Supporting Engineering Students' Thinking and Creative Problem Solving through Blended Learning

Hamidreza Kashefi[a], Zaleha Ismail[a], Yudariah Mohammad Yusof[b]

[a]Department of Science and Mathematics Education, Faculty of Education,
Universiti Technologi Malaysia (UTM), 81310 Johor, Malaysia
khamidreza4@ siswa.utm.my, zaleha@mathed.utm.my
[b]Department of Mathematics, Faculty of Science,
Universiti Technologi Malaysia (UTM), 81310 Johor, Malaysia
yudariah@mel.fs.utm.my

Abstract

The engineering curriculum with a strong preference in analytical thinking (left-brain) worked well in the past but is not producing the type of engineering graduates with generic skills like team working and communication to meet the need of human capital for today and the future. Creative Problem Solving as a framework to encourage whole-brain thinking which employs different thinking skills and tools is not sufficiently emphasized in universities. On the other hand, research findings indicate that for most engineering students, mathematics has always been one of the most difficult courses to study. Previous researches tried to overcome students' difficulties in the engineering mathematics by using some methods based on supporting mathematical thinking. In this paper, we shall discuss and propose a learning environment for supporting students' thinking and creative problem solving in engineering mathematics. Blended learning is suggested as an environment to support students' thinking powers through creative problem solving.

Keywords: Blended Learning; Engineering Mathematics; Creative Problem Solving; Mathematical Thinking.

1. Introduction

Current trends in technology and our increasingly complex society and the workplace require engineers have a greater variety of capabilities, skills, and a wider understanding of engineering as a discipline, if they want to succeed (Pappas, 2002). Educational and enterprise managers agree that too many engineering students are graduated without having effective communication and teamwork skills (León de la Barra et al., 1997). According to Lumsdaine & Voitle (1993a), industries also complain that graduate engineers are technically in competent, they lack critical problem solving skills, communications, team working, and how to set up criteria to make sound judgment. Unfortunately, the rapid change of technology in the society does not produce a corresponding change in the training and education of engineers (Lumsdaine & Voitle, 1993a). According to Lumsdaine & Voitle (1993a), the same material basically is taught with the same tools and methods that have been used fifty years ago. In other words, the traditional approach with a strong preference in analytical thinking (left-brain) worked well in the past but does not produce the type of engineering graduates for the future human capital (Lumsdaine & Voitle, 1993a). The limitations of traditional teaching styles due to the lack of employing of whole brain cause engineering students encounter many problems in the learning of mathematics which play important role in engineering (Lumsdaine & Voitle, 1993a; Lumsdaine & Lumsdaine, 1995b).

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 of applying a wide range of mathematical techniques and skills in their engineering classes and later in their professional work (Croft & Ward, 2001). Many topics in most engineering curricula are taught using mathematics and mathematical models. Knowledge of the prerequisite background in mathematics is therefore necessary for students to learn many areas of study. Research findings indicate that for most engineering students, mathematics has always been one of the most difficult courses to study. Many students will struggle as they encounter the non-routine problems that are not solved by routine methods of problem solving.

Creative Problem Solving (CPS) as a framework that encourages whole-brain which employs different thinking skills and tools can fundamentally improve the way students learn mathematics and support their generic skills such as team work and communication. CPS can be used to strengthen the productivity, quality of teamwork, thinking and communication skills of students in whole brain. Some researchers promote CPS in engineering, science, and even mathematics courses (Lumsdaine & Voitle, 1993a; Wood, 2006; León de la Barra et al., 1997; Lumsdaine & Lumsdaine, 1995b); however, the literature review indicates that there are very little researches that support students solving Engineering Mathematics problems and mathematical knowledge construction in a creative manner through CPS. In these studies, researchers try to encourage whole-brain which employs different thinking skills and tools to support students' abilities in problem solving by promoting CPS. In the case of mathematics there are researches that support students' thinking powers in the learning of mathematics by promoting mathematical thinking, but very few employ CPS (Mason, Burton & Stacey, 1982; Dubinsky, 1991; Shoenfeld, 1992; Yudariah & Tall, 1999; Gray & Tall, 2001; Tall, 2004; Roselainy, Sabariah & Yudariah, 2007).

