FIELD PROJECT-BASED LEARNING TO ENHANCE STRUCTURAL DESIGN ABILITIES FOR CIVIL ENGINEERING STUDENTS

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To my late parents Long Esah and Haji Mohd Ismail

To my beloved FAMILY

Husband : Haji Musa

Children : Musliza, Mustasha, Khairul Hakim, Khairul Hazwan and Mustika

Son in-law : Adam Muza

Grandchildren: Mohd Afiq and Farra Alya

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ABSTRACT

Design courses need to embrace the exemplary nature of the civil engineering profession and to address the concerns of employers that engineering graduates are unprepared and poorly trained to face the engineering profession. The introduction of project-based learning is important because as a constructivist learning pedagogy, project-based approach emphasizes learning by doing via direct students' engagement in projects, performed either individually or in groups. The objective of this research is to investigate the extent to which the students' design abilities are enhanced through field project-based learning in structural reinforced concrete design course. The research was carried out on groups of student who were assigned design tasks at a local design firm. The data were collected through interviews, journal entries, direct observations and document analysis. These data were analysed using content analysis method and the results were later triangulated to increase the reliability and validity of the findings. The findings of the study have suggested that field project-based learning have enhanced students' self-directed learning, fostered their professional skills as well as promoting their lifelong learning skills. The design projects have also lifted the students' problem solving skill to an appropriate level. Another component of the finding involves the measurement for design projects. The findings have also indicated that stakeholders have high expectations of design projects in preparing students for workplace environment. Hence, it is imperative that an innovative instructional approach, which includes proper assessment for design course, is implemented in making design projects relevant to the students and the engineering programs.

ABSTRAK

Kursus reka bentuk perlu memenuhi contoh amalan kelaziman profesion kejuruteraan awam kerana ianya dapat manangani kebimbangan pihak majikan berkenaan graduan kejuruteraan yang kurang bersedia serta kurang latihan untuk menghadapi cabaran profesion kejuruteraan. Penggunaan pembelajaran berasaskan projek adalah penting kerana berdasarkan pedagogi pembelajaran konstruktivis, kaedah pembelajaran berasaskan projek menekankan pembelajaran melalui aktiviti sebenar penglibatan pelajar melalui perlaksanaan projek yang dijalankan secara individu atau berkumpulan. Objektif kajian ini adalah untuk mengenalpasti sejauh mana peningkatan keupayaan pelajar dalam bidang reka bentuk yang dicapai melalui pembelajaran berasaskan projek di lapangan dalam kursus reka bentuk struktur tetulang konkrit. Penyelidikan ini telah dijalankan terhadap kumpulan pelajar yang diberi tugasan rekabentuk di sebuah firma reka bentuk tempatan. Data penyelidikan telah dikumpul melalui sesi temuduga, catatan jurnal, pemerhatian langsung dan penganalisaan dokumen. Kesemua data telah dianalisa menggunakan kaedah penganalisaan kandungan dan hasil kajian kemudian ditriangulasikan untuk meningkatkan tahap kebolehpercayaan dan kesahihannya. Hasil kajian ini mengusulkan bahawa pembelajaran berasaskan projek kerja di lapangan boleh meningkatkan pembelajaran kendiri pelajar, memupuk kemahiran professional mereka serta mencambahkan kemahiran pembelajaran sepanjang hayat. Projek reka bentuk juga didapati boleh menaikkan prestasi kemahiran menyelesaikan masalah di kalangan pelajar kepada tahap yang bersesuaian. Antara hasil dapatan kajian termasuk kaedah penilaian pada projek reka bentuk. Hasil dapatan kajian juga menunjukkan bahawa pihak berkepentingan menaruh harapan yang tinggi terhadap projek reka bentuk agar dapat mendedahkan pelajar kepada suasana persekitaran tempat kerja. Oleh itu, adalah penting bahawa pendekatan pengajaran inovatif, merangkumi penilaian yang wajar, dilaksanakan supaya projek reka bentuk adalah relevan kepada pelajar dan juga program-program kejuruteraan.

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LIST OF ABBREVIATIONS

ABET	-	Accreditation Board for Engineering and Technology
CDIO	-	Conceive, Design, Implement, Operate
CLO	-	Course Learning Outcome
CSR	-	Corporate Social Responsibility
CST	-	College of Science and Technology
DDA	-	Diploma of Civil Engineering
DDA3164	-	Subject code for Structural Reinforced Concrete Design
FPjBL	-	Field project-based learning
HOD	-	Head of Department
MIT	-	Massachusetts Institute of Technology
MQA	-	Malaysian Qualification Agency
MS	-	Malaysian Standard
PjBL	-	Project-based learning
RQ	-	Research Question
SDL	-	Student Directed Learning
UTM	-	Universiti Teknologi Malaysia
UTMSPACE	-	UTM School of Professional and Continuing Studies

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The central and the most distinguishing activity in civil engineering is design (Dym *et al.,* 2005; Akili, 2007). Design has traditionally been an important part of an engineer's training (Hasna, 2008); it is either studied as a comprehensive subject or integrated as a project in the teaching and learning of civil engineering (Sobek II and Jain, 2004). Engineering design is a challenging subject matter due to the expected design abilities in the technical and non-technical aspects, which associate both the cognitive and affective domains (Mourtos, 2011). In fact, design courses expose the students with the activities that engineers do as well as the basic elements in real design projects (Akili, 2007).

