Problem Based Learning Approach in Programmable Logic Controller

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Abstract

The revealing and changing trends in information and communication technology (ICT), as well as the automation control system had suggested the new competence and learning such as skills of critical thinking, problem solving, decision making, team working and so on are more important and critical rather than students are often forced to muddle through group processes in the effort to learn. This learning process is being utilised to our students in Electrical Engineering using Problem Based Learning approach, for example Programmable Logic Controller (PLC) subject which will be described in this paper.

Keywords: Problem Based Learning; ICT; Programmable Logic Controller

1. Introduction

Nowadays, the revealing and changing trends in information and communication technology as well as continuing evolution of design methodologies, students of electrical, electronic, telecommunication and computer engineering programs need to acquire important qualities of lifelong learning and self learning to support a through-life ability to respond to advances in technology [1]. PBL has gained acceptance and has been found effective within a variety of disciplines in higher education [2,3]. PBL satisfies three important criteria that promote optimal learning [4]. First, it provides an environment where the student is immersed in a practical, on-going activity in which he/she receives feedback from other students and the instructor. Second, the student receives guidance and support from his/her friends and peers. Learning is not uni-directional (teacher to student), but multidirectional, including other students, tutors, and lecturers. Learning occurs through the multiple interactions within the learning environment. Third, the learning is functional — based on solving a real problem. PBL is based on a foundation of collaboration and integration within a small group context.

Problem-based learning (PBL) is an efficient way to acquire knowledge. It requires student to utilize all of their skill in order to a guided question. They must research, collect data, interview, and adept information in order to present a possible solution to the presented problem. Students tend to remember things they have experienced, or had to research on their own, because it feels like it is their own question, not just one presented during class [8]. The problem-based learning (PBL)[5,6] was adopted for this course. With PBL, students are empowered to self-direct their educational experience by designing experimental systems and/or subsystems against given specifications. It is an instructional method, which uses real-world problems to facilitate students' critical thinking and problem solving skills while accomplishing the course objectives. Students get involved and take responsibility for their learning experience; and instructor becomes a resource. Instructor role changes to that of a consultant, mediator, counselor, and resident technical expert. The purpose of implementing PBL is to motivate the student to integrate and utilize knowledge rather than to re-involve the student into the learning process after an extended period of inactive listening [7].

This paper discusses how problem-based learning can be used to enhance the students' learning experience in programmable logic controller. PLC and Process Control is one of the subjects in Control, Instrumentation and Automation in three credit hour

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course with a two-hour laboratory. This course requires practical skills to complete the laboratory assignments, which give students hands-on experience. Although every phase of developing the practical skills is important, we have found that hands-on experience in applying ladder diagram using software tool to solve problems present the presents the greatest challenges in a laboratory environment. Practical experience with data acquisition and other computer applications is an important part of the engineering process.

In this paper we discuss on PLC application using a software tool to control the PLC system over Local Area Network (LAN). We find that students benefit from developing proficiency in the software applications to solve technical problems. Employing an intensive, problem-based approach helps develop this proficiency in a limited time. We recommend that the students receive clear, consistent, and reasonably complete assignments provided by the laboratory instructor. It is important that the students continue through all phases of each assignment, and fully engage in solving problems as they encounter them. We use individual set of PLC to its function such as input/output relay or temperature control for student project and it is not maximise the usability of PLC equipments which can be shared through a networking capability or in a distributed system. This paper discusses how we focused on the problem-based learning that could also be implemented for industrial projects.

2. Background of PLC

A PLC is a solid-state control system with a user programmable memory, used to read input conditions and set output conditions to control machines or processes such as motors, robots, vision systems, and conveyors which are widely used in manufacturing to coordinate a variety of complex tasks, such as security monitoring, energy consumption management, and control of machines and automatic production lines. PLCs are programmed using *ladder logic* to develop *ladder diagrams* as well as hardware and control-related commands (known as *instructions*). Bit-level instructions for example, are used to examine inputs or energize outputs at specific PLC interface bit addresses. Timer instructions are used to control the timing of events in a process, such as delaying motors from starting at the same time or opening a valve for a given time. Counter instructions turn outputs on or off after a certain number of input transitions. This paper focuses primarily on the development of lessons based on projects.

In most university engineering education curricula, “control systems” means closed loop control. PLCs tend to be viewed as “technical”, and often make a rare appearance, a best. With current technology, this is somewhat shortsighted. Control systems can be placed into three broad functional groups:

- monitoring systems, such as Supervisory Control and Data Acquisition (SCADA) systems, which provide information about the process state to the operator.
- sequencing systems, used where some process must follow a predefined sequence of discrete events.
- closed loop systems, which, as widely taught in engineering courses, are typically implemented to give some process a set of desired performance characteristics.

While PLCs are traditionally associated with the second grouping above, many have the ability to run simple closed-loop control laws, and often have in-built PID routines. Their input/output capabilities make them a better choice for teaching control system implementation than the more commonly used (bare) microcontroller board. They are also more likely to be encountered by the majority of graduates entering industry. Finally, discussions with industry advisory groups have confirmed an expectation/hope that graduates, particularly from CIA courses, have more knowledge than basic closed loop control theory; knowledge in all categories of control systems is required.

