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Engineering Mathematics Obstacles and Improvement: A comparative study of students and lecturers perspectives through creative problem solving

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Abstract

This study is part of a project concerned with the students' obstacles in face-to-face Engineering Mathematics classrooms through mathematical thinking approach. The main data collection for this study was carried out through students' structured questionnaires of three classes at Universiti Teknologi Malaysia (UTM) in the end of semester. The findings showed that the students' obstacles from students' and lecturers' perspectives are approximately the same and the majority of each group separately believed that two main obstacles in the learning of Engineering Mathematics are imaging and sketching in the 3-dimensions. The analysis showed that for both groups different thinking skills and tools from Creative Problem Solving (CPS) are less important methods that can help students to overcome learning obstacles.

Keywords: Creative Problem Solving; Engineering Mathematics; mathematical thinking; students' obstacles

1. Introduction

Mathematics is a prime constituent and infrastructure of the education of engineering students. The main goal of mathematics learning for engineering students is the ability to apply a wide range of mathematical techniques and skills in their engineering classes and later in their professional work (Craft & Ward, 2001). Calculus as an important course for engineering students, allow them to work with several mathematical ideas and also use this knowledge in their engineering fields (Roselainy, Sabariah & Yudariah, 2007).

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However, for many engineering students calculus is one of the most difficult courses in their field of study. Many students will struggle as they encounter the non-routine problems in calculus that are not solved by routine methods of problem solving. Some students' obstacles in the teaching and learning of basic calculus in undergraduate mathematics are (Tall & Schwarzenberger, 1978; Tall, 1985, 1988, 1993):

- the particular events in past experiences of students,
- the mathematics concepts which carry complex meaning,
- the way of transferring of mathematics:
  - using the ambiguities of language,
  - the appropriate learning sequence-studying simple ideas,
  - translating real-world problems into calculus formulation,
- restricting mental images of some concepts,
- selecting and using appropriate representations,
- confusion in the specific concepts,
- poor ability in algebraic manipulation – or lack of it,
- absorbing complex new ideas in a limited time,
- focusing on procedural and routine methods rather than conceptual understanding,
- poor problem solving skills,
- students beliefs and learning styles.

Basic calculus is an important course for engineering students that is offered as pre-requisite course to other advanced mathematics courses. The lack of understanding of concepts in basic calculus may hinder the understanding of other concepts. In this sense, basic calculus like analysis is a "pop up" subject, in that if a difficulty is smoothed over in one place it will pop up somewhere else (Schwarzenberger, 1980; Tall, 1992). Studies done by Yudariah & Roselainy (2004), Roselainy, Sabariah & Yudariah, (2007), and Sabariah, Yudariah & Roselainy (2008) on students' learning difficulties and on teaching challenges in multivariable calculus (Engineering Mathematics) classroom indicate that understanding basic calculus as a pre-requisite play an important role for understanding of Engineering Mathematics. Based on their findings, some students' obstacles in the learning of Engineering Mathematics are from basic calculus and some of them are new. Some teaching challenges in Engineering Mathematics classroom based on their study are:

- mathematics is not a priority to engineering students,
- wide range of mathematical abilities and different levels of mastery of prior knowledge including:
  - algebraic skills (manipulating symbols in flexible way),
  - understanding basic skills,
  - recalling of knowledge fact,
  - the ingrain students learning behavior and styles,
- coordinating multiple procedures,
- answering non-routine questions.

There are many methods for supporting students' learning to overcome their obstacles in mathematics. Creative Problem Solving (CPS) as a framework for solving problems in engineering, science, and mathematics courses employs different thinking skills and tools and fundamentally improves the ways of students' learning in these subjects especially in engineering mathematics (Lumsdaine & Voitle, 1993b). The roots of CPS are found in Osborn's works (1953, 1963) and it is adopted by many researchers like Parnes (1967), Isaksen & Treffinger (1985), and Isaksen, Treffinger & Dorval (1994). Lumsdaine & Lumsdaine (1995) state the CPS as five distinct steps: (i) Problem Definition, (ii) Idea Generation, (iii) Creative Idea Evaluation, (iv) Idea Judgment, (v) Solution Implementation and show the relations between these stages and the four-quadrant thinking of brain in Herrmann

Model (1988, 2001). They believe that the process of CPS involves all analytical, creative, critical, and visual thinking and it can be used to strengthen the quality of teamwork, thinking and communication skills of students in whole brain (Lumsdaine & Lumsdaine, 1995).

