

BLENDDED LEARNING ENVIRONMENT TO DEVELOP PERSONAS AND
THEMES IN ENGINEERING STUDENTS USING MATHEMATICAL
ORIENTED ACTIVITIES

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A thesis submitted in fulfilment of the
requirements for the award of the degree of
Doctor of Philosophy (Engineering Education)

School of Graduate Studies
Universiti Teknologi Malaysia

AUGUST 2015

DEDICATION

To

My Dearest and Nearest Aunt Ms. Koukab Tasnim Butt,

My Parents,

My Lovely Kids, Faaiz Khan and Rida Fatima

And

All My Wonderful Friends & Family

ACKNOWLEDGEMENT

In the name of Allah, The Most Gracious and The Most Merciful

All praise and thanks are for Allah who has made this journey interesting and meaningful for me. This study has been made possible through the cooperation, support, and help of several people and departments. I express my sincere gratitude especially to my supervisors, Dr. Mohd. Fauzi Bin Othman from the Faculty of Electrical Engineering (FKE), and Associate Professor Dr. Yudariah Mohammad Yusof from the Faculty of Science, Department of Mathematical Sciences. Their continuous guidance, patience, support, and encouragement over the years are deeply appreciated. I also acknowledge the financial assistance for this research by the MJIT at the Universiti Teknologi Malaysia in the form of Research Student Grant. The Centre for Engineering Education provided a platform for a continuous professional development and knowledge construction throughout my research journey.

I also want to thank the Director of the Centre for Engineering Education, Associate Professor Dr. Khairiyah Mohd Yusof who helped me interact with pioneers in the engineering education and provided me with the opportunity to expand my vision and helped me in changing my perception about engineering education. I also want to thank Dr. Fatin, Dr. Helmi, Dr. Fadzil, Dr. Narina, Dr. Dayang, Dr. Hafiz, Dr. Roselainy, Dr. Aminah, Dr. Zaleha and Dr. Ismail Said for their critical review and constructive feedback throughout my research studies.

I would also like to acknowledge the encouragement given to my research by my mentors from US, Monica Cardella (Purdue), Lisa Benson (Clemson University), and Rebecca Bates (Minnesota State University), and my peer researchers from US especially Dr. Farrah Fayyaz (Purdue) who have all helped me make sense of my research struggles and, also, Dr. Jennifer Turns (University of Washington) who helped me make sense of my reflective practice and guided me how to improve it.

I am especially indebted to the research assistants who helped me in collecting the data, transcribing the videos, and digitizing all the research documents. I also thank all the students of the first year engineering program who participated in this study.

I would also like to thank all my peer researchers, lecturers, assistant professors, and professors who were always there with their constructive feedback to help me improve the quality of this research.

In the end, I would like to thank all my friends and family for their unconditional love and support throughout this journey.

ABSTRACT

There is not only an emergent need to implement innovative pedagogies but also to understand in more depth what actually happens in engineering classrooms and how to accelerate the rate at which research on students provides influence on teaching practices. The growing trend in higher education based on previous studies, highlighted the potential of blended learning in supporting mathematical thinking among fresh engineering students. This research is designed to develop and implement a blended learning environment using a well-practiced problem solving strategy integrated with selected MIT-BLOSSOMS modules and investigated its implications by developing student personas and emergent themes of engineering students. The study starts by knowing the students, their current knowledge state and what they have already experienced relating to mathematical thinking and learning. A web-based, artificially intelligent Assessment and Learning in Knowledge Spaces (ALEKS) system is used to know the students' current knowledge state. Classroom observations and focus groups were used to investigate the emergent themes whereas written activity responses were analyzed to show the activation of mathematical thinking processes in conceptual embodiment and operational symbolism. Findings highlight the emergent themes of met-befores, met-afters, implications of blended learning and challenges whilst problem solving. The results show that blended learning can support "horizontal mathematization" during problem solving activities by manipulating students' conflicting met-befores, increasing their diligence during problem solving and improving student-teacher relationship. The student personas are developed as a potential pedagogical tool to communicate the vital research findings to the Community of Practice (CoP) and have the potential to develop empathy among engineering educators. This research is transferable and replicable to tertiary as well as secondary education by modifying the blending options on the spectra of time, space, technologies, pedagogy, format, courses, participants and complexity of the problem solving activities accordingly.