With this background, it is important to introduce some degree of problem-based learning into a Control, Instrumentation and Automation (CIA) program before students commence the capstone design project. Some degree programs do this by having “mini” design and build exercises in earlier semester, which are useful. However, in CIA, it is important to have a more structured approach to developing thinking skills in a context that encourages, in fact forces, students to integrate facts and concepts from a range of mechanical and electrical disciplines. These courses provide consolidate building blocks that feed into the capstone design project. Described in this paper is one course in the third year of a CIA degree program that uses problem-based learning in a structured way to consolidate knowledge from a range of other topics.

3. Facilities

To facilitate the learning process, the Process Control lab equipped with 15 sets of PLCs and personal computers (PC), which are standalone. Each of the PCs is installed with programming tool using ladder logic, which can be compiled, and upload to PLC unit either serial or network communication. Above figures are the facilitates that are being used by our students as shown in Figure 1 which is the lab for PLC and Process Control. In Figure 2, it is a PC connected to PLC system using a software tool that can upload and download codes in a ladder diagram form. Six units of PLCs are connected through a LAN using Ethernet, which can bring the speed faster at 10/100 Mbps as shown in figure 3 as one of the example. Figure 4, 5 and 6 are the plants that connected to individual PLC unit which are interconnected as shown in Figure 7.

Figure 1. PLC and Process Control Lab

Figure 2. PC is used for uploading/downloading program using PLC's software tools.

Figure 3. PLCs integration through network.

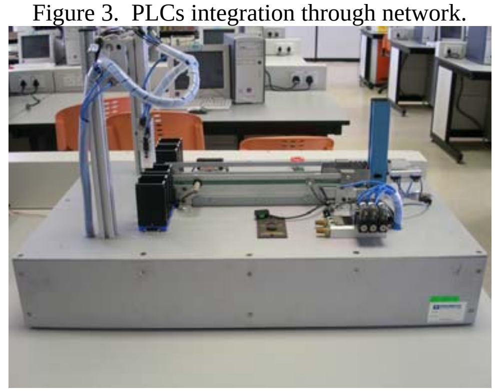

Figure 4. Plant 1 – Pick and place conveyer system

Figure 5. Plant 2 – Positioning System

Figure 6. Plant 3 - Water Level System

4. Course Background

The course in which PLC programming is taught is Process Control, a third year subject in the Bachelor of Electrical Engineering, CIA degree program at Kolej Universiti Teknikal Kebangsaan Malaysia (KUTKM). Important background material to be specifically built upon and integrated is shown in Figure 8. Referring to the figure, the background material can be placed into four categories:

- Teamwork, which is material that aims specifically to develop group dynamics appropriate for problem solving. Included in this category is a "first week project", a vertically integrated design and build competition that runs in lieu of formal lectures in the first week of semester 1. This includes specialist team-building lectures and activities. There are also formal communications subjects. It is known that simply placing students in teams does little to promote effective teamwork [9,10], and putting directed effort into developing team-skills is necessary if group-based PBL activities are to be effective.
- Theory, which in this case includes subjects on classical control, sensors and actuators, computer programming and computer systems.
- Practice, which includes "hands-on" subjects such as the lab class streams and early year design and build competitions.
- Attitude, which includes students discipline while running any practical or project.

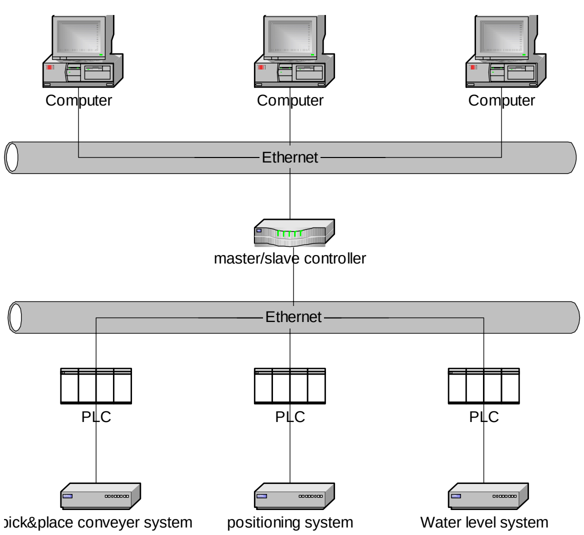

Figure 7. Plants system interconnected through LAN

The PLC and Process Control course gives students some experience with commercial programmable controllers, going beyond simple ladder logic and concentrating on control law implementation. By the end of the course, students will: know what a PLC is and what it can do; know how to implement a simple control law using a PLC; know how to read sensor signals into a control system and work with the values; and know how to program and implement a simple but complete PID control system on a PLC.

