EFFECTS OF DEEP LEARNING MODULE ON STUDENTS' ACHIEVEMENT IN PROGRAMMABLE LOGIC CONTROLLER COURSE

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DEDICATION

To my beloved family; My Wife Noraini Ahmad, My Parents Shahri Haron & Hamidah Md Rashid, My Kids Aina Syafiqah, Harun Al Rasheed, Aina Raisya Balqis & Nur Hanis Batrisya. Not forgotten, My Siblings Norsyaridah, Hairudin, Halizah and Muhammad Fitri.

Thank you for your support during my hard time.

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ABSTRACT

Learning programming for engineering technology courses is challenging as novice programmers have limited understanding of the basic concepts, and therefore have difficulty applying them. Students found that Programmable Logic Controller (PLC), a core technical course taught in Kolej Kemahiran Tinggi MARA (KKTM), Malaysia is difficult. Preliminary study conducted at KKTM found that most students used a surface learning approach for PLC, a pre-requisite course to other programming courses; therefore, they found difficult to do other programming courses as they have weak understanding on the fundamental knowledge in programming. Thus, the aim of this study is to develop deep learning module that encourage students' engagement in learning programming courses. A total of 68 second-year students from Industrial Mechatronics Engineering Technology Program participated in the study. The students were divided into two groups: 33 students in a control group and 35 students in a treatment group to examine Student Approach to Learning (SAL) in the PLC course. The adapted R-SPQ-2F questionnaires and interviews were used to measure the differences of deep learning scores before and after the intervention. The intervention strategies comprised two phases. The intervention in the treatment group was audio-video recorded. Phase one involved cooperative learning strategies, think-pair share in teaching concept inventory questions and jigsaw in programming exercises. Phase two intervention used open-ended questions with adaptations of engineering thinking and reasoning concepts. Think aloud method was used by the students to record their project assignments using audio video screen capture software. In addition, students were asked to update their learning progress weekly using suggested learning verbs of Bloom's taxonomy into SOLO's map application. Results from the video observation in phase one indicated students engagement and interest in learning. In addition, students reported that the strategies in phase two intervention helped to enhance their thinking and reasoning which lead to a deeper learning. Self-assessment R-SPQ-2F results of the t-test for the treatment group had a positive effect (less than 0.05) towards deep learning approach compared to the control group. In addition, SOLO's map final results indicated that 85% of the students were able to achieve a 'relational level' of deep learning stage. Interview results showed that students started to adapt to the deep learning approach in phase 2. The findings support that the developed deep learning module used during the intervention helps to enhance students' learning in programming courses.

ABSTRAK

Pembelajaran pengaturcaraan untuk kursus-kursus teknologi kejuruteraan adalah mencabar bagi pengaturcara amatur yang mempunyai pemahaman yang terhad tentang konsep-konsep asas justeru itu, amat sukar untuk mengamalkannya. Pelajar mendapati kursus teknikal teras Pengawal Logik Boleh Aturcara (PLC), yang diajar di Kolej Kemahiran Tinggi MARA (KKTM), Malaysia adalah sukar. Kajian rintis yang dijalankan di KKTM mendapati bahawa kebanyakan pelajar menggunakan pendekatan pembelajaran permukaan untuk PLC yang merupakan kursus pra-syarat pada kursus pengaturcaraan lain; oleh itu mereka berasa sukar dalam kursus pengaturcaraan lanjutan kerana mereka mempunyai pemahaman yang lemah mengenai pengetahuan asas dalam pengaturcaraan. Tujuan kajian ini adalah untuk membangunkan modul pembelajaran mendalam untuk menggalakkan penglibatan pelajar dalam pembelajaran kursus pengaturcaraan. Seramai 68 pelajar tahun dua dari Progam Kejuruteraan Teknologi Mekatronik Industri telah mengambil bahagian dalam kajian ini. Pelajar dibahagikan kepada dua kumpulan; 33 pelajar dalam kumpulan kawalan dan 35 pelajar dalam kumpulan rawatan untuk diuji pendekatan pembelajaran pelajar (SAL) dalam kursus PLC. Soal selidik R-SPQ-2F dan temubual telah digunakan untuk mengukur perbezaan skor pendekatan pembelajaran mendalam sebelum dan selepas intervensi. Intervensi dalam kumpulan rawatan adalah rakaman suara dan video. Modul yang digunakan terbahagi kepada dua fasa. Fasa pertama melibatkan strategi pembelajaran koperatif, *think-pair-share* bagi soalan-soalan konsep inventori dan *Jigsaw* dalam latihan pengaturcaraan. Fasa kedua intervensi menggunakan konsep pemikiran dan ketaakulan dalam kejuruteraan bagi soalan-soalan terbuka. Kaedah *think aloud* telah digunakan oleh para pelajar untuk merakam tugasan projek mereka menggunakan perisian rakaman suara dan video pada skrin. Selain itu, pelajar diminta mengemaskini rekod kemajuan pembelajaran mereka setiap minggu menggunakan kata kerja pembelajaran yang dicadangkan dalam taksonomi Blooms ke dalam aplikasi peta SOLO. Hasil penelitian rakaman video dalam fasa pertama menunjukkan perubahan positif dalam penglibatan dan minat pelajar semasa proses pembelajaran. Di samping itu, pelajar melaporkan bahawa strategi dalam intervensi fasa dua membantu meningkatkan kebolehan berfikir dan ketaakulan yang menjurus ke arah pendekatan pembelajaran yang lebih mendalam. Keputusan t-test ujian kendiri R-SPQ-2F untuk kumpulan rawatan mempunyai kesan positif (kurang dari 0.05) terhadap pendekatan pembelajaran lebih mendalam berbanding dengan kumpulan kawalan. Disamping itu, keputusan rekod akhir aplikasi peta SOLO menunjukkan bahawa 85% pelajar berupaya mencapai ‘aras relasional’ dalam pembelajaran lebih mendalam. Hasil temubual pula mendapati pelajar mula menyesuaikan diri dengan pendekatan pembelajaran lebih mendalam pada fasa kedua. Dapatan ini menyokong bahawa Modul pembelajaran mendalam yang digunakan dalam intervensi dapat membantu meningkatkan kebolehan pelajar dalam pembelajaran lebih mendalam bagi kursus pengaturcaraan.