Using CPS not only can help students in Engineering Mathematics learning but also can support students' generic skills such as communication and team work. These are the two main weaknesses of engineering students upon graduating entering the work place (Lumsdaine & Voitle, 1993a; León de la Barra et al., 1997). Literature review on engineering and science subjects indicate that very little researches is done on using CPS in mathematics; however, some researchers use other strategies to support students' learning by invoking the thinking and generic skills.

In a study on Engineering Mathematics teaching and learning, Roselainy and her colleagues (Roselainy, Yudariah & Mason, 2007; Roselainy, Sabariah & Yudariah, 2007; and Sabariah, Yudariah & Roselainy, 2008) presented a model of active learning that is based on invoking students' mathematical thinking powers, supporting mathematical knowledge construction, and promoting generic and soft skills that students need to know as an engineer. They had used themes and mathematical processes through especially designed prompts and questions to invoke and support students' use of their own mathematical thinking powers during face-to-face interactions in classroom setting. They employed varied thinking skills and strategies in their method based on mathematical thinking approach.

In this study, we attempt to overcome students' obstacles in Engineering Mathematics by promoting mathematical thinking through creative problem solving. We first identify the students' obstacles in the learning of Engineering Mathematics using this method and ways of improving them from students' perspectives as an important goal of this study. Then, we compare lecturers' perspective on students' obstacles and ways of helping them in the learning of Engineering Mathematics with the students' perspective. Finally considering both the students and lecturers views, we identify and compare to what extend employing the diverse thinking skills and tools from CPS help to support students to reduce the obstacles.

2. Engineering Mathematics through Mathematical Thinking Approach

In earlier studies by Roselainy and her colleagues (Yudariah & Roselainy, 2004; Yudariah, Roselainy & Mason, 2007; Roselainy, Sabariah & Yudariah, 2007; and Sabariah, Yudariah & Roselainy, 2008), in developing the mathematical pedagogy for classroom practice they had adopted the theoretical foundation of Tall (1995) and Gray et al. (1999) and used framework from Mason, Burton & Stacey (1982) and Watson & Mason (1998). They focused on three major aspects of teaching and learning: the development of mathematical knowledge, mathematical thinking processes, and generic skills (see Figure 1). They highlighted some strategies that can help students to empower themselves with their own mathematical thinking powers and help them in the re-construction of mathematical knowledge and soft skills, particularly communication, team work, and self-directed learning. The mathematical thinking processes thought of as powers emphasised were: specializing and generalizing, imagining and expressing, conjecturing and convincing, organizing and characterizing (Yudariah & Roselainy, 2004; Roselainy, Sabariah & Yudariah, 2007).