In this paper, the theoretical framework for promoting mathematical thinking by using computer is discussed and theoretical reasons for selecting blended learning to support mathematical thinking in mathematics through CPS are put forward. A theoretical framework that supports blended learning by integration of the benefits of both face-to-face (F2F) and computer environment has a rich structure to overcome students' difficulties in mathematics.

2. Creative Problem Solving

According to Lumsdaine & Lumsdaine (1995b), based on the Herrmann model (1988, 2001) the brain can be visualized as a four quadrants metaphorical model that are labeled A (mathematical, analytical, critical thinking), B (sequential, controlled, routine thinking), C (interpersonal, empathetic, symbolic thinking), D (imaginative, visual, conceptual thinking) and each quadrant is characterized by distinct ways of thinking, knowing, and processing information (Fig. 1). Engineering education on the average by skewing toward a strong preference in quadrant C thinking has caused many engineering students and even professors be predominantly left-brain thinkers (Lumsdaine & Lumsdaine, 1995a). This causes when engineering students are graduated they will encounter many problems in their work place that require different thinking abilities (Lumsdaine & Lumsdaine, 1995b). So the researches confirm that quadrants C and D activities must be part of the engineering curriculum (Lumsdaine & Lumsdaine, 1995a).

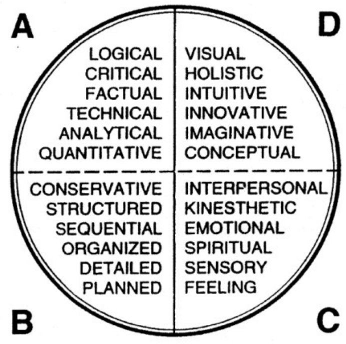

Fig. 1. The four-quadrant brain model of thinking preferences developed by Herrmann..

CPS that employs whole brain of students can play an important role to provide new generation of engineers for human capital. The roots of CPS are found in Osborn's works (1953, 1963) and it followed by many researchers like Parnes (1967), Isaksen & Treffinger (1985), Isaksen, Treffinger & Dorval (1994). Lumsdaine & Lumsdaine (1995b) 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, and critical thinking and it can be used to strengthen the quality of teamwork, thinking and communication skills of students in whole brain during of its stages (Lumsdaine & Lumsdaine, 1995b).

3. Mathematical Thinking

Mathematical thinking is a dynamic process which expands our understanding with highly complex activities, such as abstracting, specializing, conjecturing, generalizing, reasoning, convincing, deducting, and inducting (Mason, Burton & Stacey, 1982; Tall, 1991; Yudariah & Roselainy, 2004). Tall in many researches (1986, 1989, 1990, 1993, 1998, 2003) used an environment to support students' mathematical thinking (quadrant A from left-brain) to overcome their difficulties in calculus based on Socratic dialogue between teacher and students (quadrant C from right-brain) which is enhanced by the addition of the computer facilities like visualization (quadrant D from right-brain). In fact, Tall try to support mathematical thinking as a mode of quadrant A by using different thinking from other quadrants thinking concerned by visualization (quadrant D) and communication (quadrant C).

In the earlier study (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 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 construction, mathematical thinking processes, and generic skills (Fig. 2). They highlighted some strategies that can help students to empower themselves with their own mathematical thinking powers and help them in construction new mathematical knowledge and soft skills, particularly, communication, team work, and self-directed learning. Furthermore, the mathematical thinking activities can be taught of as powers were: specializing and generalizing, imagining and expressing, conjecturing and convincing, organizing and characterizing (Yudariah & Roselainy, 2004; Roselainy, Sabariah & Yudariah, 2007).