TABLE OF CONTENTS

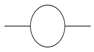
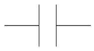
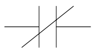
LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

3P	-	Presage-Process-Product
AKEPT	-	Malaysia Higher Education Leadership Academy
FBD	-	Function Block Diagram
FC	-	Mediation of feeling of competence
HEP	-	Higher Education Provider
HMI	-	Human Machine Interface
HOTS	-	Higher Order Thinking Skill
IL	-	Instruction List
IS	-	Mediation of interdependence and sharing
KKTM	-	Kolej Kemahiran Tinggi MARA
LD	-	Ladder Diagram
MARA	-	Majlis Amanah Rakyat
MLE	-	Mediated Learning Experience
MQF	-	Malaysian Qualification Framework
PID	-	Proportional Integral Derivative
PLC	-	Programmable Logic Controller
RO	-	Research Objective
RP	-	Mediation of reflective practice
RQ	-	Research Question
RS	-	Reset Set
SAL	-	Student Approach to Learning
SCL	-	Student Centred Learning
SCADA	-	Supervisory Control and Data Acquisition
SFC	-	Sequential Function Chart
SOLO	-	Structured Observed Learning Outcomes
SPM	-	Sijil Pelajaran Malaysia
SRL	-	Self Regulated Learning
SR	-	Set Reset
ST	-	Structured Text
TAP	-	Think Aloud Protocols

LIST OF SYMBOLS

d	-	Effect Size
M	-	Mean
σ	-	Standard Deviation
	-	Coil
	-	Normally Open contact
	-	Normally Close contact
r	-	Pearson Correlation Coefficients
χ^2	-	Chi Square

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

In preparing engineers and technologists to meet the challenges of globalization, there is a need to examine the role of educators. Gathering responses from UK engineering academics (Bourn and Neal, 2008), there is a need to consider application of curriculums across the country, roles of different technologies in teaching, and the need to relate to different perspectives of local development. Universities in the UK also experience considerable difficulties maintaining student numbers enrolled on engineering programmes (Williamson, Hirst, Bishop and Croft, 2003).

Some evidence exists to suggest that due to skill shortages and skill gaps, employers are forced to look overseas to fill engineering vacancies. Serious challenges are will be presented to future UK governments particularly in terms of a lack of suitably qualified talent (Spinks, Silburn and Birchall, 2006). Thus, several forms of planning were developed to ensure a sustainable infrastructure and global community in engineering education. A part of this planning included strategies to spark the engineering imagination of children as young as 5 or 6 years of age.

As a developing country, Malaysia realizes that students need to master various important cognitive skills such as creative thinking and innovation, problem-solving and reasoning, developing a learning capacity with the ability to independently drive one's own learning, and coupled with an appreciation of lifelong learning value (Ministry of Education, 2012). Malaysia has a history of promoting such learning which is critical for the Malaysia National Education Philosophy and the Education Act (1996).

The emphasis is no longer just on the importance of knowledge but also on developing higher-order thinking skills and improving student learning outcomes in order to achieve the government's aspiration of better prepared Malaysian students for the needs of the 21st century (Performance Delivery and Management Unit, 2011). Students were expected to be able to represent their empirical work or result mathematically and to focus on solving both common and complex problems (Firouzian, Ismail, Rahman, Yusof, Kashefi and Firouzian, 2014; Mohd. Marzuki Mustafa, 2011).

A study from Malaysia's Higher Education Leadership Academy (AKEPT) found that only fifty percent of lessons were being delivered in an effective manner (Osman and Kassim, 2014). This means that the other half of the lessons did not sufficiently engage students, where students used a passive lecture format of content delivery which was only effective in achieving surface-level content understanding instead of using higher-order thinking skills (Konting, Idris and Singh, 2009). Their findings showed that teachers were found lacking in key competencies such as creativity and high-order thinking to deliver the curriculum in creative ways that could make learning meaningful as well as interesting for students.

The conventional teaching strategies mainly train students to store and retrieve mastered information that could not satisfy the demand of engineering education in the information age which is based on rapid development of technology (Guo and Lu, 2011). Lecturers faced challenges in engaging students to use higher-level learning activities (Brabrand, 2008) and this is a global issue which also impacts engineering programs in Malaysia where students are needed to think critically to solve complex technical problems. However, this issue may be overcome by educators by shifting from teacher centred teaching and learning to student centred learning (SCL).

University learning environments take place in a critical period of time in a student's life, during which changes and challenges happen towards their cognitive development (Tanner, Arnett and Leis, 2009). Thus, educators have transformed their teaching to constructivist learning environment where they now encourage students to gain an experiences for the process of knowledge construction through exploration and towards being autonomous in their learning (Mooney, 2000). These objectives are aligned with the students' characteristics that manifest autonomy, initiative, and creativity.