Teaching civil engineering design courses through projects with the involvement of industries has increased in recent years (Akili, 2007). Moreover, graduates are now expected to be versatile (Ardington, 2011) and be able to apply higher cognitive skills such as analysing, summarizing and synthesizing information as well as thinking creatively and critically (Vogel, Wagner and Ma, 1999). In this context, a strong emphasis has been put on the need for an actual shift from teacher-centred to student-centred learning (Mills, 2002). So much so that the development of interpersonal and professional capabilities of students can be made explicitly in the learning experience (Fallows and Steven, 2000) through "learn by doing". In this way, students are able to relate the academic theory learnt and the professional practice practised at industry (Oliveira and Estima de Oliveira, 2009).

Despite the increased involvement of the industries in engineering design projects, both design faculty and design practitioners argue that further improvements on design education is necessary (Akili, 2007). Comments from the employers identified that despite possessing good technical skills, engineering graduates still lack interpersonal, organisational, and team working skills. Substantial pressure from the industries and professional bodies such as the Engineering Accreditation Council, Board of Engineers to contextualise and embed generic graduates attributes in undergraduate programs is evident in many reports (EAC Manual 2012). Hence, there is a grave need to improvise the engineering education pedagogies (Puteh, Ismail and Mohammad, 2010) to accommodate the students' need as well as the demands from industries in order to feature both the technical and the generic skills among the engineering graduates.

There is an urgent need to change design education to meet the challenges of the 21st century as stated in Malaysia's Science and Technology Policy For The 21st Century, (2009). In this report, in order to achieve the vision of Malaysia to be a fully industrialized nation by 2020, it is necessary to produce engineering graduates who are technologically and scientifically strong, with good design ability. This justifies why engineering education stakeholders are deeply concerned with graduates who lacks skills in self-directed learning, communication, abstract thinking, problem solving and group dynamics (De Vita, 2004; Ward and Lee, 2002). The emerging trend of globalization and the rising challenges in the engineering field have demanded graduate engineers to be well-prepared with innovative approaches that are able to foster and support life-long learning.

According to Reidsema (2005), the exponential growth in information and knowledge over the last 40 years has serious implications for tertiary educators in engineering. This is because the lecture-based teaching model is no longer suitable to cater for the increase in technical content and the experiential nature of design learning. Moreover, the new paradigm for engineering design education is emerging as a multi-disciplinary, multi-mode, multi-media, and multiple-partner enterprise (Akili, 2007). These dilemmas provide a challenge for engineering design educators to revise their traditional teaching methods as there is a pressing need to equip engineering graduates with long term innovative solutions and prepare them for life-long learning endeavours.

Engineering has traditionally been taught as a series of separate courses. Due to this, engineering graduates will be expected to integrate the knowledge and understanding gained from this diverse and separate compartmentalised subjects, when involved in real world design projects (Chowdhury, Guan and Doh, 2005). In this case, students often experience difficulties in integrating the knowledge gained from these separate areas. In the traditional learning method, the lecturer gives lecture on the subject relating to the syllabus. Later, students' understandings were tested in the form of tests and final examination. One shortcoming of this situation is that lecturers are not able to test other skills such as communication and team skills in students. With regards to graduating students' capabilities, engineering industries requires high level of oral and written communication skills and other attributes such as professional skills and ethics. Such attributes are highly required for the success of professional engineers (Venkatesan, Molyneaux and Setunge, 2007). Student-centred learning tasks such as project-based design courses are necessary in order to allow students to integrate their knowledge with the practical aspect of the design course.

1.2 Background of the Study

The modern society is constantly changing with the rapid advancement in knowledge and skills (Mills and Treagust, 2003). Therefore, the improvement on the quality of design education in engineering is essential to meet the needs and the demand of competent engineering professionals (Mills and Treagust, 2003). In addition, industries require that employee posses and develop skills and abilities in order to survive in the global engineering environment. Simply mastering a single specialized skill is not relevant anymore. Thus, it is imperative to improve teaching and learning such as project-based learning (PjBL) in design courses in civil engineering in order to improve students' learning process.

A structural civil engineer is responsible for using his engineering background to plan and oversee various construction efforts in many different areas of the field. Design is what they do, they develop the schemes for construction of building, decide on how loads are distributed and to which they will be subjected, while remaining safe and serviceable to people. Yet, the building retains the aesthetic as required by architect. Students apply design principles and theories and will use this knowledge in practical situations to design the products; usually drawing and calculations are used to communicate the design to other party who will build the structure. Thus PjBL can be one form of teaching instruction, where students can practice and apply their knowledge in engineering. According to Gao, Demian and Willmot (2008), students should be able to integrate knowledge and skills in professional practice in line with the continuous industrial and organizational changes if they are exposed in the field project.

More than a decade ago, Felder *et al.,* (2000) revealed that, "…*many engineering classes in 1999 are taught in exactly the same way that engineering classes in 1959 were taught*". This is a shocking revelation especially to the engineering educators. Mills and Treagust (2003) further criticized that the existing teaching and learning strategies in engineering programs is out dated and needs to become more student-centred. This has prompted a number of researchers (Droppelt, 2003; Dym *et al.*, 2005; Gao, Demian and Willmot, 2008; Smith *et al.*, 2005; Thomas and Busby, 2003) to work on identifying the most suitable and affordable teaching approach applicable for engineering education worldwide. PjBL is the answer for resolving the critical issues of engineering education because it mirrors the professional behaviour of an engineer (Mills, 2002).