However, the broader aim of the course is to consolidate knowledge from several areas and develop problem-solving skills in the context of having to implement a control system, via:

- active involvement of the students in the learning process [10,12], with emphasis on working in teams to solve problems;
- provision of activities with clear goals or objectives [13];
- provision of prompt feedback; where the academic acts more as a mentor and coach than a lecturer [10].

The PLC and Process Control course has 2 hours of formal meeting time per week. Classes are held in a PLC lab with 15 computers and PLCs, plus all equipment required to perform the activities. Students have all-hours access to the lab. There are typically 30 students enrolled in the class, working in groups of 2-4.

Students' progress through a series of projects of increasing size, moving towards the ultimate aim of being able to implement a fully functional control system starting from "scratch". The 2-hour formal meeting period typically includes roughly 15 minutes of lecture, directed at particular aspects of the week's problem. As students have already undertaken courses in classical control, formal instruction in a programming language (although not the programming language they are using with the PLCs), and several manufacturer. There are two larger (two-week) projects in the course. The first is the programming of an open-loop control system for controlling a sensor and actuator. Students are given a suggested code outline (basically, titles of the ladder logic networks without code) as a starting point. Blocks of code from each of the previous exercises can be brought to bear on the problem. For the students, the difficulty is figuring out how the complete system works. The second project is the programming of a working PID control system. Students start this problem with only a problem statement and they have to find suitable components to design the above system. Another important part is the plants integration, which are controlled by master/slave controller and allows only one PC, can access any individual plant at one time as shown in Figure 7.

5. Assessment

Assessment in the PLC and Process Control course requires, by University rules, a significant exam component 40% of the final grade). The final exam concentrates on "how would you …" questions: how would you approach this problem, how would you structure this code, etc. This is very similar to problems given during the course, with the exception of (no) actual programming. The other 40% of the final grade comes from the projects, and is comprised of formal answers to set questions as well as demonstration of working systems and answering of verbal questions from the academic. One of example is shown in figure 9 and 10 on Traffic Light Control System. The student group that assign to this project has to solve the problem on how to control the traffic light system.

6. Course Evaluation

At this early stage of the CIA program, no formal course and teaching evaluations were taken. Instead, all students were assigned to "focus groups", meeting regularly with academic staff members for one hour to discuss a range of aspects related to both the overall program and individual courses.

This focus group approach has proven invaluable in discovering lecturing problems, and deficiencies and duplications in content during the initial years of the CIA program; these can easily exist in a subject that relies upon an integration of existing Mechanical and Electrical Engineering subjects, Computer Science subjects, and custom CIA subjects. Focus group meetings are also favoured by academic staff, who enjoy the involvement with students. In general, the focus groups indicate that the course format was popular with students, and achieved the desired outcome. Student comments reinforce the need for the lecturer to be expert in the technology, to debug problems quickly. Many students would also like the short lectures to be increased in duration, although this would prove difficult if the projects are to be (mostly) completed during class time. Most problems can be grouped into three general areas: the technicalities associated with getting people started in the first two weeks (getting the PC / interface / PLC combination to function across all groups); group-related problems, where students who are expert with computers are grouped with novices; and extending from this, difficulties associated with the small subset of students who do not like any hands-on work, and who would generally prefer the short lectures to be increased to occupy the entire class time. All of these problems can be addressed by having additional help circulated amongst the groups during the class.

7. Summary

The PLC and Process Control course aims to consolidate knowledge from a number of electrical engineering topics, using PBL techniques to teaching the programming of PLCs. The learning outcomes from this course, in terms of knowledge and process skills, feed directly into the capstone design project in the following year. With PBL, students will benefit what they have learnt based on projects and understand the design and implementation of PLC which currently being used in industries.

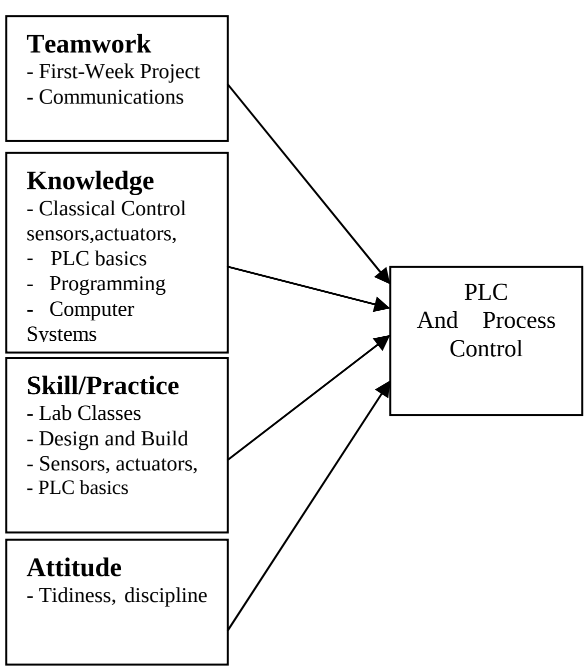

Figure 8. Characteristic and implementation of PBL in Engineering Course

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