In an Industry 4.0 era, focus is placed on smart manufacturing concepts to support the industrial transformation which can be divided into three aspects, namely, automation, smart machinery, and data processing (Rüßmann, Lorenz, Gerbert, Waldner, Justus, Engel and Harnisch, 2015). Advancements of Industry 4.0 can be mainly presented in five aspects of total interconnections, total integration, Big Data Analytics, continuing innovations, and in-depth transformation (Lee, Bagheri and Kao, 2015). To date, programmable logic controllers (PLC) remain the best option for industrial automation for the requirements of digital factories with human machine interface (Chen, Tai and Chen, 2017). Towards technology transcendence, engineering students need to prepare themselves for fundamental automation concepts. Thus, the challenge arises for educators to provide sufficient material and suitable pedagogy approaches to support industrial needs.

In mechatronics engineering, the word mechatronics can be defined as a combination of mechanical and electronics disciplines as these two disciplines have major influences on the development of mechatronics (Davim, 2012). Furthermore, students are exposed to various languages of programming related to system control, actuators, sensors and switches, robotics, and automation. Among the challenges faced are the increase in the number of operating systems together with the change in programming paradigms, programming languages, and software suites that are dependent on most recent developments in technology and more so operating systems (Govender and Govender, 2014).

Kolej Kemahiran Tinggi MARA (KKTM) Penang, Malaysia, is one of the institutions which offers a Diploma program in Industrial Mechatronics Engineering Technology. Compulsory courses such as Programmable Logic Controller (PLC) courses together with automation system, Instrumentation and control system, Microcontroller, and Programming techniques are taught in this program. Traditionally, this course was taught by focusing primarily on computer software and hardware architecture (Goyanka and Patil, 2014; Nunnally, 1996). Student entry requirement for KKTM are a minimum of three credits from Sijil Pelajaran Malaysia (SPM) in Bahasa Melayu, Mathematics, either one science or technical course, and they are needed at a minimum to pass the English course. There are eleven KKTM MARA institution in Malaysia under Ministry of Rural Development offer technical programs.

There are two major components taught in these programming courses. The first major component is a theoretical part which covers the basic construction of controller, hardware configuration, interfaces, introduction to instruction sets, and programming language. There are also theoretical assignments and tests according to the topics. The second component of the course is a practical session which covers programming skills of the students based on tasks given in a Work Sheet by the Lecturer. Training workbenches are used to carry out practical activities. Practical work is assessed in the engineering courses.

In addition, the aim of a science and engineering curriculum is to help students understand and be able to use the accepted explanations of the behaviour of the natural world (Biernacki and Wilson, 2011). The nature of engineering and technical courses tought in current local colleges and universities in Malaysia are saperated between the theoretical and practical part of teaching. However, for courses that have both theory and practical components, students need to grasp both parts of knowledge and are then expected to apply the knowledge in practical tasks.

With the assistance of computer-based software and training workbenches, students are exposed to real industrial problems. The program has to be downloaded into a controller and a simulation will run on the computer. As part of the practical scheme, students will be given a Work Sheet according to the chapter they have learned. They are required to read the instructions inside the Work Sheet and then attempt to solve the problems either in a group or individually.

1.2 Background of Study

MARA is an agency under the purview of the Ministry of Rural Development, was established on 1 March 1966 as a statutory body by an Act of Parliament responsible for developing, encouraging, facilitating and fostering the Bumiputera economic and social development in the federation, particularly in rural areas. MARA Technical and Vocational Division (BKT) is accountable for developing and maintaining TVET educational programmes in preparing students for occupations that contribute to Malaysia's economic development. These programmes are categorised into twelve different clusters such as electrical, electronics, automotive, manufacturing, biomedical, and more. All clusters of these programmes are implemented at eleven Kolej Kemahiran Tinggi MARA (KKTM), and fourteen Institusi Kemahiran MARA (IKM) in Malaysia. MARA TVET institution becoming the choice and focus of the public as it proved success in producing quality and competitiveness graduates. Therefore, TVET MARA is aimed to develop the best human capital among Bumiputera that can stabilise skills training to support industrial development and technological mastery and subsequently reduce national dependency on technology and skilled manpower from abroad. Graduates from MARA TVET were equipped with soft skills encompassing non-academic skills such as positive values, leadership, entrepreneurship, team work, communication and continuous learning. MARA has proven its commitment to produce skilful TVET graduates with establishing TVET education centre at each state to meet the demands of the community and industry.

KKTM Balik Pulau is one of MARA TVET institution located in Penang, Malaysia that offer five main Engineering Technology in Diploma. The programmes are Industrial Mechatronics, Stamping Die, Injection Moulding, Product Design and Manufacturing. All of these programs are designed for a period of three years in full time mode including industrial internship in the final semester. Currently, KKTM Balik Pulau has 620 students and from that, 120 students are Industrial Mechatronics Program (DMK) students.

The main challenge for students of this program is to understand courses related to programming such as PLC, Microcontroller, Programming Technique, Industrial Robotics, and Automation System. From the list of courses above, PLC is a *killer* courses among students. PLC course is a course that will be applied in almost every discipline and area in Industrial Mechatronics Engineering Technology Program (Pratumsuwan and Pongaen, 2011). This course is taught in second year for DMK students and it is a fundamental prerequisite for subsequent cours es such as automation system, production system, mechatronic system design and control system. Moreover, PLC course is applied in preparing the proposals and projects during final year project that emphasize on industrial automation system. Other than KKTM Balik Pulau, PLC is also a subject taught in KKTM Kuantan and KKTM Beranang. However, the strategy, technology and approach used at each institutes is different.