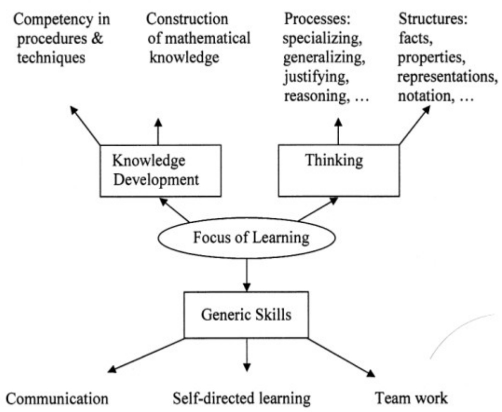

Fig. 2. Focus of mathematical learning.

Roselainy, Sabariah & Yudariah (2007) had 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).

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

Fig. 3 gives a summary of their model for active learning (Roselainy, Sabariah & Yudariah, 2007; and Sabariah, Yudariah & Roselainy, 2008).

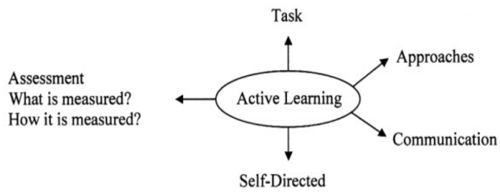

Fig. 3. Model of active learning.

In other words, 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). Their model of active learning environment involves components that are approximately from whole brain such as communication and discussion; however, they did not invoke strong tools to support them. Moreover, in this method is not used the potentials of other thinking like visual thinking by using computer facilities.

It seems that each methods of supporting students' thinking powers to overcome their difficulties in mathematics did not use all potentials of whole brain. Then we need a learning environment that not only has the benefits of both Tall and Roselainy & her colleagues methods but also uses different activities from four quadrants of whole brain.

4. Blended Learning

There are many definitions of blended learning in the literature review; however, the term is still vague (Oliver & Trigwell, 2005; Graham, 2006; Hisham Dzakiria et al., 2006). The three common definitions of blended learning are: the integrated combination of instructional delivery media, the combination of various pedagogical approaches, and the combination of online and F2F instruction (Oliver & Trigwell, 2005; Graham, 2006; Huang, Ma & Zhang, 2008). The third definition indicate that the blended learning is an opportunity to use synchronous and asynchronous e-learning tools including chat rooms, discussion groups, podcasts and self-assessment tools to support traditional teaching methods including lectures, in-person discussions, seminars, or tutorial (Reay, 2001; Thorne, 2003; Graham & Valsamidis, 2006; Allan, 2007).

Blended learning has gained considerable interest in recent years as an environment for supporting learning and teaching of mathematics (Iozzi & Osimo, 2004; Groen & Carmody, 2005; Harding et al., 2006; Hinch, 2007; Sojka & Plch, 2008). Carman (2002) noted that five important elements of blended learning process are:

(i) Live Events: Synchronous, all learners participate at the same time in a live virtual classroom or traditional F2F classroom as instructor-led learning events.
(ii) Online Content: Learning experiences that the learner completes individually such as interactive, Internet-based or CD-ROM training.
(iii) Collaboration: Environments in which learners communicate with peers and lecturer by: e-mail, threaded discussions, and online chat.
(iv) Assessment: A measure of learners' knowledge. For determining prior knowledge pre-assessments can come before live or self-paced events, and also post-assessments can occur following scheduled or online learning events to measure learning transfer.
(v) Reference Materials: Job aids materials that enhance learning retention and transfer, including PDA downloads, and PDFs.

