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Peer Tutoring in Engineering Mathematics Learning

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Abstract: This was an action research that investigated the effects of peer tutoring in engineering mathematics learning to address the perceived problem of student underachievement in engineering mathematics in a Singapore polytechnic. About 400 students were guided by their lecturers in the first round of peer tutoring of selected topics, in the first semester, 2009. The data showed that both lecturers and students agreed on the usefulness of peer tutoring in improving engineering mathematics learning. However, they also believed that several issues had to be addressed before the benefits of peer tutoring could be more fully actualised. On the basis of this analysis, the teaching team, of which the author was its member, revised the peer tutoring process. The same batch of students then went through this second round of peer tutoring in the second semester, 2009. The results of the students in the e-quiz, mid-semestral test, and semestral examination in both semesters were compared. There was improvement across the three assessments in the second run of the peer tutoring process. Since this research has yielded positive outcomes in improving the learning of engineering mathematics, the use of peer tutoring can be further deliberated and improved to be implemented on a larger scale to benefit more engineering mathematics students in the concerned polytechnic.

Keywords: Peer tutoring; Engineering mathematics; Engineering mathematics learning

Introduction

Mathematics is important to engineers as it is "a tree of knowledge: formulae, theorems, and results hang like ripe fruits to be plucked" (Steen, 1988, p. 611) or "a well stocked and vital warehouse" (Peterson, 1996, p. 1). These formulae, theorems, and results are at the disposal of the engineers to be used in solving engineering problems. It goes without saying that engineering mathematics is an integral part of engineering studies. Thus, the learning of engineering mathematics is an important component of the success of any engineer. It is within this context that this research was conceptualised. A group of mathematics lecturers from a Singapore polytechnic, saw the need to improve the teaching and learning of engineering mathematics because they believed that many students in the polytechnic were not achieving their full potential in mathematics. They felt a necessity to encourage more ownership of engineering mathematics learning by their students through active learning. The

lecturers also felt that a constructivist form of teaching could improve their pedagogies so as to enhance student learning. Thus, they decided on utilising and customising peer tutoring, because it has been proven to be an effective technique across different cultures and learning contexts, as shown by the literature review below.

Literature Review

Different definitions of peer tutoring have been proposed by researchers such as Boud, Cohen, and Sampson (2001), Damon and Phelps (1989), Gaustad (1993), Griffiths, Houston, and Lazenbatt (1995), Tang, Hernandez, and Adams (2004). They emphasise different aspects of peer tutoring, which can be personal, social, and emotional. Consequently, there is no common agreement or consistency in the conceptualisation of peer tutoring. Therefore, there is a need to clearly define peer tutoring as used in this study.

Griffiths, Houston, and Lazenbatt (1995) defined peer tutoring as "… a structured way of involving students in each other's academic and social development. As a reciprocal learning experience it allows students to interact and to develop personal skills of exposition while increasing their knowledge of specific topics. It is thus an involvement that benefits both tutors and students" (p. 7). This comprehensive definition fits this study well as it promotes mutual benefits for the tutors and tutees both academically and socially. This is especially important in academic settings where no students should be marginalised in any event or activity. Thus, the peer tutoring process used in this study would ensure that the elements as mentioned in Griffiths, Houston, and Lazenbatt (1995) had been included.

In school settings, peer tutoring often involves three parties: teachers (who plan the peer tutoring), tutors, and tutees. Armis (1983) reported that students can learn more effectively through teaching their peers as compared to being taught by their teachers. The key to effective peer tutoring is explained by Damon and Phelps (1989) as follows:

> Unlike adult-child instruction, in peer tutoring the expert party is not very far removed from the novice party in authority or knowledge; nor has the expert party any special claims to instructional competence. Such differences affect the nature of discourse between tutor and tutee, because they place the tutee in a less passive role than does the adult/child instructional relation. (p. 138)

Bargh and Schul (1980) and Ramaswamy, Harris, and Tschirner (2001) added that students tend to study more in depth the content they are supposed to teach to their peers. Anchoring on this unique relationship between the tutor and tutee, Griffiths, Houston, and Lazenbatt (1995) reported that peer tutoring allows students to talk, teach, and assess one another. This will facilitate reflection, synthesis, abstraction, and evaluation of the learning process.