According to Lahtinen (2006), Eckerdal (2009) and Bubica (2014), novice programmers are typically limited to surface knowledge. It was found also they do not understand the basic concepts and therefore have difficulty applying knowledge. Students' difficulties have often led to high dropout rates in programming courses (Lahtinen, 2006). There are several of methods have been used to write programs for industrial control applications and PLC (Gomis-Bellmunt, Montesinos-Miracle, Galceran-Arellano, Bergas-Janeá and Sudriaà-Andreu, 2007). Some of PLC trainings required for students to integrate with other external devices to automate manufacturing cells and communicate to other systems (Bellmunt, Miracle, Arellano, Sumper and Andreu, 2006). There are also tutorial systems for PLC to enhance student learning (Hsieh and Hsieh, 2003) but less material able to assist students towards deep learning. The scenario found during Automation System and Final Year Project courses whereby students unable to relate the knowledge learned in PLC course into their project.

It was discovered that students face multiple challenges in learning PLC course such as difficulties acquiring the correct understanding of abstract concepts, less resources, lack of personalized instructions, large number of students in a group work, as well as the heterogeneous ability and background of the students (Miller, 2000; He, 2015). Thus, proper designing instructions are required to suit every student need and this becoming a difficult task. Current Job sheet and notes adapted from PLC manual exercises are seems only work for surface learning students. The tasks instructions are arranged step by step which not promotes deep learning among students.

Current instructional module in three KKTMs are identified as not clear in term of theory and model used. PLC course acquired the ability and understanding in problem solving. Failure to master PLC course will lead engineering and technical students in analysis and critical thinking to solve complex problems (Mccord, 2014; Paul, Niewoehner and Elder, 2007). Therefore, the best instructional design model must be identified to ensure it works well with learning theory. For example, students from Industrial Mechatronics Engineering Technology Programme in KKTM Balik Pulau were engaged more in practical work rather than solving problematic or theoretical questions which required students to apply PLC course in problem solving (Shahri, Rahman and Hussain, 2017). The same scenario also can be seen in theoretical classes where students were faced difficulties to understand the content.

Besides that, students' achievements in practical courses are comparatively better than their theoretical courses. Lecturers are looked more comfortable and confident using traditional teaching method or teacher-centred. The teaching method uses instructions focus only on verbal communication, printed words, rote memorization, and instruction driven (Schneider and Renner, 1980). Students who were taught traditionally are told what they are expected to know and concepts are presented deductively (Cooper and Robinson, 2000; Huba and Freed, 2000), which creates an environment where the lecturer conducts lessons by introducing and explaining concepts to students and then expect students to complete tasks to practice the concepts. The routine tasks have proven that it limit and stop students level of curiosity as they merely expected to just complete and implement the task given.

In engineering education, practical activities in a laboratory is essential in order to ensure the learning in the theory class is well understood (D'Andrea, Giannetti, Manara, Michelini and Nepa, 2008). At KKTM, practical and theoritical activities are combined and conducted at the same workstation. This is a priveledge where the lectures can have practical and theoritical activities in one time at one place. Final year students are required to design and develop an automation system. Therefore, PLC course is applied for the entire process and project. At this point, students need to think deeper beyond their fundamental course scope.

According to Hall (2004), surface approach to learning is claimed not to enhance students' engagement with their subject material. This will not help in improving analytical and conceptual thinking skills among students. Throughout the observation, majority of the KKTM lecturer used traditional teaching method during their classes which involved directs instruction to students in learning process. This approach will not encourage active participation and problem solving in constructing knowledge among students. It has failed to encourage students to adopt deep approaches to learning (Lord, Travis, Magill and King, 2005). According to Entwistle (2000), students' approaches to studying are affected by the different kind of teaching and assessment that will shown in students' academic performance and achievement. Students also have option to change their learning approach from surface to deep learning (Baeten, 2010). Therefore, introducing a comprehensive teaching and learning method is important to foster students' engagement during the lesson.

The introduction of a student centred learning (SCL) nowadays have been suggested to promote better understanding of conceptual fundamental knowledge for students (Boylan-Ashraf, Freeman and Shelley, 2014). Thus, methodologies that connect science to life using active learning pedagogies need to be emphasized in engineering classrooms too. Modern interpretations of SCL include project based learning, case based learning, discovery learning, and just in time teaching with three instructional approaches of active learning, cooperative learning, and problem based learning (Prince and Felder, 2006). However, further study is needed to determine the best student centred strategies that give positive impact on student learning especially the effects of SCL in upper level major classes (Boylan-Ashraf, Freeman and Shelley, 2014). Hence, lecturers need to continuously learn and understand new approaches to teaching and learning as proposed by several researchers (Felder and Brent, 2007; Slavin, 2014). In general, lecturers have the privilege and full authority of restructuring courses. This is a good platform for them to venture the best and the most appropriate student-centred pedagogies that will stimulate students' ability and talent. This opportunity will also give good experience to them in renewing crafting of teaching style.

Several literatures suggest a change in curriculum development in teaching engineering courses. Constructivism view is the idea come from combination of learning model and cooperative learning model. A strong framework will come to fruition in order to help students to have better understanding in fundamental engineering concepts (Boylan-Ashraf, Freeman and Shelley, 2014). In this study, the structure of learning progression for HFC3042 PLC course is explored.