ABSTRAK

Terdapat keperluan yang berkaitan dengan pelaksanaan pengajaran inovatif untuk memahami dengan lebih mendalam apa yang sebenarnya berlaku di dalam kelas kejuruteraan dan bagaimana untuk mempercepatkan kadar di mana kajian mengenai pelajar memberi pengaruh ke atas amalan pengajaran. Kadar peningkatan yang semakin meningkat dalam pendidikan tinggi berdasarkan kajian sebelum ini, menekankan potensi pembelajaran digabungkan dalam menyokong pemikiran matematik di kalangan bakal pelajar kejuruteraan. Kajian ini bertujuan untuk membangunkan dan melaksanakan persekitaran pembelajaran yang digabungkan dengan menggunakan penyelesaian masalah strategi yang diamalkan, disepadukan dengan modul MIT-BLOSSOMS telah dipilih dan disiasat implikasinya bagi membangunkan aktiviti yang berorientasikan penyelesaian masalah dalam pemikiran matematik. Kajian utama dimulakan dengan mengenali pelajar, mengetahui keadaan pengetahuan semasa pelajar dan memahami apa yang telah para pelajar pelajari berkaitan dengan pemikiran dan pembelajaran matematik sistem pintar berasaskan sesawang yaitu Pentaksiran dan Pembelajaran dalam Ruang Pengetahuan (ALEKS) digunakan untuk mengetahui keadaan pengetahuan semasa pelajar. Pemerhatian di dalam bilik darjah dan kumpulan sasaran digunakan bagi mengenal pasti faktor-faktor yang menyumbang kepada pembentukan karakter pelajar, manakala tindak balas bertulis dari pelajar dianalisa bagi mengetahui kadar pemahaman dan proses pemikiran matematik pelajar dalam bentuk konsep dan simbolik. Penemuan kajian mengetengahkan faktor-faktor yang menyumbang kepada pembentukan karakter pelajar adalah berdasarkan faktor *met-befores*, *met-afters* dan implikasinya kepada pembelajaran dicampur dan cabaran manakala penyelesaian masalah. Hasil kajian menunjukkan bahawa pembelajaran dipadukan boleh menyokong '*horizontal mathematization*' semasa aktiviti penyelesaian masalah dengan memanipulasikan konflik *met-befores* pelajar, meningkatkan ketekunan mereka semasa menyelesaikan masalah dan memperbaiki hubungan guru dan pelajar. Personaliti pelajar dibangunkan sebagai alat yang berpotensi untuk menyampaikan hasil penyelidikan penting kepada Komuniti Amalan (CoP) dan mempunyai potensi untuk membangunkan pemahaman dan rasa untuk dikongsi di kalangan pendidik kejuruteraan. Kajian ini boleh dipindah milik dan boleh diulangi untuk pengajian tinggi dan juga pendidikan menengah dengan mengubah pilihan pengadunan pada spektrum masa, ruang, teknologi, format, kursus, peserta dan kerumitan masalah aktiviti menyelesaikan sewajarnya.

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LIST OF ABBREVIATIONS

ALEKS	-	Assessment and LEarning in Knowledge Spaces
AR	-	Action Research
BL	-	Blended Learning
BLOSSOMS	-	Blended Learning Open Source Science Or Math Studies
CoP	-	Community of Practice
EER	-	Engineering Education Research
F2F	-	Face-to-Face
ITL		Inductive Teaching and Learning
MIT	-	Massachusetts Institute of Technology
MOE	-	Ministry Of Education
MOOC	-	Massive Open Online Course
MTL	-	Mathematical Thinking Lab
OER	-	Open Educational Resource
PS	-	Problem Solving
PSA	-	Problem Solving Activity
P12	-	Preschool to Grade 12 (Equivalent to Secondary Education)
RQ	-	Research Question
RU	-	Research University
STEM		Science, Technology, Engineering and Mathematics
UTM	-	Universiti Teknologi Malaysia

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CHAPTER 1

INTRODUCTION

1.1 Introduction

There is an emergent need associated with the implementation of innovative pedagogies to understand in more depth what is actually happening in engineering classrooms in the context of new learning environment. Before making in-depth inquiries, it is needed to know “what knowledge, skills, and attitudes do learners bring to their engineering education that influences what (and how) they learn in a new learning environment?” and then “how do learners progress from naïve conceptions and partial understandings to richer knowledge and skills that facilitate innovative thinking?” (EERC, 2006). It is further needed to comprehend the emerging themes in a new learning environment besides knowing the variance of knowledge, skills, and attitudes of engineering students in different scenarios/situations (EERC, 2006).