Peer tutoring allows students to learn good communication skills such as active listening, questioning techniques, and different modes of explanation. One benefit for the tutors is that they learn to take responsibility for their tutees (Topping, 1988). By reworking what they know to make them understandable to their peers, the tutors are in fact reinforcing and internalising their current knowledge. Lazerson, Foster, Brown, and Hummel (1988) reported that peer tutoring enables the tutors to strengthen their internal locus of control. Furthermore, peer tutoring can satisfy the social and psychological needs of the students (Topping, 1988). Greenwood, Delquardi, and Hall (1989) considered the improvement of academic results and peer relationships as the important benefits of peer tutoring. For the tutees, Damon and Phelps (1989) stated that mathematics learning benefits significantly from peer tutoring. In fact, the effects of peer tutoring are stronger on mathematics achievement than reading (Cohen, Kulik, & Kulik, 1982). However, these studies were not conducted in the Singapore context of engineering mathematics learning. This study aims to fill this gap in the literature.

To achieve the best gains in academic performance for both tutors and tutees, Magin (1982, cited in Griffiths, Houston, & Lazenbatt, 1995) reported several facilitating factors: the peer tutoring settings should be highly structured, the tutors need to manipulate the instructional materials actively, the relationships between the tutors and tutees need to promote social growth, and the unique needs of the tutors and tutees must be met. This is further supported by Topping (1988), who asserted that the tutoring methods, materials, and process are very important to ensure the success of a peer tutoring programme. Boud, Cohen, and Sampson (2001) felt that the emotional aspect of peer tutoring should be taken care of too. Thus, the teaching team had considered including these factors in its peer tutoring programme.

In a less than perfect world, there are also hindrances to peer tutoring. These include a tutee's resistant behaviour, a tutor's lack of teaching skills, unavailability of time common to both tutors and tutees, lack of chemistry between tutors and tutees, and so on. This study could illuminate whether some of these hindrances to peer tutoring might occur in engineering mathematics learning. This brief review concludes that peer tutoring is beneficial for the tutors, tutees, and teachers.

Research Aims and Research Questions

The general aim of this study was to understand the effects of variables that might affect peer tutoring on the learning of engineering mathematics through reflections of the lecturers and students, in the classroom context of a polytechnic. The study allowed the manipulation of some of these variables in a second cycle, using perceived influencing variables of peer tutoring suggested by the lecturers and students. However, the study did not include factors such as students' internal characteristics and environmental factors such as weather and room temperatures.

The three research questions were as follows:

1. What were the perspectives of polytechnic students and lecturers toward peer tutoring?
2. How would peer tutoring be revised through utilising reflections on the peer tutoring process provided by the students and lecturers?
3. How did the revised peer tutoring affect the students' learning outcome?

Collectively, these questions examined to what extent peer tutoring could be helpful in the learning of engineering mathematics among polytechnic students.

Methodology

Context of research

This study involved two engineering mathematics modules, Engineering Mathematics A (EM A) and Engineering Mathematics B (EM B), conducted in the School of Engineering in the polytechnic for students pursuing the Diploma in Electrical and Electronic Engineering. EM A consists of topics such as Laplace transforms, descriptive statistics, simple probability, and selected discrete and continuous probability distributions. EM B covers methods of integration, infinite series, Fourier series, and vectors.