Some studies in lecture based settings in classrooms found that there were no significant differences between surface and deep learning among students. (Katrien Styven, 2006). Others claim, inaccurate learning strategy and lack of motivation will contribute to high failure rate (Baeten, 2010; Entwistle, 2001; Valle, Cabanach, Rodríguez, Nuñez, González-Pienda, Solano and Rosário, 2011). According to Hall (2004), Felder and Brent (2003) and Biggs (2007), changes in the learning environment able to influence the learning approaches. Several researchers (Baeten, 2010; Cihat Tetik, 2009; Entwistle, McCune and Hounsell, 2002; Rosário, Núñez, González-Pienda, Valle, Trigo and Guimarães, 2010) investigated the effects of learning methodology on approaches to learning, especially on the deep approach. However, those studies were vague and gave varied results. Researchers who have investigated this topic presented several possible explanations for their results and suggest various suggestions also the factors that encourage or discourage the adoption of deep approach learning in SCL environments (Baeten, 2010).

Several researchers discovered that students do not seem to be inclined towards deep learning in the traditional learning environment due to several limitations. Among the limitations are lack of feedback in teaching and learning process and also various issues connected to working in groups (Hänze and Berger, 2007; Krause, Stark and Mandl, 2009). There was also several studies on mixed learning environment (Sivan, Leung, Woon and Kember, 2000; Wilson and Fowler, 2005), but no study found in the context of deep learning effect. In addition, less study found to estimate the effects of SCL environment on students' approaches to learning in methodology. Thus, the findings from qualitative research and quantitative research will compliment both findings.(Baeten, 2010).

Currently, Student Approaches to Learning (SAL) theory is used to study the influences in students' learning conceptions, goals, learning tasks, and type of assignments. SAL theory is a tool to access students` academic perceptions of the situation demands. Beside that, HEPs also need the information in helping them in inculcating deep approaches to learning in order to improve academic achievements. (Rosário, Núñez, González-Pienda, Valle, Trigo and Guimarães, 2010). The problem statement will explain the problem that is clearly based on the studies.

1.3 Statement of the Problem

Preliminary study was conducted among 85 Industrial Mechatronics Engineering Technology students program (DMK), 58% of students were found to lean towards surface approach in their learning. The survey findings are supported by face to face interviews which indicated that the students were inclined to surface learning approach whereby most of them study only to get good grades in their final examinations. Throughout the observation, majority students tend to do what ever lecturer says during class and follow instructions as stated in worksheets step by step regardless learning outcomes achieved or not. Thus, the way students approach their learning is very important to determine study success and it reflects not only from the teaching and learning process but also motivation in constructing knowledge.

Malaysian Qualification Framework (MQF) suggest Higher Education Provider (HEP) apply variety of active learning settings such as work-based, practice-based and various form of practical training. However; reality is not all lecturer ready to adapt these method of teaching. The scenario same as in KKTM, where the teaching and learning method for Diploma programs was implemented using the traditional approach which emphasizes direct instruction and lecture, seatwork, and students learning through listening and observation with more to lecturer based or lecturer centred approach. As the result from refection in PLC's course assessment report as shown in Appendix U, these routine tasks unable to inculcate students' curiosity towards the courses taught and discouraging students in reasoning their thoughts. Although much work has been devoted in teaching and learning approaches, relatively little has been done in qualitative study focus on deep learning.

Furthermore, final examination results from January-June 2014 and July-December 2014 sessions for PLC course did not demonstrate good achievements. This can be inferred from the respective dropout statistics 22% and 25% respectively where examination marks scored were below 50% as shown in Appendix H. According to KKTM PLC course assessment report shown in Appendix U, students have weak in writing and testing the program for any given basic problem description as stated in Course Learning Outcome 3 (CLO 3). In addition, students found more interest in practical session regardless their fundamental knowledge ability in understanding PLC concept or theory. The cases highlighted in Mechatronics Program Meeting section 2.1.6 (*Senat*) and 2.5.4 (*Final Year Project dan kursus-kursus lain*) as in Appendix V. Therefore, it is important to develop a more comprehensive teaching and learning module as same as formative and feedback tools to measure students learning progression towards deep learning.

This research attempts to investigate the students' approaches to learning PLC course HFC 3042 in KKTM Balik Pulau. This research explores a mixed teaching and learning method using cooperative learning with integration of engineering thinking and reasoning elements. In addition, this research also explores the used of self-assessment among students to monitor their learning progression over time. The findings of this research will guide the development of module fostering students towards deep learning approach.

1.4 Research Objectives

There are three research objectives (RO) as follows:

1. To determine the students learning approach in learning PLC course;

2. To design teaching and learning intervention strategies for deep learning approach;
3. To assess the effect of deep learning modules to students' achievement.

1.5 Research Questions

To achieve the above ROs, the following research questions (RQ) are used.

RO1: To determine the students learning approach in learning PLC course.

RQ1 What are the learning approaches for DMK students in PLC course?

RO 2: To design a teaching and learning intervention strategies for deep learning approach.

RQ2a What are the teaching and learning strategies that promote and support students to increase their use of deep learning approach?

RQ2b How to assess students' use of deep learning approach?

RO 3: To assess the effect of deep learning module to students' achievement.

RQ3a. What are the effect of deep learning module to students' achievement?