Following the trend of blended learning in engineering education, first an interpretive action research is selected from the pool of emerging methodologies in engineering education research, and then employed in this study. A blended learning environment is developed and implemented for developing student personas and emergent themes using mathematical thinking oriented context-rich problem solving activities for first year engineering students. Mathematical thinking oriented problem solving is an essential component in the skill set required for future engineers (Broadbridge and Henderson, 2008). Sometimes, engineers join the workplace with inadequate mathematical thinking and problem solving skills. That is because the teaching emphasis is on content mastery rather than learning mathematical thinking processes and problem solving strategies (Alpers, 2010; Cardella, 2007a; Ferri, 2012;

Gainsburg, 2006; Goold and Devitt, 2013; Trevelyan, 2009). To deal with the above issue, a well-practiced evidence-based problem solving strategy by Mason et.al. (2010) is first integrated with selected MIT-BLOSSOMS modules to develop problem-solving activities followed by their implementation to create a blended learning environment. Mixed-ability students practiced the problem solving strategy to solve the context-rich problems in collaborative groups. The research process is assisted by understanding the human innate abilities to think mathematically, knowing the students, their current knowledge state and their prior experiences related to mathematical thinking and then implementing a blended learning environment conducive to context-rich problem solving. The action research is conducted followed by monitoring and evaluating the activated mathematical thinking processes and resulted in some interesting and emergent themes during this study. Blended learning in this research successfully activated embodied mathematical thinking processes thus supported students in horizontal mathematization and affected students' met-befores in a supportive way. The instructional approach not only evidenced the improved problem solving skills of the students at all ability levels but also the improved engagement of all the students. One of the main outcomes is the evidence-based student personas presented as a potential pedagogical tool to transfer implications of this research to Community of Practice (CoP) that includes engineering and mathematics faculty, junior researchers and postgraduate students. The trajectory of the practitioner as a researcher is also captured through detailed descriptions that will be a valuable contribution towards bridging the research and practice gap through this research. The narratives during the transformation from practice to praxis showed struggles of the researcher in the way to become a reflective teacher and action researcher. This research also has the potential to make impact on P12 (secondary) engineering education by reporting the status of mathematical thinking and problem solving skills of the students leaving P12 (secondary education) and joining engineering education. It is thus suggested to revamp the instruction at secondary level to help students in entering the engineering program with adequate skills (Tolbert and Cardella, 2013).

This chapter will further provide the background of the problem, statement of the problem, research objectives, research questions, importance of the study, and

thesis outline. In the next section, the background of the study is described in the context of engineering education.

1.2 Background of the Problem

The developing knowledge on effective teaching and learning, evolving social and global needs, and sprouting intents and anticipations of stakeholders make it vital that we change the way we educate our future engineers (Siddiqui, 2014). Engineering expertise of a civilization always maintained its significance for a sustaining modern economy and its progress towards future advancements, whereas the inclination towards engineering as a career has diminished in Western as well as in Eastern countries (Becker, 2010; Elliott, 2009; Forfás, 2009; King, 2008; McKinsey, 2011; Organisation for Economic Co-Operation and Development, 2010).

In recent times, the emerging concern to drive the efforts for improving the science, technology, engineering, and mathematics (STEM) education has become wide-ranging from under-representation of minorities and issues of high attritions of students from STEM majors to the broader problems related to the quality of education and the shifting emphasis from teacher-centered to learner-centered (Adams et al., 2011; Seymour, 2002). In the new century, there is an utter need to train and equip engineers in such a way that they can function effectively in an altering context of the engineering profession (Sheppard et al., 2008). Technological advancements and rapidly changing global economy with their associated challenges resulted in engineers working globally (Lynn and Salzman, 2009). The major change in the culture of how people think, act, and perceive their roles professionally and personally is essential to address the sustainability challenge (Sterling, 2004).

Traditional ways of engineering education are not aligned with today's needs for training engineers (Duderstadt, 2010). Tomorrow's engineers should be more flexible and creative to address the changing world demands and that is only possible through the transformation of engineering education (Bransford, 2007; Chubin et al., 2008; Duderstadt, 2008; EERC, 2006; National Academy of Engineering, 2005; National Science Foundation, 1995). The engineering curricula and teaching and learning practices need to be changed to attract and retain students with diverse talents

and backgrounds in engineering education, for providing engaging learning experiences to the students and to prepare them for work in the new realisms (Siddiqui, 2014).

Goold and Devitt (2013) also shared similar concerns specific to the role of mathematics for engineering education. It is also highlighted that practising engineers use broader mathematical thinking rather than what they have been taught through the syllabus (Alpers, 2010; Cardella, 2007a; Gainsburg, 2006; Goold and Devitt, 2013; Trevelyan, 2009). Moreover, it is evident that major engineering practices depend on the engineers' mathematical thinking skills, like contextual and prior experiences, reasoning and justification of inferences, and designing new solutions (Gainsburg, 2006). Problem solving, including working collaboratively on complex problems, critical thinking, complex data analysis, numerical reasoning, and appropriate applications of technology are valuable for employers (English 2002).