Two groups of students were involved: one group took EM A and the other took EM B in Semester 1; they then took the other module in Semester 2. The study was carried out in Academic Year 2009/2010. There were 11 tutorial classes for each module per semester, with about 12 to 20 students per class, resulting in 391 students in each module per semester. All the students participated in this peer tutoring exercise. In Semester 1, there were three lecturers for EM A and three lecturers for EM B, whereas for Semester 2, three lecturers for EM A and four lecturers for EM B. Due to staff turnover, only five of them taught both semesters.

Peer tutoring process

The whole peer tutoring process was divided into the following three stages.

(a) The Peer tutoring Preparation Process

(1) Topics: Descriptive Statistics (EM A), Simpson's rule (EM B)

(2) Students: Students were placed into groups of fours or fives. Each student was given an instructional guide (for peer tutoring process) and reflection guidance (for providing learning reflection). Within each group, the students studied the lesson "Descriptive Statistics" or "Simpson's rule" for the assigned topics with the following study materials:

- Online lessons
- Course-books
- Selected Tutorial Questions
- Descriptive Statistics Online Self Test

The students were given 2 hours to prepare the lesson they had to deliver to the whole class. Each student in the group delivered a selected section of the topic assigned to them.

(3) Lecturers: They were given the instructional guide, scoring rubrics, reflection and observation guide, and student briefing guide. These materials were prepared by the two module coordinators with inputs from the teaching team.

(b) The Peer tutoring Process

(1) Students conducted their peer tutoring during tutorials. There were four groups in each 2-hour tutorial class and each group was allocated about 20 minutes for their tutoring process. This process was assessed by their lecturer and this accounted for 3% of overall grade of the module.

(2) Lecturers observed the interactions between tutors and tutees during the tutorial with the help of an observation guide since they were not trained researchers.

(c) Reflection

(1) Students were given ample quiet time to reflect on the peer tutoring process (10-15 minutes) at the end of the tutorial. Six tutorial classes were randomly selected in Semester 1 for in the student reflection process. The students in the remaining classes did their reflection in Semester 2.

(2) Lecturers reflected on the whole process with the help of a reflection guide that gave them advice on the aspects of the peer tutoring process they could focus on.

After gathering insights from the lecturers and students on the first run of peer tutoring, the team revised the original peer tutoring process and this revised process was implemented in the second semester when the students swapped the mathematics modules.

Data collection and analysis

Table 1 shows the data collected.

Table 1
Data collected in First and Second Semesters

Data	First semester	Second semester
Open ended voluntary reflections by students on the whole process.	113	114
On-site observations of process by lecturers.	6	7
Open ended reflections by lecturers on the whole process.	6	7
Students' marks on the peer tutoring topics: e-quiz, mid-semestral test and semestral examination.	√	√

Findings

In the following sections, selected quotes from the students and lecturers are given. Their identities are protected and identified with alpha-numerical representation such as Z1, X13, W5 for students and L1 to L7 for the lecturers. The findings below could address the first research question, "What were the perspectives of polytechnic students and lecturers toward peer tutoring?"

Classification of students' perspectives of peer tutoring

Students' perspectives of peer tutoring encompass their roles as peer tutors and peer tutees (students). Each of these two categories of their perspectives is further subdivided into categories as shown in Figure 1 below.