RQ3b. What are the general principles of teaching and learning strategies to promote students' use deep learning approach?

1.6 Conceptual Framework

A conceptual framework is an analytical tool with several variations and contexts either graphical or written in narratives form (Miles and Huberman, 1994). Conceptual frameworks guide researchers in testing their proposals, variables, and to explore relationships (Creswell, 2013; Miles and Huberman, 1994). The conceptual framework for this research is shown in Figure 1.1.

The framework is based on the ROs that need to be considered when investigating the concepts and designing the teaching and learning activities. The components of teaching and learning activities include cooperative learning approaches (think aloud problem solving, think pair share, and jigsaw), adaption of engineering thinking and reasoning elements in students assignment, and learning assessment (Brent and Felder, 2012; Kagan and Kagan, 2009; Paul, Niewoehner and Elder, 2007).

One set of PLC and automation multiple choice concept inventory questions, five sets of PLC programming exercises, and two sets of open ended questions were developed to investigate students' conceptual progression which is discussed in detail in section 4.3. The multi-staged intervention processes will be discussed in detail in section 3.7.4.

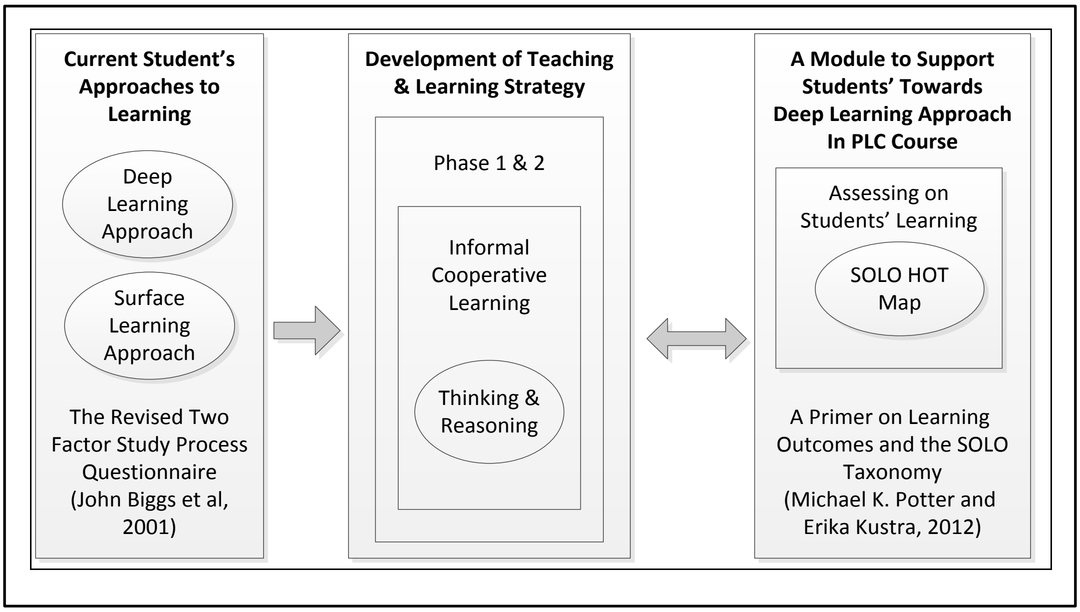


Figure 1.1 Conceptual frameworks

Variables such as teaching strategy and current students' learning approaches defined towards the intervention. The analysis will see the changes in students' conceptual progression towards deep approach to learning. Findings about students' approaches to learning in a PLC course before and after treatment will be discussed.

1.7 Significance of the Research

The findings of this research is a significant contribution in order to enhance students' learning PLC course. Since students seems found difficult to verbalize their thoughts during learning processes, participating in cooperative learning activities perhaps could get better concept progression in basic PLC and automation system besides overcoming their own difficulties. By verbalizing their thoughts in the phase one stage, students have better retention of their fundamental knowledge. Students are able to become active learners when the learning is incorporated with think pair share and think aloud tasks. Furthermore, students have direct interaction and involvement with the learning process which increases their interest and enables them to acquire scientific knowledge.

The most prominent implication of this study is useful in order to determine students' engagement in learning, and thus help to inform on how to support and foster students towards deep learning approach in PLC programming course. Through mediated learning theory and engineering reasoning, several elements were used in designing an instructional approach to assist students in better grasping conceptual understanding. Thus, this study can be extended to the application of non-traditional teaching and learning approach to further investigate students' improvements in deep learning approach in all related engineering disciplines. In addition, students were equipped with their learning monitoring progression through Structure Observed Learning Outcomes (SOLO) map and this will guide them towards a deeper learning approach over time.

A significant contribution to pedagogy was highlighted in terms of identifying an effective approach for teaching and learning activities for the PLC course. The developed module to assist student toward deep learning approach assist students' learning especially on the willingness of students to take part in cooperative learning activities, which indirectly enhanced their motivation, and learning strategy. The lecturers and university must be ready to indulge in teaching and learning activities with supported modules through cooperative learning approaches. The developed approach assists lecturers for a student-centred environment. Through the simulation, several abstract concepts about PLC programming can be explained and discussed by lecturers easily. This research is conducted to gain insight into teaching and learning activities with their approaches to learning and thus provide a module and framework as a guide for other researchers in designing an instructional approach for assisting students towards deeper learning approach.