The literature is reviewed on various efforts in improving the mathematical thinking and problem solving skills among engineering students (Abdul Rahman and Mohammad Yusof, 2008; Abdul Rahman and Mohd Yusof, 2002; Abdul Rahman, 2008, 2007; Abdul Rahman et al., 2010, 2007, 2005; Baharun et al., 2008, 2007; Borovik and Gardiner, 2006; Broadbridge and Henderson, 2008; Ismail and Kasmin, 2008; Kashefi, 2012; Mohammad Yusof and Abdul Rahman, 2004, 2001; Mohammad Yusof and Tall, 1999; Mohammad Yusof et al., 1999). The previous studies highlighted the difficulties of engineering students in manipulating concepts, coordinating multiple procedures, manipulating symbols in a flexible way, answering non-routine problems, lacking problem solving skills, and the students' inability to select and use appropriate mathematical representations. Therefore, there is still a room to develop learning environments conducive to mathematical thinking and problem solving at undergraduate level (Bergsten, 2007) and addressing the low level of engagement in the classroom (Fritze and Nordkvelle, 2003; Smith et al., 2005).

The persistent gulf between research and practice (Finelli et al., 2014; Fink et al., 2005; Smith, 2000; Turns et al., 2013) has also become a major concern in engineering education research. Therefore, future research should not only focus on

exploring the emergent themes during an innovative classroom practice to foster the mathematical thinking skills among future engineers but should also devise an effective way to minimize the research-practice gap. In the next section, the researcher formulated a problem statement by focusing on the research gaps from related literature and by following the trend of blended learning environment and by evaluating the needs and demands of engineering education research.

1.3 Statement of the Problem

Keeping in view the perspective “the evolving challenges facing engineers, and how engineering education must adapt to suit these needs” (Fortenberry, 2006), “the engineering profession is calling for new and better kinds of learning by engineering students. Accomplishing this, requires new and better kinds of teaching and curricula, which in turn requires engineering faculty to think about teaching and learning in more scholarly ways” (Fink et al., 2005). It is also needed to “get on with the task of making deep and solid inquiries into learning processes, using the best methods we can bring to bear to advance scientific knowledge and understanding of learning from the variety of research perspectives that are available” (Anderson et al., 2000). Moreover, “the emergence of a new research trend that attempts to develop better understanding of the nature and processes of teacher change and the factors that affect these processes” (English, 2002) should also be in focus.

During the transition from secondary education (P12) to engineering education, students are expected to be equipped with adequate mathematical thinking skills so that they can undergo rigorous design thinking processes afterwards (Tolbert and Cardella, 2013). However, the lack of resources and didactic teaching during P12 (secondary education) hinder their development of mathematical thinking processes and thus students join engineering programs with insufficient mathematical thinking skills (Mahmood et al., 2012). On top of that, the similar methods of teaching mathematics at tertiary level stress on the content of mathematical theory rather than the motivations and thoughts that underlie this content (Mamona-Downs and Downs, 2002). Moreover, a disconnection perseveres between “theories of individual

mathematics learning” and the “teaching and learning practices in the classroom” Kress (2011b). Kress (2011a) also argued that “explorations around what happens in the black box of mind have not fully resolved the daily problems faced by students and teachers” in the real classroom whereas, Goos, Galbraith, and Renshaw (2002) emphasize that, “given our incomplete understanding of mathematical thinking, we need further research on mathematics learning in authentic environments before continuing to make changes in the classrooms.” Kress (2011a, p. 194) specifically mentioned that more research is needed to improve teaching “practice of mathematics by exploring the social dimension of learning (which complements theories that explain individual cognitive processes).” That is a way to “develop better curriculum materials, refine pedagogy, and improve the structuring of classroom environments.” Serious considerations should be given to find ways to enhance the process of mathematical thinking, even if some sacrifice in content may be needed to achieve this (Mamona-Downs and Downs, 2002). The technological advancement and educational research have also developed to a level that raise a demand to introduce the emerging strategies and techniques of teaching and learning even at first year in an engineering program. Students should learn more what is presently customary the “process of mathematical thinking” rather than the “product of mathematical thought” (terms borrowed from Skemp, 1971 as cited by English, 2002).

Some local researchers have also attempted to enhance engineering students’ mathematical competency through mathematical thinking (Baharun et al., 2007), enhance mathematical thinking through active learning in engineering mathematics (Abdul Rahman et al., 2007), change teacher and student’s attitudes towards calculus through mathematical thinking (Abdul Rahman, 2008), recognize a student’s struggle through mathematical knowledge construction (Abdul Rahman et al., 2005), translate learning theories into practice in enhancing a student’s mathematical learning (Abdul Rahman, 2007), change attitudes towards university mathematics through problem solving (Mohammad Yusof and Tall, 1999), facilitate thinking and communication in Mathematics (Baharun et al., 2008), cultivate mathematical thinking in differential equations through a computer algebra system (Zeynivandnezhad, 2014) and employ blended learning to cultivate mathematical thinking in multivariable calculus (Kashefi, 2012). Various issues and challenges emerge from the above research initiatives, such as different students’ learning styles, their typical beliefs and attitudes, insufficient