In traditional engineering education, lessons are commonly dominated by hour-long lectures (Mills, 2002). For example, the lecture on the Structural Reinforced Concrete Design is taught in a transmittal mode with little active participation from students. These lessons are mainly designed for the development of technical knowledge and skills. Skills developments such as personal and interpersonal skills are given little focus as described by Mills (2002). Teck (2009) argued that this traditional approach is inadequate to prepare the graduates with expertise in their field of qualification as well as with highly developed interpersonal, personal and transferable professional skills attributes. A change of approach in project implementation is emphasized to prepare students for scenarios, which mimic those faced by engineering practitioners (Montufar-Chaveznava, Yousuf, and Caldelas, 2008). PjBL has helped students to conceptualise engineering fundamentals in order to develop holistically acceptable solutions for engineering design problems as mentioned by several authors (Woods *et al.,* 1997; Gibson, 2005; Mills and Treagust, 2003). Project-based learning such as field-project exposes students to professional situations in either exploring a project or a problem with more than one way during problem identification and project implementation. The PjBL approach employs a problem as the driving force for learning the fundamental principles that are required to find a solution

Projects can operate in diverse contexts, such as fieldwork, or class approaches by using a single lecturer or course team that uses traditional methods of teaching. Lecture-based teaching is a dominant approach in project-based learning because it is efficient in providing students with large amounts of information in short amounts of time (PBLE, 2003). However, such overuse lecture-based in project may create a situation where students are disengaged with learning (Wurdinger and Rudolp, 2009). For example, students lost their attentions in the class due to long lecture hours. If institutions and educators want to improve the learning environments, they should consider engaging students with more active methods of learning, which would inspire and motivate students to engage in PjBL. Wurdinger and Rudolp (2009) reaffirmed that students are most excited about learning when they are actively involved in the learning process through group discussion, hands-on experience and practical application of the theory learnt in the classroom. Sax *et al.,* (2002) and Levine and Cureton (1998) claimed that students prefer active methods such as problem solving that can expose them to constructivist learning (Tam, 2000).

Felder and Brent (2005) claimed that students process the information presented to them in different ways. They would normally adopt their own learning preferences to better understand certain concepts (Felder and Brent, 2005). In certain cases, they might utilize learning approaches, which they may not be initially comfortable with. According to Felder and Brent (2005) and Cassidy (2004), students are usually taught in a manner, which they prefer or less preferred. This will gradually lead to an increased comfort level during the process of learning and boost their motivation to learn a difficult subject.

Several authors have described that PjBL has shown to be effective in increasing student motivation and improving students learning skills such as problem-solving and thinking skills (Arumala, 2002; Akili, 2007). Motivation of students is influenced by the learning activities in PjBL and the skills developed by learning through projects (Hilvonen and Ovaska, 2010). The motivation will indirectly help students, so that they are ready and confident when they are ready to begin their careers (Akili, 2007). As a result of motivation of students, this PjBL approach provides a context that makes learning the fundamentals more relevant and, hence, results in better engagement of learning by them. Since the project-based learning is commonly carried out in groups, it is natural that the quality of teamwork influences the motivation of individuals.

There are several reasons that rationalize the application of PjBL approach in design courses in engineering programs. Firstly, project tasks are closer to professional reality (Mills and Treagust, 2003) and relate to the fundamental theories and skills of an engineer. Secondly, almost every task in an engineering profession involves the development of projects bearing the differences in time scales and levels of complexity. Not only that, project component also address critical issues of engineering education as it fosters student-centred learning, The collaboration experience promote team working, communication and problem solving skills (Gao, Demian and Willmot 2008; Prince and Felder, 2006; Sheppard and Jenison, 1997). Thus, the successful completion of projects brings about the integration of all areas of undergraduate training in the design process, which an engineer has been exposed to.

1.2.1 The Research Gap

Each of the design process models by Khandani (2005), Oakes (2004), Volan (2004), Nicolai (1998) and Mourtos (2011) promotes a distinctive design process via convergent-divergent thinking (Nikolai, 1998), crucial in design work. Not only that, the models advocate iterative cycling through which the design process is repeated several times and foster the development of better and improved solutions. However, these models are insufficient in integrating the students' abilities in design. Abilities such as team working and communication are not integrated in these models despite the emphasis by the accreditation bodies such as Accreditation Board for Engineering and Technology (ABET, 2000) and Malaysian Qualification Accreditation (MQA, 2007) on these components. In addition, Nguyen (1998) and Zaharim *et al.* (2009) stressed the importance of professional skills in assessing engineering students' work. Even though these skills are addressed in the course learning outcomes of the engineering programs, these skills are not clearly assessed in the engineering project evaluation.

This study therefore, aims to address these gaps in the literature by investigating the inadequacies of the design process models by addressing the design abilities of the students that are essential when executing the design process. It is also aimed at addressing the deficiency in assessing the teamwork and communication components in design projects.

These gaps are also reflected in the challenges and shortcomings of the current PjBL approach at College of Science and Technology as below:

1. The projects presented to the students are not authentic.

2. Students are not exposed to the real project work and the real issues and challenges that arise from the project. Some lecturers are not aware of the challenges in project work, as they do not have the experience working in the construction industry.

4. There is no input from the construction or design consultant on the project as the linkage between the industry and the university is vague.

5. The current assessment on design projects does not consider the generic skills such as the team working and communication skills demonstrated by the students.

6. The design course is too focussed on engineering science and technical courses without providing sufficient integration of topics or relating them into industrial practice.