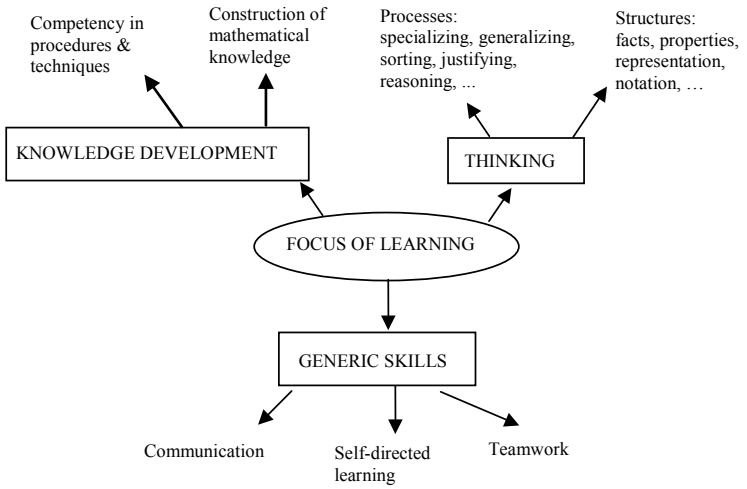

Fig. 1. Focus of mathematical learning

Roselainy et. al. had further developed and implemented their model of active learning in the teaching of Engineering Mathematics at UTM. They considered the following aspects in the implementation of active learning in Engineering Mathematics classroom (Roselainy, Sabariah & Yudariah, 2007; and Sabariah, Yudariah & Roselainy, 2008).

i. classroom tasks- by categorizing the workbook as *Illustrations*, *Structured Examples* and *Reflection* with *Prompts and Questions*.
ii. classroom activities (approaches)- by working in pairs, small group, quick feedback, students' own examples, peer-teaching, discussion and think-pair-share, directed reading and writing to learn.
iii. encouraging communication- by designing prompts and questions to initiate mathematical communication.
iv. supporting self-directed learning- by creating structured questions to strengthen the students' understanding of mathematical concepts and techniques.
v. identifying types of assessment- by incorporating both summative and formative types.

Figure 2 gives a summary of the model for active learning (Roselainy, Sabariah & Yudariah, 2007; and Sabariah, Yudariah & Roselainy, 2008).

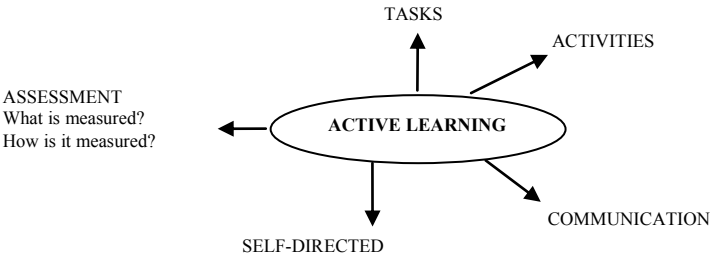

Fig. 2. Model of active learning

In short, they had provided and promoted a learning environment where the mathematical powers are used specifically and explicitly, towards supporting students (i) to become more aware of the mathematics structures being learned, (ii) to recognize and use their mathematical thinking powers, and (iii) to modify their mathematical learning behavior (Yudariah & Roselainy, 2004; Roselainy, Sabariah & Yudariah, 2007; and Sabariah, Yudariah & Roselainy, 2008).

3. Method

This study is part of a project concerned with the students' learning of Engineering Mathematics in face-to-face classroom through Roselainy and her colleagues' method carried out at UTM in Semester I 2009/2010. The course Engineering Mathematics is offered at UTM as a three credit course to first-year engineering undergraduates. The pre-requisite for this course is basic calculus and it focused on the following topics: functions of several variables, partial derivatives, multiple integrals, vector functions, and vector calculus. These topics are covered within 14 weeks with 3 hours of lectures and one hour of tutorial per week (Yudariah & Roselainy, 2004). The *Engineering Mathematics for Independent Learners* written by Yudariah, Sabariah & Roselainy (2009) was used as the main workbook throughout the semester. This book was written based on the mathematical thinking approach and consists of five chapters that cover all topics in Engineering Mathematics course.

The sample of this study consisted of 178 first year undergraduates from three Engineering Mathematics classes in the Faculty of Electrical Engineering at UTM who were taught using Roselainy et. al.'s method. In addition, 10 lecturers from the Department of Mathematical Sciences of Faculty of Science at UTM involved in the teaching of Engineering Mathematics were selected for a survey on their perspective about students' obstacles and their ways of improving them.

