help us.<br>2. The tutor has a lot of content knowledge. |
| Social Congruence | 1. The tutor showed that he/she liked informal contact with us.<br>2. I was not afraid to tell the tutor when I did not understand something.<br>3. The tutor showed interest in our personal lives.<br>4. Our efforts were appreciated by the tutor |
| Cognitive Congruence | 1. We could understand the questions asked by the tutor.<br>2. We were interrupted several times by the tutor, which disturbed the progress of the group discussion.<br>3. The tutor helped us to understand the topic.<br>4. I had difficulty understanding the words/terminologies used by the tutor. |

# Propositions

I. Cumulative learning occurs in Problem-based learning (PBL) whereby knowledge is progressively built as students advance through the different learning phases.

II. The amount of knowledge gained through collaborative and self-directed learning is influenced by the skills of the PBL tutor to facilitate and guide students through the problem-solving process.

III. The creation of learning environments that encourage an open exchange of ideas can be credited to the social congruent behaviour of the PBL tutor.

IV. Students facing academic challenges are more inclined to rely on the PBL tutor to guide and motivate them to achieve the learning goals.

V. The perceptions that students have of their PBL tutor affect their attitudes and motivation towards learning.

VI. Students who are actively engaged in the learning process have a greater chance of academic success.

VII. Effective PBL tutors are subject-matter experts with the ability to connect informally and understand the learning difficulties faced by students.

VIII. Students form judgements of the PBL tutors' abilities to facilitate learning by observing their behaviours exhibited in the classroom.

IX. It is possible for the behaviours of a PBL tutor to change over time.

X. "Nine tenths of education is encouragement." *Anatole France*

XI. Mutations in genes coding for major histocompatibility complex (MHC) molecules on tumour cells impair T-cell recognition, resulting in tumour development.

# Curriculum Vitae

Esther Chng was born in Singapore on 25 June, 1982. She completed her primary school education in Singapore before moving with her family to Uganda, East Africa in 1995 where she continued her education at an international school. After 3 years, she relocated to England where she completed her secondary school education at a boarding school and eventually went on to obtain a Bachelor of Science (Honours) in the field of Biomedical Science from King's College London, United Kingdom. Upon graduation in 2004, Esther returned to Singapore and decided to embark on a teaching career with Republic Polytechnic. She joined the School of Applied Sciences as an academic staff and has since been involved in curriculum development, supervising student projects and facilitating modules in the field of Biomedical Science. She is also engaged in student development activities and oversees alumni matters. To further develop and enhance her professional skills, Esther pursued a Master of Education from Monash University and was later given an opportunity to embark on a PhD under the supervision of Professor Henk Schmidt, Erasmus University. Esther currently holds the position of Academic Manager in the School of Applied Sciences at Republic Polytechnic and still tutors PBL classes on a regular basis.