prior knowledge, insufficient problem solving skills, inappropriate selection and use of mathematical representations, poor conceptual knowledge, poor symbolic manipulation skills and difficulties in answering non-routine problems. Some other researchers reported issues like exam-oriented culture, insufficient assessment methods, lack of resources, and the minimal role of technology in supporting mathematical thinking (Rahman et al., 2012a, 2012b; Tall, 1998). However, the optimal ways to improve students' mathematical thinking and problem solving skills are not well understood yet. Many instructors and commentators place the poor performance of fresh engineering students in problem solving to a deficit of knowledge base and/or conceptual understanding in mathematics (Gupta and Elby, 2011). The future recommendations are to use pedagogical and technological tools to improve problem solving and mathematical thinking skills in new learning environments (Bersin, 2004; Bourne et al., 2005; Garrison and Vaughan, 2008; Graham and Dziuban, 2008; Güzer and Caner, 2014; Inoue, 2010; Kaur, 2013; Picciano, 2007).

Understanding the underpinning human abilities to think mathematically, knowing the students' current knowledge state and their prior experiences related to mathematical thinking (Tall, 2013), are the key factors that need to be understood before understanding how future engineers learn to think mathematically. The traditional learning environments are not supportive for mathematical thinking and problem solving due to the lecture based teaching of mathematics at undergraduate level (Bergsten, 2007). Instead of active learning, the students are passive learners with low level of engagement in the class (Fritze and Nordkvelle, 2003; Smith et al., 2005). Therefore, mathematics is viewed as a non-creative subject with minimum social engagement and collaboration (Alsina, 2002; Weber, 2004), less affective and non-supportive to higher-order thinking (Breen and O'Shea, 2011; Dubinsky and McDonald, 2001; Leron and Dubinsky, 1995). However, by providing a new environment for learning to cultivate mathematical thinking explicitly, the in-depth understanding is needed, of what actually happens, specifically when innovative pedagogies are implemented in the real engineering classrooms (Light and Case, 2011).

The one end of continuum of mathematical thinking and learning practices is a didactic or constructive way of teaching in the classroom and the other end is “a synchronous broadcast model” (Bourne et al., 2005) so that lectures can be viewed immediately or recorded for future playback. Same level of interaction as in typical classrooms can be achieved through synchronous online systems. However, it is more difficult to implement constructivist approaches (Bourne et al., 2005) to implement in the fully online practices supporting mathematical thinking and its associated challenges (Rahman et al., 2012a, 2012b; Sam and Yong, 2006; Tall, 1998). Some researchers (Bourne et al., 2005) predicted that the online education and traditional on-campus education will become more blended or integrated to entertain factors like time, space, attitude, disparity in knowledge, and cognitive demands whereas Kashefi (2012) suggested the use of blended learning for engineering mathematics to support the mathematical thinking of new students joining engineering education. Bridging research and practice in engineering education can also help the engineering educators to advance their research in the guided direction to fulfil the futuristic workplace demands. The potential of blended learning to activate mathematical thinking processes during context-rich problem solving activities should be investigated to inform the scholarship of teaching (Harun, 2012; Hull et al., 2013; Kashefi et al., 2013, 2012; A Mahmood et al., 2013; Mohammad Yusof et al., 2012; Sam et al., 2009) and to develop new pedagogical tools like student personas to bridge research-practice gap and improve teaching practices (Adlin and Pruitt, 2010; Elliott, 2005; Faily and Flechais, 2011; Goodwin, 2008; Grudin and Pruitt, 2003; Nielsen, 2013; Turns et al., 2013; Wikberg Nilsson et al., 2010). However, the lack of framework persists in developing and implementing blended learning for supporting mathematical thinking. We also have insufficient knowledge of what themes would emerge and how differently students learn in different teaching and learning scenarios.

The driving force in conducting this research is to investigate the potential of blended learning to develop student personas and emergent themes while supporting mathematical thinking processes besides developing problem solving expertise among first year engineering students. This empirical research will get the insights of new learning experiences of first year engineering students during their context-rich problem solving activities utilizing open educational resources. The emergent themes and student personas while activating the mathematical thinking processes during

problem solving activities through blended learning will guide the practitioner how to improve further or influence future teaching and learning experiences, in turn, improving the mathematical thinking skills among prospective engineers.

In short, by implementing innovative pedagogies in the real engineering classrooms through blended learning to support mathematical thinking of prospective engineers during problem solving activities, the in-depth investigations in the form of emergent themes are essential of what actually happens during the new learning experience. It is also required to develop the engineering students' personas as potential pedagogical tools to accelerate the rate of translating the research into practice.

1.4 Research Objectives (ROs)

The following are the research objectives of this study:

1. To develop and implement a blended learning environment using mathematical thinking oriented problem-solving activities.
2. To develop engineering students' personas and emergent themes while investigating the implications of blended learning on students' mathematical thinking during problem solving activities.