7. The current design course does not provide sufficient design experiences to students.

8. Incorporating field project in design would allow opportunities for students to develop communication skills and teamwork experience.

9. To develop awareness amongst students of the social, environmental, economic etc.

10. The current teaching and learning strategies in design is out dated and needs to become more students-centred.

For this study, the field project-based learning (FPjBL) approach is used to directly address some of the problems in the above issues with students are directly linked with the design industry. FPjBL is increasingly adopted in various courses in higher education and has been said to increase learning effectiveness (Hilvonen and Ovaska, 2010). In engineering education, there has been a long history of using project work to integrate disciplines and motivate students (Heitman, 1996; Heywood, 2005). Thus, the design project is used as the vehicle to enhance the design abilities of engineering education students.

1.3 Statement of the Problem

The structural design courses are crucial for the success of students in civil engineering program (Shepherd, 2003). Moreover, during the last several years, the progress in pedagogy in design education has led the new methods of teaching and learning in design project. Traditional approach to structural design education in Structural Reinforced Concrete Design is content-driven where it places a heavy emphasis on lecture-based delivery, which focused on problems intended for the students to apply the theory. This scenario is supported by Hung and Choi (2003) that courses in structural design courses placed too much emphasis on technical theory and too little on the application and integration of real engineering problems. Moreover, the knowledge of theoretical concepts from traditional teaching does not ensure that students can solve real industrial problems (Hasna, 2008).

Design projects in structural design courses are also given varying emphasis by different lecturers in higher institutions as mentioned by Manry, Bray, and Phoha (2012). Most lecturers have difficulties in finding the balance between theory and practice. Majority of the lecturers would provide familiarity with design codes as part of the education is clearly inadequate as it offers insufficient authentics design exposure to students (Mills and Treagust, 2003). Therefore, many students lacked the background knowledge of design skills and abilities in projects (Avery, *et al*., 2010). Therefore, it is essential to take students outside the classroom and increase their exposure to engineering practice through projects such as case studies, problem-solving workshops, visits to major companies and sites, and other interactive sessions as suggested by Kartam (1994).

Rapid growth of infrastructure development in Malaysia recently has increased chances of job opportunities to many graduates. In order to keep up with the demands, universities hold responsibility to produce students with sufficient background and excellent qualification. An assurance for the performance of students is highly dependent on the standards, preparation and exposure to the practical training, especially in design courses. Design projects in design courses can be used as a medium for students to bridge the theory they learnt into practice. Due to the global environment and continual technological and organizational change in the workplace, graduates are expected to develop relevant skills and abilities in order to survive (Hasna, 2008). They are expected not only to be knowledgeable in their disciplines but they are also expected to perform professional practices as well. As such, in order to keep pace with these demands of commercial realities of industrial practice in engineering, graduates shall be ready for the changing of work environment in the industries since their demand is changing with time (Noordin *et al.,* 2011). PjBL is the best method to resolve the issue, which involves active learning and early exposing students to engineer's job in industries (Noordin *et al.,* 2011). In addition, the projects could provide students with valuable experience if they can experience working at industries.

Students should be equipped with structural designs knowledge that is dealt not only with structural design theory and concepts but also with various analytical tools and design methods. It should also instil students' problem solving skills such as critical thinking and reasoning abilities. While doing the projects, students would develop a consistent understanding of their learning process in problem solving, analysis, synthesis and evaluation (Arciszewski and Lakmazaheri, 2001). In addition, they can apply their acquired knowledge to solve real-life and authentic design problems through project-based learning.

According to Steward (2007), the integration of project-based learning in engineering design education has fewer structured learning activities. For example, the self-directed learning tasks are guided through consultations with lecturers. At this instance, students are normally presented with guided instructions so that they are able to achieve the desired course learning outcomes for a particular design course. Thus, this kind of implementation of current education system is seldom successful in attaining some of the objectives of the course learning outcomes (Platanitis and Pop-Iliev, 2010). This is due to the fact that the project-based learning implemented does not promote the active learning that require students to be self-directed in their learning and to take 'ownership' of their own education. Many projects in design courses always dealt with 'real world' problem (Akili, 2007). One goal of PjBL as stated by Mergendoller (2006) is to allow students to manage the development of their long-term life-long learning skills (Hilvonen and Ovaska, 2010; Helle, Tynjala-Olkinuora and Lonka, 2007; Thomas 2000).

PjBL seems to be the best method to resolve this issue as early students' exposure to an engineer's job at industries can provide them with valuable experience working as engineers at industries (Noordin *et al.,* 2011). Graduates are able to practice the desirable skill expected of them such as communication, teamwork, leadership and management. These desirable skills are expected of our graduates and are critical in professional careers. Therefore, providing a comprehensive engineering design experience such as field project-based learning is an extremely important part of any undergraduate engineering program. Moreover, Accreditation Board for Engineering and Technology (ABET, 2000) Criterion 4 requires that;

> "*students be prepared for engineering practice through the curriculum, culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating engineering standards and realistic constraints*"

PjBL influences the motivation of students (Hilvonen and Ovaska, 2010). While communicating the fundamental knowledge of design, students can be optimally motivated if they see design education as personally relevant to their interest. In PjBL, since students are self-regulated, they would facilitate and motivate their learning. Evaluation of project-based courses as reported by Savage, Vanasupa and Stolk (2007) show increases in student motivation, as well as engagement in their learning. Students demonstrated greater self confident and improved learning abilities (Shepherd, 2003) that provide the opportunity for them to reflect and involve their beliefs and values (Mergendoller, 2006). These beliefs and values are indirectly increase students' achievement in their personal goal and development; consequently increase their motivation and engagement.