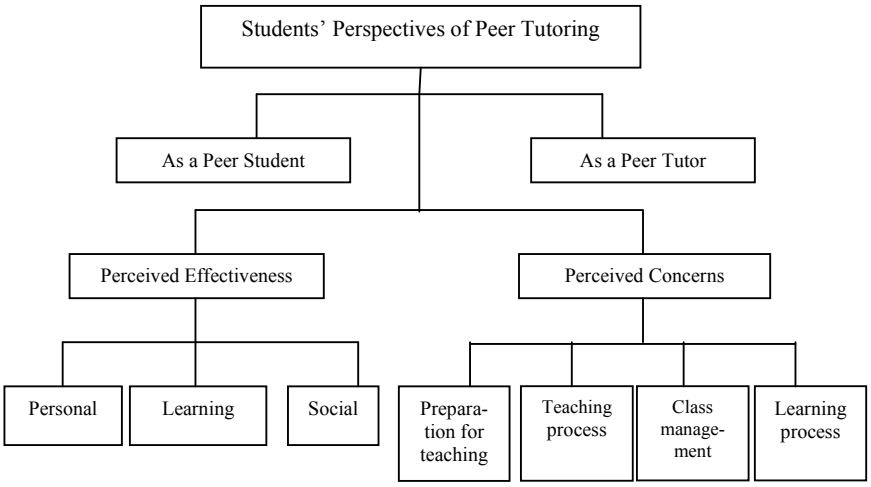

Figure 1. Classification of Students' Perspectives of Peer Tutoring.

First semester: Students' perspectives of peer tutoring

The students' perspectives of peer tutoring from the first semester are categorized into three main categories of personal, social, and learning factors in terms of effectiveness to learning and concerns about peer teaching. The categories are as depicted in Tables 2 and 3.

On the roles of peer tutor, some students wrote that:

Z2: hone our teamwork and presentation skills…
X1: The person who is teaching understands the topic well.
W3: actually peer teaching can build better understanding and friendship.
U11: students would be able to learn from each other….
Z14: It also helped me to communicate better with ours.

Their comments about roles as tutees include:

W12: I feel very comfortable when my fellow classmates are teaching us.
Z3: you have to present to the class which will improve your confidence level.
Z7: We have the courage to question out and clear our doubts.
V1: we can sometimes understand the topic better and faster as our education level is almost the same.

Table 2
Perceived Effectiveness of Peer Tutoring (Students)

Roles	Personal	Social	Learning
As peer tutor	• More assuring of own knowledge • More discipline (through more effort) in learning • Builds up more confidence in presenting to big groups • Put in more persistence in learning • Assume more responsibility in peer learning	• Share problem solving strategies with peer students • Able to help peers in learning • Improve communication skills	• Need to be familiar with teaching materials • Need to actively research on content • Learn more by teaching • Good for self learning
As peer student	• Build up confidence through questioning peer teachers • Learn to be more critical of peer teaching	• Improve communication skills • Learn more about the characters of peer teachers	• Allows more interactive discussions • Learning more user- and understanding-friendly • Learn from the mistakes made by peer teachers • Learning less intimidating

Table 3
Perceived Concerns of Peer Tutoring (Students)

Preparation for Teaching	Teaching Process	Class Management Issues	Learning Process
• Instructions not clear • Lack of training in delivery • Shortage of preparation time • Preparation time does not justify marks weightings • Not learning other topics not teaching • Teamwork • Unbalanced preparation work • Limited support from lecturers	• Poor methods of delivery • Impeding emotions such as anxiety, fear in delivery • Not aware of key concepts • Unsure of accuracy of teaching content	• Disruptive peer students • Lack of control mechanism due to similarity in age • Unresponsive peer students • Inattentive peer student	• Lack of attention if learning prior knowledge • Cynical about peer teachers' teaching ability • Lack of seriousness • Distraction from peers

Some of their concerns were:

V10: at times it is difficult to understand what our classmates are teaching.
X6: they are only prepared for their part and fail to understand other parts.
Y1: But it would have been more effective if students are taught on delivery skills.
U6: only disadvantage – noisy.
V19: we risk learning the wrong stuff from our peers.

The analysis also showed a typology of three types of students in terms of their reflection. The first category is the group of students who wrote only about the usefulness of peer tutoring to their learning. They believed in peer tutoring and perceived that it could help them effectively learn engineering mathematics. The second category consisted of students who not only wrote about the usefulness of peer tutoring but also mentioned the constraints in implementing it. These students were appreciative of the effectiveness of peer tutoring but, at the same time, were pragmatic enough to understand the obstacles that could drastically reduce its effectiveness. The last category consists of students who only reflected on the negative parts of peer tutoring. These students strongly opposed peer tutoring as a useful form of mathematics learning. The ratio of the three categories was approximately 3:5:2 respectively.