1.5 Research Questions (RQs)

This research is conducted to answer the following questions:

1. What knowledge (mathematics), skills (mathematical thinking and problem solving) and prior experiences do students bring along that influence how they learn to think mathematically in a blended learning environment?
2. What would be the process to develop, and implement a blended learning environment that incorporates a well-practiced problem

- solving strategy and a pedagogical tool supporting engineering students' mathematical thinking, learning, and problem solving skills?
3. What are the emergent themes translating into the implications of the blended learning on the students' mathematical thinking and learning during problem solving activities?
 4. What would be the process to develop the students' personas to describe archetype students in different scenarios (the Classroom and the MTL) and illustrate the activation of their mathematical thinking processes in embodied and symbolic world of mathematics?

1.6 Importance of the Study in the context of Engineering Education

The importance of this study is highlighted by relating the ROs and RQs with respective engineering education research areas and strands of inquiry as shown in Table 1.1.

The educational importance will be achieved by not only developing and implementing but also unfolding the potential of blended learning to improve the current mathematical thinking and problem solving skills among prospective engineers. The pragmatic importance is related to utilizing and/or producing innovative ideas, resources, and tools to introduce and encourage non-traditional teaching methods in engineering mathematics classroom, and to improve a practitioner's learning about her own practice involving integrating, implementing, testing, and disseminating such materials and methods. The professional importance is emphasized by welcoming assistance and cooperation from our colleagues from mathematics education, and to work with them in an open, inclusive, collaborative, and practice-based research environment to improve the overall quality of engineering education and to inform the Community of Practice (CoP) on how to use the student personas as pedagogical tool in their own complex contexts.

From this study, the engineering educator-cum-researcher will have the opportunity to extend her existing professional development experiences to further

meet the engineering educator's needs. That would also help her to draw "future recommendations" for refined pedagogy, improved curriculum materials, and the structuring of the classroom environment to fulfil the needs of first year engineering students in helping them to become better mathematical thinkers.

Table 1.1: Importance of the study in the context of engineering education by relating the ROs and RQs with respective engineering education research areas and strands of inquiry (EERC, 2006)

RO	RQ	EER Area	Strand of Inquiry
RO1: To develop and implement a blended learning environment using mathematical thinking oriented problem solving activities <i>(RO1 is targeted in the Chapter #4 of this thesis)</i>	RQ1: What knowledge (mathematics), skills (mathematical thinking and Problem solving) and prior experiences do students bring along that influence how they learn to think mathematically in a blended learning environment?	Area 2: Engineering Learning Mechanisms	Knowing our Students (the variance of knowledge, skills, and attitudes of students) [What knowledge, skills, and attitudes do learners bring to their engineering education that influences what (and how) they learn?]
	RQ2: What would be the process to develop, and implement a blended learning environment that incorporates a well-practiced problem solving strategy and a pedagogical tool supporting engineering students' mathematical thinking, learning, and problem solving skills?	Area 3: Engineering Learning Systems	Designing (Developing and implementing) learning environments Teaming and Collaborative Learning
RO2: To develop engineering students' personas and emergent themes while investigating the implications of the blended learning on students' mathematical thinking during problem solving activities <i>(RO2 is targeted in the Chapter #5 of this thesis)</i>	RQ3: What are the emergent themes translating into the implications of the blended learning on students' mathematical thinking and learning during problem solving activities?	Area 2: Engineering Learning Mechanisms	The learning progressions (trajectories) of learners and their educational experiences that develop knowledge, skills and identity necessary to be an engineer. [How do learners progress from naïve conceptions and partial understandings to richer knowledge and skills that facilitate innovative thinking?]
	RQ4: What would be the process to develop the students' personas to describe archetype students in different scenarios (the Classroom and the MTL) and illustrate the activation of their mathematical thinking processes in embodied and symbolic world of mathematics?	Area 2: Engineering Learning Mechanisms	The variance of knowledge, skills, and attitudes of students in different scenarios (situations)

1.7 Operational Definitions

The following terms and constructs have specific meaning in this thesis as given below:

Action Research: is a form of self-reflective problem solving, which enables practitioners to better understand and solve pressing problems in educational settings. The action (what you do) aspect of action research is about improving practice. The research (how you learn about and explain what you do) aspect is about creating knowledge about practice. The knowledge created is the knowledge of one's practice (McNiff and Whitehead, 2010).

Blended learning: is the integration of online with face-to-face learning in the form of mathematical thinking oriented problem solving activities in a planned, pedagogically valuable manner.

Community of Practice: is a group of people sharing similar problems, concerns, and passion about a topic who interact with each other on regular basis to improve their knowledge base and expertise in the related area (Wenger et al., 2002).