Teaching a course in engineering design well has always proved to be a substantial challenge. The nature of the course is fundamentally different than traditional lecture courses. It requires that students work in teams, which introduces grading difficulties, and requires that faculty deal with interpersonal skill issues. New projects must be either created by the faculty or solicited from industry each year. In either case, the projects should require an integration of a broad range of the student's coursework, provide a significant technical challenge, and finally, be interesting so that the students are well motivated. Design courses also generally involve significant writing content, oral presentations, and substantial students and lecturers' time, all of which conspire to make such courses very demanding on faculty time.

Students' fieldwork at industry through design projects can expose them to authentic project works or other interactive sessions as suggested by Kartam (1994). In this research, the researcher uses the Field project-based learning (FPjBL) approach that offers students a wide range of skills and design abilities to civil engineering students at the diploma level. The FPjBL approach can equip graduates with the knowledge, skills, and attitudes at the workplace and to prepare students to succeed in today's dynamic workplaces (Gonzales and Nelson, 2005).

1.4 Objective of the study

This research attempts to investigate the implementation of field project-based learning (FPjBL) in Structural Reinforced Concrete Design course at a local institution. The intended learning objectives and outcomes of the project will be examined. Accordingly, this research will explore the students' design abilities related to design work. The findings of the research will guide the development and implementation of field project-based learning (FPjBL) instruction.

This study is aimed to achieve the following objectives:

1. To investigate the design abilities demonstrated by students engaged in project.

2. To investigate how the field project-based learning (FPjBL) approach is able to enhance the design abilities of students in a structural reinforced concrete design course.

3. To design and develop the FPjBL instruction guide for Structural Reinforced Concrete Design course.

1.5 Research Questions

In order to achieve the above research objectives, the following research questions (RQ) are used.

Objective 1: To investigate the design abilities demonstrated by students engaged in project.

RQ1. What is the design abilities expected of civil engineering students?

RQ2. What are the design abilities of students engaged in the FPjBL?

Objective 2: To investigate how the FPjBL component is able to enhance the design abilities of a structural design project.

RQ3. How does the FPjBL develop design abilities among students?

Objective 3: To design and develop the FPjBL instruction guide for Structural Reinforced Concrete Design course.

RQ4. What are the improvements that can be made to the Structural Reinforced Concrete Design course?

1.6 Conceptual Framework

The conceptual framework in this study is governed by theories and studies in preparing future engineers as reported by the National Academy of Engineering (NAE, 2005). The challenges and attributes of future engineers involved surviving in the ever fast-paced global knowledge economy as well as possessing excellent design abilities and skills. The conceptual framework is represented in a graphical form to show the concepts that encapsulate the core of this study. According to Miles and Huberman (1994), conceptual framework is used to assist the researcher to decide the types of data collection and variables. It also guides the researcher during the data interpretation (Svinicki, 2011) by allowing the researcher to make choices about the relationships between the data.

Engineers of tomorrow will face great challenges. Technological and social challenges such as information explosion, communication technology, globalization, environmental contamination, infrastructural damage are some examples that engineers need to deal with. They will need to solve these problems where they have to perform and innovate at an ever-accelerating rate. According to Engineers 2020 (NAE, 2005), the key attributes that will support the students' success are strong analytical skills, good communication skills, understand the principles and having high ethical standards, professional, dynamic, agility, resilience and flexible as well as lifelong learners. Thus, it is imperative to realize that students in the 21st century are interested, committed and ambitious about what they have learnt and at which situations they are exposed to.

Field project-based learning (FPjBL) characterizes a constructivist teaching and learning approach. It is a comprehensive instructional approach to engage learners in a sustained, cooperative investigation as reported by Bransford and Stein, (1993). The learning theory encompassed the FPjBL activities is known as constructivism in which students reflect on their experiences and construct their own understanding of the learning (McHenry *et al.,* 2005). It is also a search for meaning in the issues and tasks around the students are actively trying to construct the meaning through the design project. This meaning requires understanding parts of the design tasks as well as the context of wholes of the project. Constructivism guides a set of instructional principles for the teaching of design in project work. It underlies the beliefs about knowledge and learning in which students "learn by doing".

According to Thomas (2000) project-based learning such as FPjBL promotes constructivism as its underlying principles. It enhances the student-centred learning using authentic projects and real life experiences. Real problems in project tend to engage learners more because of the large context of familiarity of the problems in project (Gao, Demian and Willmot, 2008). For example, this allows the learners to become active builders of their own knowledge through real design projects (McHenry *et al.,* 2005).

McHenry *et al*. (2005) elaborated that student's work collaboratively to plan for projects within the curricular content using authentic tasks that emphasize on time management and innovative assessment. In this context, students learning are enhanced by interaction with peers within the projects' activities because in constructivist learning, collaboration plays a vital role as knowledge is socially constructed when students work in a team (Hasna, 2008).

In FPjBL the learning strategy that engages the learners in complex activities usually requires multiple stages and an extended duration. The project learning May requires more than a few class periods or even a full semester. According to Thomas, Mergendoller and Michaelson (1999); Brown and Campione (1996), projects are challenging because each task is based on questions that may need further rectification. These challenging questions served to organize and drive students activities and engage them in a meaningful project. The problems in the project give learners the opportunity to work autonomously over extended periods of time. In addition, the problems in projects culminate realistic products or presentations such as artefacts, personal communication, or consequential tasks that meaningfully address the driving questions.