First semester: Lecturers' perspectives of peer tutoring

Their perspectives of peer tutoring were generally based on views about the influencing factors in peer tutoring. These influencing factors are shown in Table 4.

Table 4
Perceived Influential Factors of Peer Tutoring (Lecturers)

Peer Students' Attitudes	**Peer Tutors' Delivery**	**Class Management Issues**
• Level of commitment (seriousness) • Level of prior knowledge • Level of interest • Level of rapport with peer	• Level of prior knowledge • Level of rapport with peer students • Time management of delivery • Status of peer teacher in class • Level of cooperation between peer teachers • Level of difficulty of content • Attractiveness, clarity, confidence and accuracy of delivery	• Level of meaningful interaction • Level of attention • Level of distraction

Some of their views about these factors are:

L1: peer tutors are not willing to address some disrupting incidents by peer students.
L2: "tutors" do not treat themselves as tutors, instead they felt they were there to do a simple presentation.
L3: two of my classes have better bonding. As such, when other groups are teaching, they responded positively… Many groups exceeded the time limit.
L4: only a couple of students turned out to be serious listener…their voices are weak and could not present in a lively manner.
L5: mentoring and training of students are required to raise the level of active participation…the teaching and presenting elements were not there.
L6: the contents are sometimes not taught correctly or confidently.

These influencing factors were perceived to affect the level of effectiveness of peer tutoring, which in turn, determines the level of success of student learning in engineering mathematics through peer tutoring. This is addressed in the next section.

Improving peer tutoring in second semester

As it was not feasible to deal with all the factors and issues brought up by the lecturers and students, the team decided to focus on only some common areas raised by both parties, leaving the other issues for future consideration. These included the following class management and content delivery issues:

(a) Refine the instructional guide to make it more detailed and clearer.
(b) Instruct the peer tutors on basic teaching techniques.
(c) Provide more lecturers' assistance during preparation.
(d) Instruct the peer students on their role as students and set rules during lesson delivery.
(e) Provide a more assuring and encouraging environment for peer tutors.
(f) Assist peer tutors to maintain discipline in class.

These recommendations were implemented in the next cycle of this action research in the second semester. This would address the second research question about perspectives after the peer tutoring process was revised based on feedback from the lecturers and students.

Second semester: Students' perspectives of peer tutoring

The same analysis was used on data from Semester 2. The typology of student responses was the same for both semesters. However, one noticeable difference is the ratio of the frequency of concerns raised in Semester 1 compared to Semester 2, with regards to class management and content delivery issues was approximately 5:1. This suggests that the obstructing variables relating to class management and content delivery were handled more effectively in the second semester.

Second semester: Lecturers' perspectives of peer tutoring
For the second run, the lecturers noted the following improvement:

(a) Students are more consciously aware of their roles as peer tutors and peer students.
(b) Class disruption, though still present, is less frequent.
(c) Peer tutors generally perform better in their explanation.
(d) Peer tutors are generally more confident in their lesson delivery.
(e) The contents taught by the peer tutors are generally more comprehensive and useful.

The five lecturers who had gone through the two cycles tutoring unanimously agreed that peer tutoring in Semester 2 was more effective in its delivery as compared to Semester 1. They also felt that the students generally learned better in Semester 2. Thus, their reflections generally support the notion that the revised more smoothly and effectively compared to the initial process. Their perceptions of the effectiveness of peer tutoring in engineering mathematics learning might be supported by the students' assessment results in the two modules, as shown in the next section.

Results of mathematics assessment
This section answered the third research question, "How did the revised peer tutoring affect the students' learning outcome?" Table 5 compares the results in three assessments, namely, e-quiz (EM B), mid-semestral test (EM B), and semestral examination (EM A) for the topic (Simpson's rule or Descriptive Statistics) that was taught by peer tutoring only. The e-quiz was based on five questions related to the peer tutoring topic taken immediately after the peer tutoring was over. Similarly, the results of the mid-semestral test in Table 5 was based on a 10-mark question related to the peer tutoring topic, taken two weeks after the peer tutoring session. As for and the final semestral examination, it was also based on a a 10-mark question related to the peer tutoring topic but it is one of the seven optional questions which the students needed to choose five out of seven.