1.8 Scope and Limitations of the Research

This study has been limited to students in Year 2 and third semester who learn PLC courses. The students have already passed fundamental courses such as digital system, electrical and electronic devices courses as in section 3.5. The student population was selected from KKTM Balik Pulau where the sample is purposively taken among students taking Diploma in Industrial Mechatronics Engineering Technology Program (DMK). The students range from 18 to 20 years of age in the study as highlighted in the Majlis Amanah Rakyat (MARA) entry requirement. Besides that, only those who are taking or familiar with Programming courses were included in this research.

Although this research involved two groups, the performance of students (grades) who are taking the same course in this institution are not compared and other factors such as students' interest, gender, and social background will also not be taken into account. All computers in PLC laboratory are equipped with Siemens Simantic Manager Software, S7300 PLC and simulator at each workbench. In addition, students also will be provided with Simantic Micro Win S7200 PLC simulator free license for them to practice PLC programming outside of class sessions when actual PLC courses are not readily available.

1.9 Operational Definition

Listed below are operational definitions of terminologies used in this research. Terminologies such as students' approaches to learning, constructivism, social development learning theories, cooperative learning, engineering thinking and reasoning, SOLO taxonomy, Bloom's taxonomy, intervention framework, mediated learning experience, and simulation software were used in these thesis.

1.9.1 Students approaches to learning

Students approaches to learning is an approach that involves monitoring the development of one's own understanding (Entwistle, 2000). It consists of two main categories which are surface and deep learning approaches. Under both main categories, there are motives and strategic learning approaches (Biggs, Kember and Leung, 2001a). Deep approach to learning states the intention to extract meaning produces active learning processes that involve relating ideas, looking for patterns, principles, using evidence and examining the logic of the argument (Pask, 1988). In contrast, the surface learning approach states the intention is just to cope with the task, which sees the course as unrelated bits of information and leads to much more restricted learning processes, in particular to routine or memorization.

1.9.2 Constructivism

Constructivism as a paradigm posits that learning is an active and constructive process. The learner is an information constructor and actively construct or create their own subjective representations of objective reality. New information is linked to prior knowledge, thus mental representations are subjective. (Mooney, 2000). Constructivism states that learning is an active, contextualized process of constructing knowledge rather than acquiring knowledge. Knowledge is constructed based on personal experiences and hypotheses of the environment. Learners continuously test these hypotheses through social negotiation.

1.9.3 Social development learning theory

This research made use of social development theory that argues on social interaction precedes cognitive development. Two terms relate to social development theory are the more knowledgeable other (MKO) and the zone of proximal development (ZPD). MKO refers to anyone who has a better understanding than the learner concerning a particular task, process or concept. ZPD is the distance between a student's ability to perform a task under adult guidance or with peer collaboration and the student's ability solving the problem independently. According to Vygotsky, learning occurs in this zone and he believes that the internalization of these tools leads to higher thinking skills (Kozulin, 2003).

1.9.4 Cooperative learning (CL)

Cooperative learning is part of SCL. CL refers to students working in teams on an assignment or project under certain conditions and criteria to be met, including individual accountability for the complete content of the assignment or project (Felder and Brent, 2007).

1.9.5 Engineering thinking and reasoning

Engineering thinking and reasoning can be explained as engineers with a good thinking routine with applied intellectual standards to the elements of thought as they seek to develop the traits of a mature engineering mind then applying intellectual standards to the elements of reasoning (Paul, Niewoehner and Elder, 2007). The intellectual standards introduced by Paul consists of intellectual humility, autonomy, integrity, caurage, perseverance, emphaty, confidence in reeason and fair mindness.

1.9.6 SOLO taxonomy

Structure of observed learning outcomes (SOLO) describes levels of increasing complexity in a student's understanding of a course through five different stages which are pre-structure, uni-structure, multi-structure, relational and extended abstract. SOLO provides a simple, reliable and robust model for levels of understanding which are surface and deep conceptual learning (Biggs and Collis, 1982a) (Biggs and Tang, 2007). From a student’s perspective, learning progression can be recorded in SOLO’s map whereby students' knowledge development is monitored over time (Taber and Watts, 1997). However, from a teacher’s perspective, learning progression can be explained as a tool for teachers to understand how transferable skills develop and progress over time.

1.9.7 Blooms taxonomy

Bloom’s taxonomy is a model constitute of thinking hierarchy according to six cognitive levels of complexity. Bloom’s model consists of three lower levels (knowledge, comprehension, and application) being more basic than three higher levels (analysis, synthesis, and evaluation) (Bloom, 1956). Bloom’s model has been updated to account for 21st century needs (Anderson, Krathwohl, Airasian, Cruikshank, Mayer, Pintrich, Raths and Wittrock, 2001).

1.9.8 Intervention framework

Intervention framework consists of a set of principles which determine the character of all the work (Daniels, Williams and Psychologists, 2002) and in this research, SAL, engineering thinking and reasoning, constructivism learning theory, and SOLO model are the main principles applied into teaching and learning strategies exploratory towards a deep learning approach.

1.9.9 Simulation Software

Simulation, or in this research used simulation software can be explained as an activity based on the process of modelling a real phenomenon with a set of mathematical formulas. It is, essentially, a program that allows the user to observe an operation through simulation without actually performing that operation (Collins, 2007). In this research two simulation software used which are S7200 PLC Simatic manager and PC Simu simulation software.

1.9.10 Mediated Learning Experience (MLE)

Mediated learning experience (MLE) refers to the way in which stimuli is experienced in the environment and are transformed by a mediator for example a parent, teacher, sibling, or other person among the life of the learner (Tan, 2003).