Blumenfeld *et al.* (1991) supported the issue of real problems in real environment from the perspective of knowledge construction, that learners construct knowledge by solving complex problems. These complex problems would indirectly get students to use their cognitive tools, finding sources of information and other individuals as resources. Helle, Tynjala-Olkinuora and Lonka (2007) agreed that real life problems in project promote the important of knowledge restructuring for the development of expertise. Other study by Prince and Felder (2006) highlighted the benefits of authentic or real project on the perspective of knowledge and skill transfer.

Student-centred learning is another key feature of the constructivist learning that encompasses activities in projects (Gao, Demian and Willmot, 2008; Helle, Tynjala-Olkinuora and Lonka, 2007). Brown and Campione (1996) listed three features of student-centred learning. These are the freedom of choice, students' responsibility for their own learning and the creation of a supportive learning environment. Students have more control of their learning and the role of the lecturer is to facilitate and guide the learning. In FPjBL, students have the oppurtunity to exercise their choices and control what to work on, how to work, and what is required to generate the final product. According to Blumenfeld *et al.* (1991) choices and controls are critical to enhance students' motivation in their learning. Learner control also encourage students to utilise their prior knowledge and experience (Puteh, Ismail and Mohammad, 2010; Prince and Felder, 2006).

The conceptual framework of the study shown in Figure 1.1 attempts to integrate the related theories and beliefs about knowledge and learning, which underlie FPjBL (Mills, 2002). With the adopted orientation of design process from Khandani (2005) in FPjBL, the development of the design abilities and skills in students is expected to be enhanced.

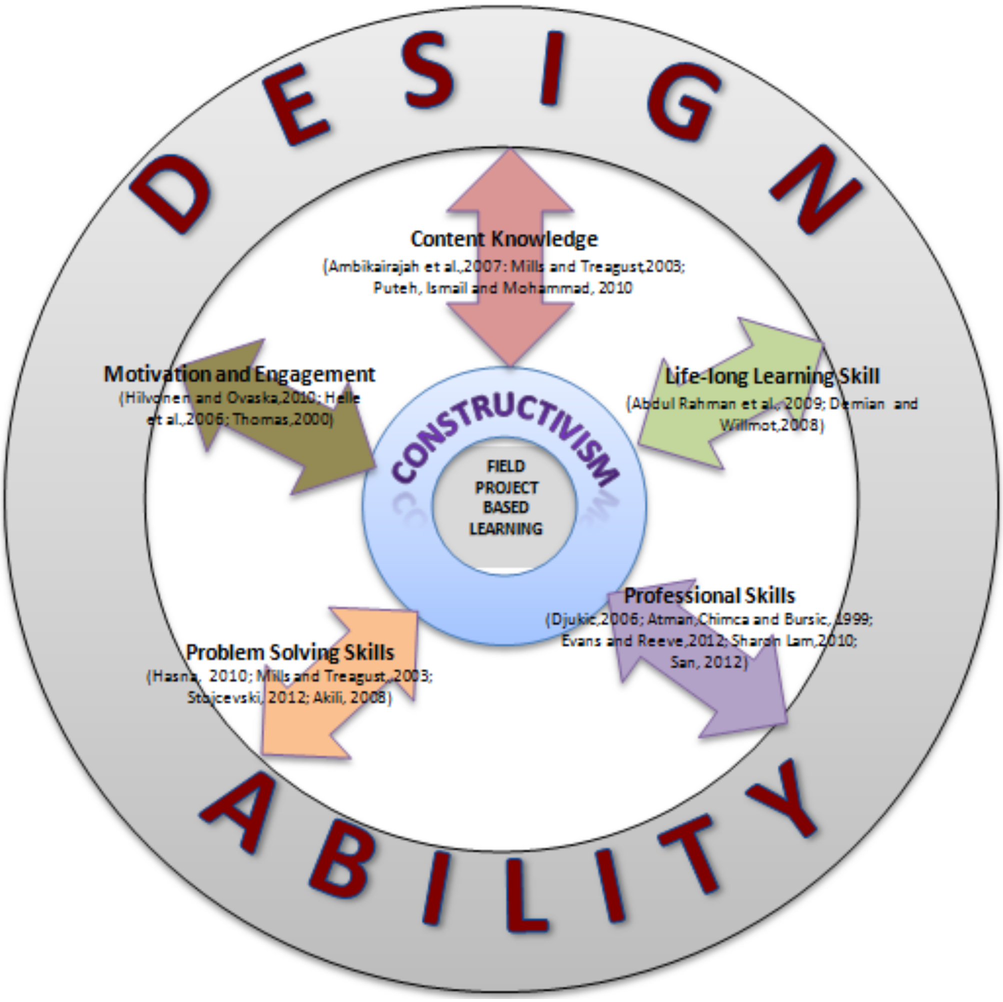

Figure 1.1: Conceptual Framework of the research

The implementation of FPjBL in structural reinforced concrete design course, students are exposed to the technical and non-technical aspects of design, which is associated with the cognitive, psychomotor and affective domains of knowledge. Content knowledge is the most obvious skill required by students because students should possess good knowledge of fundamental engineering science and maths in order to successfully achieve the outcome of the design course (Penuel and Means, 2000; Thomas, 2000; Boaler, 1997).