The results for the second cycle were better than those in the first cycle. In addition to the increase in mean scores shown in Table 5, the percentage of the number of students who did not attempt the optional peer teaching topic question in the semestral examination decreased from 31% to 9%. This translated to 91% of the students in Semester 2 opting this question as one of the five they were supposed to choose from the seven optional questions.

Table 5
Means (SD) of Mathematics Assessments of Peer Tutoring Topics

Type	Maximum score	S1: Initial process	S2: Revised process
e-quiz	5	3.3 (1.5)	3.6 (1.4)
Mid-semestral test	10	7.8 (3.0)	8.5 (2.4)
Semestral exam	10	4.1 (3.7)	5.9 (3.3)

Both groups of students were of equal academic ability as their final mean scores in the two mathematics modules were similar: 73.1 vs. 73.6 in EM A and 72.9 vs. 82.0 in EM B. Furthermore, the questions set in the three modes of assessment were of similar standard in both semesters as ascertained by the lecturers. Given these considerations, the findings in Table 5 suggest that the revised peer tutoring had stronger effects compared to the initial process, even though the results compared two different groups of students. However, one must be mindful that this conclusion may not be robust because the students might have learned or revised the materials using other forms of learning prior to each mode of assessment. Nevertheless, the increase in the number of students attempting the optional question related to their peer tutoring topic (Descriptive Statistics) in the semestral examination gave support to the claim that the second peer tutoring process was more effective than the first one as more students understood this topic and were more willing to attempt it.

Discussion and Conclusion

This action research attempted to involve polytechnic students and their lecturers in the implementation of an active learning process in the form of peer tutoring with reflection of their experiences. It aimed to understand how peer tutoring might help in the learning of engineering mathematics.

The literature has generally shown that peer tutoring can help to improve learning. Both the qualitative and quantitative data from the lecturers and assessments in this study provide evidence that the peer tutoring process has indeed helped to improve learning of engineering mathematics for these students. The above results generally confirm the benefits of peer tutoring mentioned by many researchers (Cohen, Kulik, & Kulik, 1982; Damon & Phelps, 1989; Greenwood, Delquardi, & Hall, 1989;

Houston & Lazenbatt, 1995; Tang, Hernandez, & Adams, 2004; Topping, 1988). In the case of engineering mathematics learning in the concerned polytechnic, a number of factors needed to be considered if lecturers are implementing peer tutoring as a form of effective active learning. These factors include proper guidance in the form of clear instructions, basic teaching techniques and lecturers' assistance during students' preparation and implementation of peer tutoring. This consideration agrees with the studies conducted by Magin (1982) and Topping (1988), who claimed that highly structured peer tutoring programmes can better support higher academic achievement. However, these two researchers did not mention guidance in the form of lecturers' assistance in maintaining class discipline and a non-threatening environment during the implementation. If the peer tutoring process could not be delivered smoothly, then students, playing the roles of tutors and tutees, would not be able to learn the delivered content effectively. This was evident from the second cycle described above.

As mentioned in the analysis section above, one group of students was strongly opposed to peer tutoring. Although there was no evidence that they were disadvantaged in their learning through peer tutoring, their interest in learning should not be compromised because of the mismatch of the pedagogical approach with their belief of how learning should take place. Certain measures may be taken to help them appreciate the benefits of peer tutoring.

In summary, this research has yielded positive outcomes in improving the learning of engineering mathematics. To build on the positive outcomes of peer tutoring at this polytechnic, peer tutoring can be further improved and implemented on a larger scale to benefit more engineering mathematics students.

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