1.10 Organization of the Thesis

Summary of the thesis flow organization is as shown in Figure 1.2. Chapter 1 provides the introduction, research background, statement of problem, research objectives, conceptual framework, significant of the research, scope and limitation, and operation definition of the study.

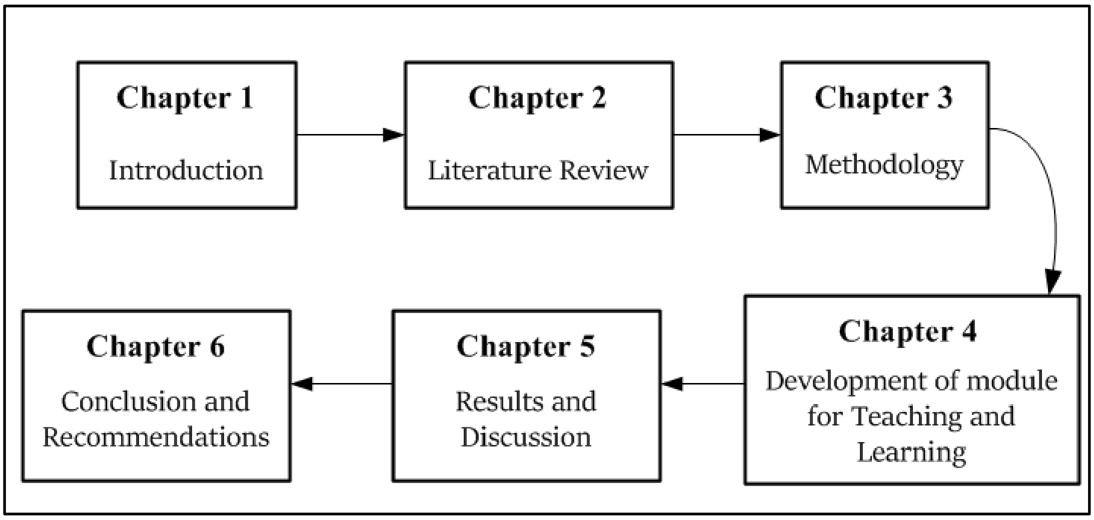


Figure 1.2 Organization of Thesis

Chapter 2 presents this study's literature review on teaching and learning strategies, students' learning PLC, assessing high order thinking (HOTS), and instructional design models. The discussions on research findings by other researcher are also presented.

Chapter 3 presents the research methodology. The topics consist of research design, operational framework, research instruments, research samples and setting, pilot study, method in collection data, data analysis, reliability, and validity of the instruments. Credibility and transferability are described in this chapter as well.

Chapter 4 presents development of the teaching and learning module which involve integration of modules according to the ADDIE model, the module development, instruments to measure SAL, adaptation of semi structured interview, and self-reflection on the intervention.

Chapter 5 provides research results and discussion. The results, analysis, and discussion related to students' approach to learning are elaborated in this chapter. The sub chapter consists of determining the current practice of approach to learning among students, evaluation of intervention using developed module, assessing deep learning, the effect of a deep learning module, determinants of the intervention framework, triangulation of data, framework in enhancing deep learning, and issues in research process.

Chapter 6 presents conclusions and recommendations of the research findings. The contribution of the research and implications are discussed. Several recommendations to improve the current teaching and learning activities are also presented.

1.11 Summary

This chapter discussed the current teaching and learning issues related to approaches to learning and learning progression research in industrial mechatronics engineering technology education. The current teaching and learning activities on students' approaches to learning were also provided. The focus of the discussion was on students' approaches to learning in KKTM Balik Pulau, Penang, Malaysia. The current teaching and learning activities depends on slide presentations, passive learning, and lecture. Moreover, the students themselves act as passive listeners.

To tackle the problem of students' poor learning outcomes, this research attempts to assist students' approaches to learning by inducing teaching and learning with cooperative learning activities incorporated with engineering thinking and reasoning tasks together with utilization of SOLO maps record to assess students' learning progression. The challenge is to gain a deep approach to learning among students. The literature review related to this research is discussed in Chapter 2.

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LIST OF PUBLICATIONS

Non-indexed Journal

1. Shahri, N., Rahman, R. A., & Hussain, N. H. (2017). Enhancing Students' Deep Approaches to Learning Among Industrial Mechatronics Engineering Technology Students. *Sains Humanika, 9*(1-2).

Indexed Conference Proceedings

1. Shahri, N., Rahman, R. A., & Hussain, N. H. (2014, 11-13 April 2014). *Student Approach to Learning in Programming Courses among Industrial Mechatronics Engineering Technology Students.* Paper presented at the Teaching and Learning in Computing and Engineering (LaTiCE), 2014 International Conference on. **(Indexed by SCOPUS)**

Non-Indexed Conference Proceedings

1. Shahri, N., Rahman, R. A., Hussain, N. H., & Mohammad Yusof, Y. (2016). *Teaching and Learning Intervention Strategy to Increase Students' Use of Deep Learning Approach*. Paper presented at the Regional Conference in Engineering Education 2016, RHEd/APCETE/REES 2016, Universiti Teknologi Malaysia, Kuala Lumpur

2. Shahri, N., Rahman, R. A., Hussain, N. H., & Mohammad Yusof, Y. (2016). *Assessing Students' Learning Outcomes and Students' Approaches to Learning Through SOLO Taxonomy and BLOOM'S Taxonomy.* Paper presented at the I-PHex 2016, Universiti Teknology Malaysia.