In completing a project, students use problems to construct meaning as recommended by Ambikairajah *et al.* (2007). The most important ability of students in FPjBL is to solve ill-structured problems in which the problems drive the learning of the learners. This is because the solution of a problem or a completion of a task requires students to complete a number of educational activities that drive the learning (Palmer and Hall, 2011). Problem solving in engineering design requires students' ability to reach a solution, therefore, students understanding of the problems is essential when they know how to the problem should be solved. According to Thomas (2000) it is crucial that students are allowed the freedom to ask different questions and approach the problem differently in PjBL. This freedom of choice can generate multiple solutions (Blumfeld *et al.,* 1991) which students are exposed in FPjBL.

Other aspect of design ability identified in Figure 1.1 is professional skills. Students are expected to work in a team, while maintaining the professional and ethical responsibility. In addition, professional skill such as communication and understanding the impact of engineering solution in a global, economic, environmental and societal contexts are needed for students to acquire during FPjBL. ABET 2000 stated that students must be prepared for engineering practice through the curriculum. Students are also expected to engage in design experience based on the knowledge and skills acquired in their coursework which incorporated the engineering standards and realistic constraints.

Another design ability available in Figure 1.1 is lifelong learning. Lifelong learning is learning to know, learning to do, learning to live together and with others and learning to be (Ambikairajah *et al.* 2007). Helle, Tynjala-Olkinuora and Lonka (2007) reported similar findings on lifelong and self-regulation learning of students engaged in design projects. FPjBL emphasizes the use of problems to trigger students' self-directed and collaborative learning as well as their lifelong learning skill development.

The ability to sustain, become more engaged and interested in design contributes to the motivation and self-worth of students (Hilvonen and Ovaska, 2010). PjBL increases motivation of students participating in the project design course. According to Thomas (2000) students are more motivated to bring out and test their ideas and increase their level of understanding when they are confronted with authentic projects. Motivation and engagement are required in PjBL because they support students' learning and practicing skills (Baillie and Fitzgerald,2000; Helle, Tynjala-Olkinuora and Lonka, 2007; Lutz and Schachterle, 1996; Ambikairajah *et al.,* 2007). They involve interest and value due to the novelty of tasks in the projects and the authenticity of the problem. In addition, Blumenfeld *et al.* (1991) discovered that students felt the 'ownership' towards the project when they are given the opportunity to question and to solve the project on their own.

The focus of this research is the implementation of project-based learning in structural reinforced concrete design course. Students were attached at a local design firm. Themes are presented with quotes arising from the study and that includes: the content knowledge (Penuel and Means, 2000, Thomas, 2000, Boaler, 1997), life-long learning (Ambikairajah *et al.,* 2007), professional capacities (Ngai, 2011; San, 2012, Gavin, 2011), problem solving skills (Barron, *et al.,* 1998; Gavin, 2011), motivation and engagement (Baillie and Fitzgerald, 2000; Helle, Tynjala-Olkinuora and Lonka, 2007; Lutz and Schachterle,1996; Ambikairajah *et al.,* 2007).

1.7 Significance of the Research

This research offers an innovative method of project-based learning for enhancing design abilities and skills of structural reinforced concrete design course in civil engineering students. The contributions of this research are:

1. To provide an innovative method of project-based learning to enhance students' design abilities and skills. The courses employed project-based learning activities as an important focus of the course to transfer the gap of theory into practice. The skills developed by learning through field projects will indirectly help students, ready and confident to begin their careers (Akili, 2007).

2. The findings of the study are expected to inform relevant authorities such as faculty administrators to provide guidance and insights into curricular changes, teaching methods, and exposure to civil engineering practice in

Malaysia and helps in establishing enduring connections with the industrial sector.

3. This study is also significant in assisting design lecturers to manage the contextualization of engineering design theory and practice. It can provide guidance and insights that would contribute to the understanding of the type of teaching approaches adapted by higher learning institutions.

4. Besides that, this study is also expected to guide the current assessment method on assessing students' skills in design projects and provide an input for the instructional process in project works including learning outcomes, teaching and assessment method.

1.8 Scope and Limitation of the Research

This research investigates the current project-based learning practice in Structural Reinforced Concrete Design course of a three-year diploma program at a local higher learning institution in Malaysia. This research only examines the current learning objectives or outcomes as stated in the course outline. It did not investigate the formulation of the learning objectives or outcomes prepared by the lecturers.

The research is limited to third-year students who took this course prior to their diploma graduation. Due to the shortage of resources, only two groups of students were exposed with the field project-based learning carried out at a consulting firm. The students did not have any training or experience prior to this field project-based learning.

This study is a qualitative research, which was conducted to gain deep understanding of the situation, event or people. According to Merriam (2009), the information obtained may not be generalized in other setting. Creswell (2003) added that generalization and reliability are insignificant factors in a qualitative research. Furthermore, the project-based learning in this study could help students enhance their design abilities so that they are able to transfer their design knowledge into real practice.

1.9 Definition of Terms

This research uses some common terms from civil engineering and the education discipline. Few terminologies used throughout the thesis are clarified for better comprehension below.

1.9.1 Project

A project is an activity where the participants have some degree of choice in the outcome (Hiscocks, 2012). It is a complex effort that requires an analysis and must be planned and managed, because of the desired changes (The Aalborg PBL Model, 2010). It involves a problem or task and the result is completed and functional (Hiscocks, 2012).