A structured questionnaire aim to gather students' view on obstacles in Engineering Mathematics course and ways of improving them was distributed in at the end of the semester. The questionnaire included two open ended questions (Question 1 & 3) and a ranking question (Question 1) as follows.

1) What are the greatest difficulties facing you in Engineering Mathematics?
2) How would you rank the following methods (see Table 1) to help your learning in Engineering Mathematics? (1 for the most important …13 for the least important)

Table1. The methods of improving students' obstacles

Method	Average ranking
Choosing relevant topics	
Choosing problem related to the real world or students' major	
Simplified concept	
Teaching at students' level (peer teaching)	
Lecturer encouragement	
Individual homework and assignment	
Group project	
Quiz/ test/ assessment or exam	
Group work (collaboration) in the class	
Classroom discussion with the peers and lecturer	
Peer and lecturer online /offline supports in the outside of class (Chat/ email/ online bulletin board …)	
Using computer facilities (software / simulations/ calculator …)	
Using online facilities (website/ web learning modules/ online self assessment/ library…)	

3) Do you have any suggestion to help your learning in Engineering Mathematics besides the above-noted methods?

The students' structured questionnaire, with a slight modification was distributed to the Engineering Mathematics lecturers at the end of the semester. This allows the students' obstacles to be compared directly with those expected by the lecturers as well as to compare the students' suggestions to improve these difficulties with the methods which lectures preferred.

4. Discussion

4.1. Student's Questionnaires Results

The visualisation and sketching in 3-dimensions were the greatest difficulties for majority of students in the learning of Engineering Mathematics based on common students' respond to this question: "what the greatest difficulties are facing students in Engineering Mathematics." In class during the lectures, the student' visualisation and sketching were supported by illustrating the graphs using the overhead projector and the use of the workbook. This approach it seems was not sufficient to support students' imagining and expressing processes. Furthermore, most students mentioned that too much concepts, facts, theorems, formulas, memorising, fail to remember methods and formulas, complex calculations, and poor recall of prior knowledge were some of the reasons that hinder their learning and understanding of the subject matter.

Students ranked the methods that can help them in the learning of Engineering Mathematics as the following:

Table 2. Methods ranked from students' perspective

Method	Average ranking
Simplified concept	4.40
Teaching at students' level (peer teaching)	4.87
Individual homework and assignment	5.16
Classroom discussion with the peers and lecturer	5.25
Lecturer encouragement	5.79
Choosing problem related to the real world or students' major	6.39
Choosing relevant topics	6.59
Quiz/ test/ assessment or exam	6.80
Group project	7.58
Group work (collaboration) in the class	7.66
Peer and lecturer online / offline supports in the outside of class (Chat/ email/ online bulletin board …)	9.62
Using computer facilities (software / calculator …)	10.08
Using online facilities (website/ web learning modules/ online self assessment/ library…)	11.21

Referring to above table (Table 2), simplified concept and peer teaching (students teach each other) are the highest important methods and using computer facilities (offline & online) are the lowest important methods to help students' learning in Engineering Mathematics from students' perspectives. Furthermore, some methods such as online and offline communication, group work, grouping project, and even classroom discussion do not have high rank from students' views.

Many students suggested that more and different examples, exercises, assignments, and tutorials can help to improve students' difficulties in the understanding of Engineering Mathematics besides the above-noted methods. Some of them mentioned about supporting their learning by solving some questions that are the same with the

final exam questions. This indicates that students' behaviour is on procedural learning and thinks only in passing the final exam rather than on deep learning of the topics that may help them in their field of study. It is interesting that many students believed that the visualisation and sketching are their greatest difficulties in the learning of Engineering Mathematics; however, just a few of them mentioned that online and offline computer facilities can help them to overcome these difficulties. The rest of the students also did not give any suggestions of alternative methods that can support visualisation and sketching in 3-dimensions. Based on Table 2, using an offline and online computer facilities considered as the most important way in supporting visual thinking, had the lowest ranking among all the methods from students' perspectives.