5. Discussion and Conclusion

According to the theory of three modes of representation of human knowledge (Bruner, 1966), enactive, iconic and symbolic are the three forms of representation in mathematics. Furthermore, the various forms of symbolic representation also are: verbal (language, description), formal (logic, definition), and proceptual (numeric, algebraic etc) (Tall, 1995). This representation leads to the idea that there are not only three distinct types of mathematics worlds; there are actually three significantly different worlds of mathematical thinking as: *conceptual-embodied, proceptual-symbolic, axiomatic-formal* (Fig. 4) (Tall, 2003, 2004, 2007).

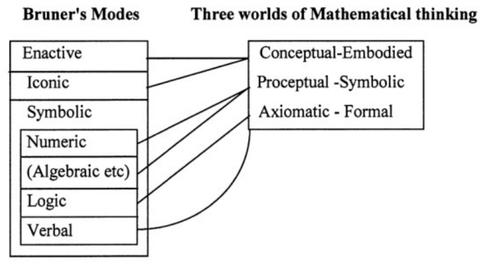

Fig. 4. ‹The relation between three Bruner's modes and three worlds of mathematical thinking.

On the other hand, the theory of Skemp (1979) identifies three modes of building and testing conceptual structures as shown in Table 1 (Tall, 1989, 1993).

Table 1. Reality construction

Mode	Reality Building	Reality testing
1	experience	experiment
2	communication	discussion
3	creativity	internal consistency

According to Skemp (Tall, 1989, 1993), pure mathematics relies on Mode 2 and 3, but it is not at all based only on Mode 1 (Tall, 1986). On the other hand, computer environment brings a new refinement to the theory of Skemp (Tall, 1986) and Tall (1989) extended this theory to four modes: Inanimate, Cybernetic, Interpersonal, and Personal. The last of these corresponds to Skemp's Mode 3.The interpersonal mode of building and testing concept also corresponds to Skemp's Mode 2, whilst the first two are a modification of Skemp's Mode 1 (Tall, 1989, 1993). In fact, the computer provide an environment and that give us a new way for building and testing mathematical concept by supporting all these modes. Therefore, computer environment can be used in all these modes and learner also may build mathematical concepts by considering examples (and non-examples) of process in interaction with this environment especially in embodiment world (Tall, 1986).

In other words, computer environment provides not only a numeric computation and graphical representation; it also allows manipulation of objects by an enactive interface (Tall, 1986) that by using them we can improve students' difficulties in embodiment world. To achieve these goals Tall (1989) defined *generic organiser* as an environment to build an embodied approach to mathematics. However, the generic organiser does not guarantee the understanding of the concept and there were some cognitive obstacles that aroused using generic organiser by students. To overcome these obstacles Tall (1986) suggested that teachers can play a role as an *organizing agent*. Teachers as organizing agent do not have a directive role and they only answer questions which may arise in the course of the student investigations through a Socratic dialogue with them (Skemp's Mode 2) which is enhanced by the presence of computers (Fig. 5) (Tall, 1986).

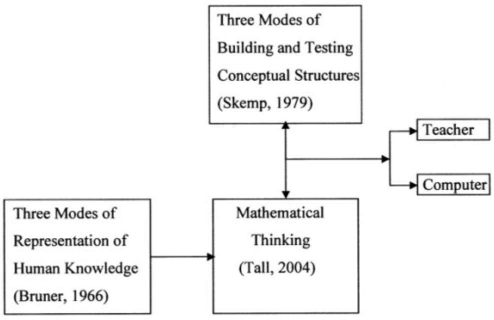

Fig. 5. The relation between the theories of Bruner, Tall, and Skemp to promote mathematical thinking by using computer and teacher.

Defining of blended learning as the combining synchronous physical formats (such as instructor-led classrooms and lectures) and self-pased as asynchronous formats (such as online or offline learning) identifies an environment including two important components of Tall's method that are organizing agent (teacher) and computer. In fact, this environment has rich facilities to extend of Tall's approach for using of computer to promoting mathematical thinking. So this environment has also potential to use some relevant strategies in F2F engineering mathematics through mathematical thinking approach.