1.9.2 Project work

Project work integrates the investigations of a given topic. It is presented in a form of written report with detailed illustrations such as, the calculations, sketches and drawings (Blumenfeld *et al.,* 1991). The project (for students) must "*be crafted in order to make a connection between activities and the underlying conceptual knowledge that one might hope to foster* "(Barron *et al.,* 1998).

1.9.3 Project-based learning

Project-based learning (PjBL) is a model that organizes learning around projects (Thomas, 2000). Project work follows traditional instruction in such a way that the project serves to provide illustrations, examples, additional practice, or practical applications for material taught initially by lecture-based. Students learn the central concepts of the discipline via the project thus it is a student-centred approach to learning (Chandrasekaran *et al.,* 2012; Prince and Felder, 2006).

PjBL encompasses a diversity of approaches, the researcher adopted the defination by Prince and Felder (2006) for the study:

> *Project-based learning begins with an assignment to carry out one or more tasks that lead to the production of a final product – a design, a model, a device or a computer simulation. The culmination of the project is normally a written and/or oral report summarizing the procedure used to produce the product and presenting the outcome.*

This definition encompasses a project that are central, not peripheral to the curriculum, a range of educational activities are imposed on students such as active and collaborative learning; the problem-based learning in PjBL drives students to encounter the central concepts and principles of the discipline; the projects involve students in a constructive investigation of ‘real’ design problems and student-driven to some significant degree to projects.

1.9.4 Engineering Design

Design is widely considered to be the central and most distinguishing activity of civil engineering (Akili, 2007). Design has been employed as a vehicle for project-based learning and exposes on how theory is brought into practice. In this research, the design as in structural reinforced concrete design course, DDA3164 using the engineering design process described by Khandani (2005).

1.9.5 Field Project-based Learning

Field project-based learning is learning incorporating "hands-on" activities through projects by developing interdisciplinary themes as well as conducting field trips. Thus it is project-focused based on experiential education or active learning (Thomas, 2000).

1.9.6 Design Abilities

Design courses emerged in education as a means for students to be exposed to theory and practice where they could learn the basic elements of the design process by doing real design projects. Design abilities encompass the Outcomes 3a–3k of ABET 2000 in which graduates should have the knowledge, skills, and attitudes of learning. These skills and attitudes are both technical and non-technical and come from cognitive and affective domains (Mourtos, 2011). These skills include analytical skills, open-ended problem solving skills, a view of total engineering, ability to use design tools as well as interpersonal, communication and team skills.

1.9.7 Life-long Learning

Life-long learning is a continuous learning process that stimulates and empowers individuals to acquire all the knowledge, values, skills and understanding they will require throughout their lifetimes (Savage, Chen, and Vanasupa, 2006).

1.9.8 Student-Directed Learning-(SDL)

SDL is a continuous engagement in acquiring, applying and creating knowledge and skills in the context of an individual learner's unique problems (Steward, 2007). It places the responsibility on the individual to initiate and direct the learning process and can enable an individual to adapt to change (Savage, Chen, and Vanasupa, 2006).

1.9.9 Problem Solving Skills

According to Stojcevski, (2012) problems are often complex, ill defined and with no singular process model. There are different kinds of problems which exist in design. It requires system, procedural and strategic knowledge that students need to develop for contextual thinking and decision-making.

1.9.10 Collaborative Skills

Collaborative skills are the ability to work effectively and respectfully with team members (Göl and Nafalski, 2007). Students should also able to exercise the flexibility and willingness to be helpful in their respective teams and in making necessary compromise to accomplish a common goal among their teams. In addition, students should be able to share responsibility for collaborative work, and value the individual contributions made by each team member.

1.9.11 Assessment Method

Methods or procedures used to evaluate students achievements based on performance or student learning (Aziz, 2009). The evidence is based on what students can do and what they know (Biggs and Tang, 2007).

1.10 Organization of the Thesis

Chapter 1 provides the introduction and background of the research. The conceptual framework of the research, the research problems and research objectives, which guide the study are also presented in this chapter.

Chapter 2 reviews the literature related to the research. The project-based learning in design is highlighted in relation to the attributes and abilities, as well as, the models in PjBL. The relevant educational theories, skills required for project-based learning and the assessments of project are also provided.

Chapter 3 describes the research methodology of PjBL approach. The details of the study such as the choice of case study institution, data collection methods, data analysis and issues related to the reliability and validity of the data is also presented in this chapter.

The result, analysis and discussions of the research are provided in Chapter 4. The discussions are presented in relation to learning attributes and abilities demonstrated by the students engaged in field project-based learning.

Chapter 5 presents the conclusion of the research findings. The field project-based instruction to enhance the students' design ability is presented together with some recommendations for project-based learning practice. This research also offers an improved assessment method to focus on student design effort on communication and teamwork. Lastly, recommendations for further research are also offered.

1.11 Conclusion

This chapter discusses the current project-based learning in structural design course that includes the learning objectives and outcomes, teaching and learning activities in the course and the assessment method. The current and most common project-based learning is classroom-based and does not address and correspond the learning outcomes and objectives. Moreover, the design processes of students learning and reasoning within a task-based context need to balance the theory learnt and practice in design as expected by the industry. Thus, the focus of the research is the field project-based learning (FPjBL) in a structural design course where students are partially engaged at the industry. The challenge is to produce the field project-based learning instruction guide that could inculcate the knowledge, practical and attitudes acquired by students. The literature review related to this research is discussed further in Chapter 2.

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