4.2. Lecturer's Questionnaires Results

According to the data collected from the lecturers' questionnaires, most lecturers also believed that the visualization in 3-dimenssion is the biggest difficulties that the students encountered in Engineering Mathematics. Half of the lecturers believed that the lack of the basic skills and background knowledge are other students' obstacles in Engineering Mathematics. In addition, some of them noted other students' obstacles such as difficulties to relate the subject and its applications and also memorising and failed to understand the concepts.

Lecturers ranked the methods that can help students in the learning of Engineering Mathematics as the following:

Table 3. Methods ranked from lecturers' perspective

Method	Average ranking
Simplified concept	2.1
Teaching at students' level (peer teaching)	4.1
Choosing relevant topics	4.7
Lecture encouragement	5.8
Individual homework and assignment	6.1
Group work (collaboration) in the class	6.5
Classroom discussion with the peers and lecturer	6.5
Choosing problem related to the real world or students' major	6.7
Group project	7.7
Quiz/ test/ assessment or exam	7.8
Peer and lecturer online/ offline supports in the outside of class (Chat/ email/ online bulletin board …)	8.8
Using computer facilities (software / simulations/ calculator …)	9.3
Using online facilities (website/ web learning modules/ online self assessment/ library…)	10.6

Based on Table 3, simplified concept and peer teaching (teaching at students level) are the highest important methods and using computer facilities (offline & online) are the lowest important methods to help students' learning in Engineering Mathematics from lecturers' perspectives. Similar to the students' views, online and offline communication, group work, group project, and even classroom discussion do not have high rank to support students' obstacles from lecturers' views.

Majority of lecturers suggested that using computer facilities is the best way to overcome students' obstacle in visualization. However, it is interesting that using computer facilities (offline & online) as a way to support students' visualization has the lowest rank among all methods to support students learning from the lecturers perspective. Some lecturers suggested that doing more explanation and solving more exercise and examples especially from engineering fields can help students to overcome their difficulties.

5. Conclusion

Based on the collected data from students' questionnaires, visualisation and sketching in 3-dimensions are the greatest students' obstacles in Engineering Mathematics from students' perspectives. Our data from lecturers' questionnaires support this finding and they also believed visualization is the greatest difficulties facing students in Engineering Mathematics. It seems that Roselainy et. al.'s method was insufficient to support students' visualisation and sketching in Engineering Mathematics. Most lecturers suggested the computer facilities (offline & online) as a way for supporting visualization. However, the findings (see Table 2 and 3) indicated otherwise where both students and lecturers ranked the computer facilities (offline & online) as the least important methods to support learning and visual thinking.

Many students noted that they cannot understand Engineering Mathematics due to the following reasons: too much concepts/ facts/ theorems/ formulas, memorising, fail to remember methods and formulas, complex calculations, and poor recall of prior knowledge. Based on the lecturers' opinions, most of them believed the lack of the basic skills and background knowledge and memorising of concepts are other students' obstacles in the learning of Engineering Mathematics. It seems that the elements of active learning were not enough to support students to reduce these difficulties, particularly in recalling prior knowledge. Moreover, some students believed that the examples with the solutions in the workbook would help them for better understanding. This may be due to the ingrained learning behaviour and styles attributed to their previous mathematics learning. However, some lecturers believed that doing a lot of exercise remained a relevant way that can help students to learn better.

Comparing between Table 2 and 3, the same ranking is given from the students and lecturers perspectives in overcoming Engineering Mathematics difficulties. We can see that the highest important methods ranked are simplified concept and peer teaching (students teach each other), while the least important methods are using computer facilities (offline & online). Surprisingly, the analysis showed that for both students and lecturers the varied thinking skills and tools from CPS such as communication, team work, and visualization are the lowest ranked important methods for helping students in the learning of Engineering Mathematics. These results confirmed the needs and the importance of some reforms in engineering education not only in the learning and teaching of courses like mathematics considered not a priority subject from students' view but also in supporting engineering students' generic skills such as communication and team work.

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