On the other hand, Fahlberg-Stojanovska & Stojanovski (2007) noted that the best learning can takes place when all three primary senses of seeing (visual), hearing (audio) and doing (enactive) are involved in an interactive environment. They linked between these senses and two components of blended learning as the following (Fig. 6):

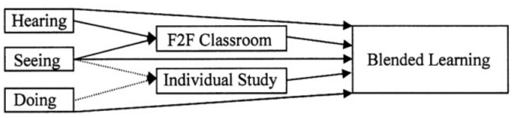

Fig. 6. The relation between three primary senses and blended learning.

Therefore, due to the relation between Bruner's modes and primary senses on one hand we can see a link between the components of blended learning and Bruner's theory and also the relation between primary senses and blended learning on the other hand (Fig. 7).

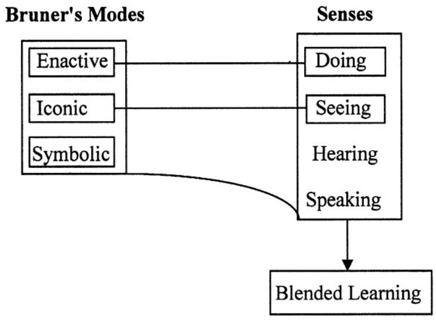

Fig. 7. The relation between three Bruner's modes and blended learning through primary senses.

Fig. 8 shows the relation between mathematical thinking and blended learning through Bruner and Skemp theories.

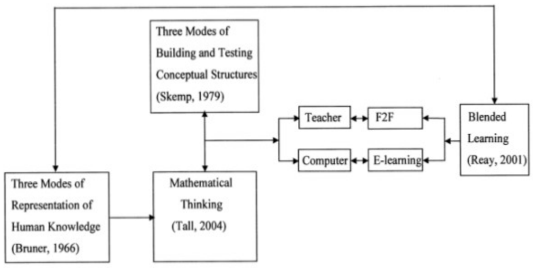

Fig. 8. The relation between Mathematical thinking and blended learning.

Lumsdaine & Lumsdaine (1995b) explained how five stages of CPS from their approach employ other thinking especially mathematical thinking and some components of four quadrants of brain based on Herrmann model (1988, 2001) such as team work and communication. On the other hand, computer as the best analogy of the functioning of the human brain can be used at least in four distinctly different ways: database and data processor (calculator), teaching machine, communication tool, simulator and visualizer (graphics) (Lumsdaine & Lumsdaine, 1995b). In the context of teaching, learning, and thinking the four different ways of using computers have relations in order with four quadrants of brain A, B, C, and D. Lumsdaine & Lumsdaine (1995b) also explained that how computer facilities are used during the process of solving problems in CPS based on their approach. Then, blended learning as an environment that has online and offline tools such as software, email, chat room, and bulletin boards can help some components of four quadrants of brain such as visualization and communication for better supporting of mathematical thinking through CPS.

The following chart (Fig. 9) is a whole picture of a framework perspective that identifies blended learning is a relevant environment to support students' mathematical thinking powers and generic skills such as communication in mathematics through CPS.

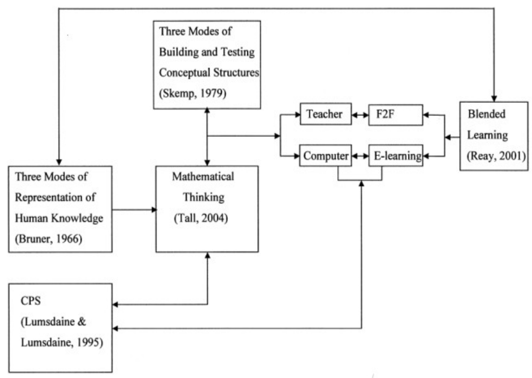

Fig. 9. The relation between blended learning, mathematical thinking, and CPS.

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