Constructivist teaching: is based on the conjecture that learning occurs if students are actively engaged in their knowledge construction. The role of the teacher is that of 'guide on the side' and a facilitator during that learning (Heinze, 2008).

Constructivism: "recognizes that knowledge construction about the social world and ourselves is reliant on human perception, convention, and social experience rather than just reflecting an external reality (Elliott, 2005).

Didactic teaching: occurs when knowledge is 'imposed' on the learner. The role of the teacher is that of the 'sage on the stage'. It is opposite of constructivist teaching" (Heinze, 2008).

Empathy: is the feeling as a result of understanding and sharing another person's emotions and experiences. "It is a basic process of social observation, where whatever observed are purposive actions rather than raw physical objects and behaviour from which action is inferred (Elliott, 2005). In this research, the empathy is not just a feeling, rather it is a skill to effectively participate in teaching and learning practices.

Face-to-face: is a mode of interaction between individuals in an environment based on their physical presence. So the body language and other non-verbal communication clues can serve as an effective way that interaction (Heinze, 2008).

Learning: is an enduring change in behavior, or in the capacity to behave in a given fashion, which resulted from practice or other forms of experiences (Schunk, 2012, p. 3).

Mathematical Thinking: is a specialized function distinctive from generalized thinking. It is best seen as a continuous, cyclical process of cognition in which a person strives to make sense of a vast sea of sensory data, map the mathematical world, attend to social convention while coping with individual differences in the beliefs of every mathematical thinker and finally extending his/her choices.

Met-after: is a new structure that students will develop in their brains as the effect of new experience of blended learning related to mathematical thinking, learning and problem solving.

Met-before: is a current structure that students have in their brains as a result of experiences they have met before related to mathematical thinking, learning and problem solving.

Nodes: are used to conceptually represent codes during the process of data analysis using QSR NVivo 10 software program (Heinze, 2008).

Node tree: is a tree hierarchy showing the logical composition of nodes in the NVivo. Root of the tree is placed at the top in the tree node diagrams as used in this study. An automatically assigned unique number in QSR NVivo software identifies a node. For example if a node is located within the third tree, seventh branch, tenth twig and fourteenth leaf then its node number will be (3 7 10 14) (Heinze, 2008).

Pedagogy: is an art and science of teaching based on specific assumptions related to learning processes.

Persona: is an evidence-based description of a person within the context of Engineering Mathematics I Class and the Mathematical Thinking Lab (MTL), whose pertinent characteristics and challenges are of importance in this research. The use of

personas is said to be a human behaviour, based on the presumption that first year engineering students join engineering education along with their prior experiences that can be either supportive or conflicting in learning new concepts and skills in different and new learning environments.

Sense making: is developing understanding of a situation, context, or concept by connecting it with existing knowledge. (NCTM, 2009)

1.8 Thesis Outline

This section will outline the details of all the chapters. Figure 1.1 also elicits the whole research process in terms of constituent components and their placement in this thesis under respective chapters.

Chapter 1: Introduction

In this chapter, the researcher started with the introduction of this research and described what, why and how this research is needed to be conducted. Then the background of problem, statement of problem, research objectives, research questions, and importance of the study are discussed.

Chapter 2: Literature Review

After introducing the chapter, the researcher explained the role of mathematics in engineering education. The key concepts and ideas are then discussed under the headings of blended learning, mathematical thinking, and mathematical thinking as problem solving. Then the researcher explained HPL meta-framework followed by the theoretical framework adapted from the three worlds of mathematical thinking for this research. Before describing the research paradigm and methodology considerations, a brief introduction of student personas is also provided.

Chapter 3: Research Methodology

The researcher introduced the chapter followed by a comparison of her philosophical assumptions with different research paradigms. The qualitative research process

comprising epistemology, theoretical perspective, and methodology are then discussed. After rationalizing the choice of the action research methodology, its cycle and process are described, followed by the data types and data collection techniques. Then the researcher explained the research paradigm-implementation process, the research setting, the participants of the research, the researcher's background, and the research method-implementation process. The data collection, the two staged data analysis is then discussed followed by the integration process of problem solving strategy with BLOSSOMS modules to develop a blended learning environment conducive to mathematical thinking. The persona development process is then described followed by their problem solving activity response analysis. The discussion is closed by presenting the way in which the quality of the research is addressed.

Chapter 4: Developing and Implementing Blended Learning Environment

After introducing this chapter, the initial idea of the research, reconnaissance, and initial planning followed by preliminary action research cycle and pilot action research cycles 1 and 2 are described in detail. The researcher then described the details of "knowing the respondents" and "knowing their current knowledge state" in the main study. The initial diagnosis and discussion followed by the description of the main action research cycles I and II are given in detail.

Chapter 5: Emergent Themes and Student Personas

In this chapter, introduction is followed by emerging themes of this research. Students' met-befores and the challenges whilst problem solving are first discussed. Then the impact of blended learning as students' met-afters, diligence during mathematical problem solving and student teacher relationships are discovered and reported. The evidence-based students' personas are then discussed followed by the scenarios for problem analysis and idea development. The modified rubric to assess the activation of mathematical thinking processes based on pre-identified deductive coding scheme is then discussed followed by written activity response analysis of selected personas. The discussion is closed by presenting the results of problem solving activity response analysis for all the personas.

Chapter 6: Discussions

Introduction is followed by discussions in accordance with the research objectives and questions. Making sense of researcher's reflective practice, challenges faced during the study; and limitations and delimitations of the study are also discussed in this chapter.

Chapter 7: Conclusions and Future Recommendations

After drawing the conclusions, the implications of this research and future recommendations are presented in this last chapter.

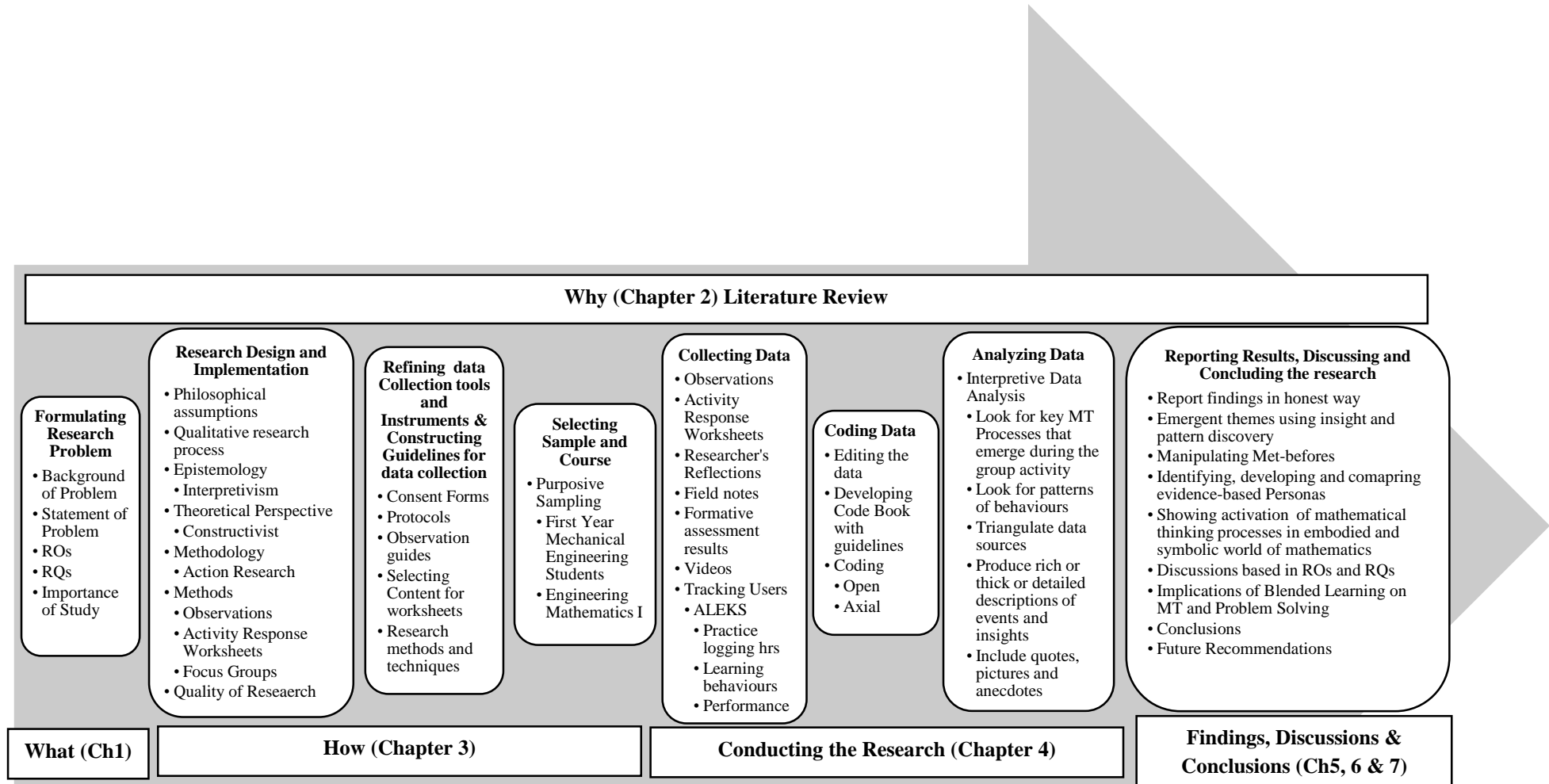


Figure 1.1: Research Process of this research

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