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Retrofitting of Machine Based Learning in Mechatronics Engineering

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ABSTRACT

Retrofitting of machine has become an interesting option for manufacturing and processing of the industry. It offers numerous advantages in the area of cost-saving as well as in maintaining a high quality. For these reasons will affect directly on the competency and demands of engineers in the industry. Thus, this paper presents the retrofitting of machine through the problem-based learning (PBL). This study was adapted such a scenario as the main approach to the questioning and assessment. The results of implementation with the third-year mechatronics students shows that the students can retrofit the machine successfully and achieve defined objectives. Therefore, this retrofitting of machine based learning was an alternative to promote learning and prepare mechatronics students on the according basis with the actual demands of the industry.

KEYWORDS

Retrofitting of Machine; Problem-Based Learning; Mechatronics Engineering; Programmable Logic Controller.

1 INTRODUCTION

The knowledge-oriented and fast-changing economy requires intellectual workers with skills of problem-solving, team working, and self-learning. The traditional curriculum cannot meet the requirements. PBL is one of the proposed learning ways to tackle this problem. PBL was firstly applied in the medical study and has been applied to other subjects. Different studies show that PBL assist students to have an in-depth knowledge understanding and develop transferable skills. Moreover, it helps students to build up confidence to apply the acquired knowledge to new situation [1]-[6].

The PBL method has been applied to curriculum development in some areas of mechatronics engineering. Some works recognize the effort needed to motivate students in laboratory work [1]-[3]. More research has been carried out to include virtual laboratories that aim to enhance learning or as an alternative to real laboratories [5], [7]. The overall results have been a positive learning experience for students. However, because of the diversity and differences in the content and context of each course, the applying of PBL to cover all the objectives is complicated. Therefore, the increasing popular term "PBL" does not refer to a specific educational method. It can have many different meanings depending on the design of the education method employed and the skills of the teacher [8].

Since "Retrofitting" has become an interesting part for manufacturing and processing companies. More and more companies have made use of this option lately. It offers numerous advantages in the area of cost-saving and in maintenance a high quality. By the term "Retrofit" we generally understand the cost-effective modernization of used production plants. This can be realized by replacing the mechanical components along with modernizing electrical components, especially the machine control [9], [10]. Therefore, the retrofitting of such a directly impact on the competency and demand for engineers in the industry.

Nowadays, universities around the world, most often in collaboration with the industry to encourages research and innovative in products and processes development as well as provide and train students and general personnel to expect a requirement of the industry. Department of Teacher Training in Mechanical Engineering, King Mongkut's University of Technology North Bangkok (KMUTNB) was in this situation as well. In this way, some companies have to support the old machines to the department applied for the promotion of mechatronics education.

All of the above mentioned, when the old machine is to be encouraged and supported by the industry as well as regular curriculum of the department, therefore, this paper presents the retrofitting of machine based learning (ROMBL) in programmable logic controller (PLC) course of mechatronics engineering. This study, the methods of problem-solving is still a generic PBL model, but it has taken the retrofitting of machine in the industry as the main approach to the questioning and assessment. This is to encourage and prepare students with the knowledge, skills, and experience to accordance with the requirements of the industry, which the details are discussed in the following orders.

2 RETROFITTING OF MACHINE

Retrofitting refers to the addition of new technology or features to older system. Principally retrofitting describes the measures taken in the manufacturing industry to allow new or update parts to be fitted to old or outdated assemblies. More and more companies have made use of this option lately. It offers numerous advantages in the area of cost-saving, the optimization of existing plant components, adaptation of the plant for new or changed products, as well as in maintaining a high quality [9]. A retrofit, rebuild or remanufacture will cost somewhere between 1/3 to 2/3 the cost of purchasing a new machine. It is important to recognize not only the differences in purchase price, but also the additional costs of any new tooling requirements, transportation and rigging, modifications or replacement of special foundations, modification of part programs and processes, and the associated training for the operators and maintenance personal. Not all machine tools are good candidates for a retrofit based on simple economics. Small commodity machines benefit from an economy of scale in production and in the price of the procured components. Since a retrofit can require one-time engineering charges, it is often cheaper to purchase a new replacement commodity machine. The large, more expensive machines used in the heavy construction equipment, power-generation, aerospace and defense industries are often ideal candidates for a retrofit [9], [10].

However, a review of the relevant literature [9]-[13] can be concluded as the steps of typical retrofitting of machine, which consists of six steps: analyze existing design and review documentation, create a new design or re-engineering design, simulate to verify functionality, assemble prototype to verify design, validate through testing and demonstration of prototype, and generate complete technical data package to support design. All of which can be represented by the block diagram shown in Fig. 1. Which these steps will be adapt as a ROMBL on the basis of PBL.

3 PBL METHODOLOGY

PBL is one of the student centered approaches and has been considered by a number of higher educational institutions in many parts of the world as a method of delivery. PBL is a total pedagogical approach to education that focuses on helping students develops self-directed learning skills. It derives from the theory that learning is a process in which the learner actively constructs new knowledge on the basis of current knowledge. PBL provides students with the opportunity to gain theory and content knowledge and comprehension. PBL helps students develop advanced cognitive abilities such as creative thinking, problem-solving, and communication skills [1]-[6], [14]-[17].

However, the problem-solving of the generic PBL model [14], [17] usually consists of 10 steps, as shown in Fig. 2. Step 1, teacher explores problems in the real-world, which is consistent with the course content. Step 2, the teacher presents a problem challenge to the students. Step 3, students identify the problem using the ideas or hypothesis, fact, learning issues, and action plan. Step 4, students use "triggers" from the problem case or scenario to their own learning objectives, subsequently they do independent, this step is to self-directed learning. Step 5, group discuss and refine their acquired knowledge. Step 6, group solve problems and make decisions. Step 7, group presented the results from the solution. Step 8, debrief the problem learner interaction and between groups. Step 9, summary of problem-solving based on science and technology. Step 10, evaluation of the PBL process. For steps 4-9, beyond students to increase knowledge and understanding, there are several other desirable attributes such as sharing information, communication skills, independent responsibilities for learning, problem-solving, teamwork, promote generic skills and attitudes to learning.

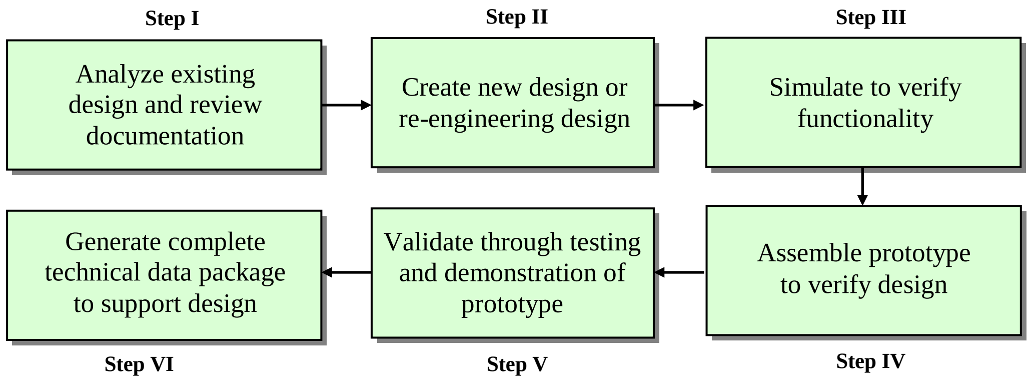

Figure 1. General procedures for retrofitting of machine.

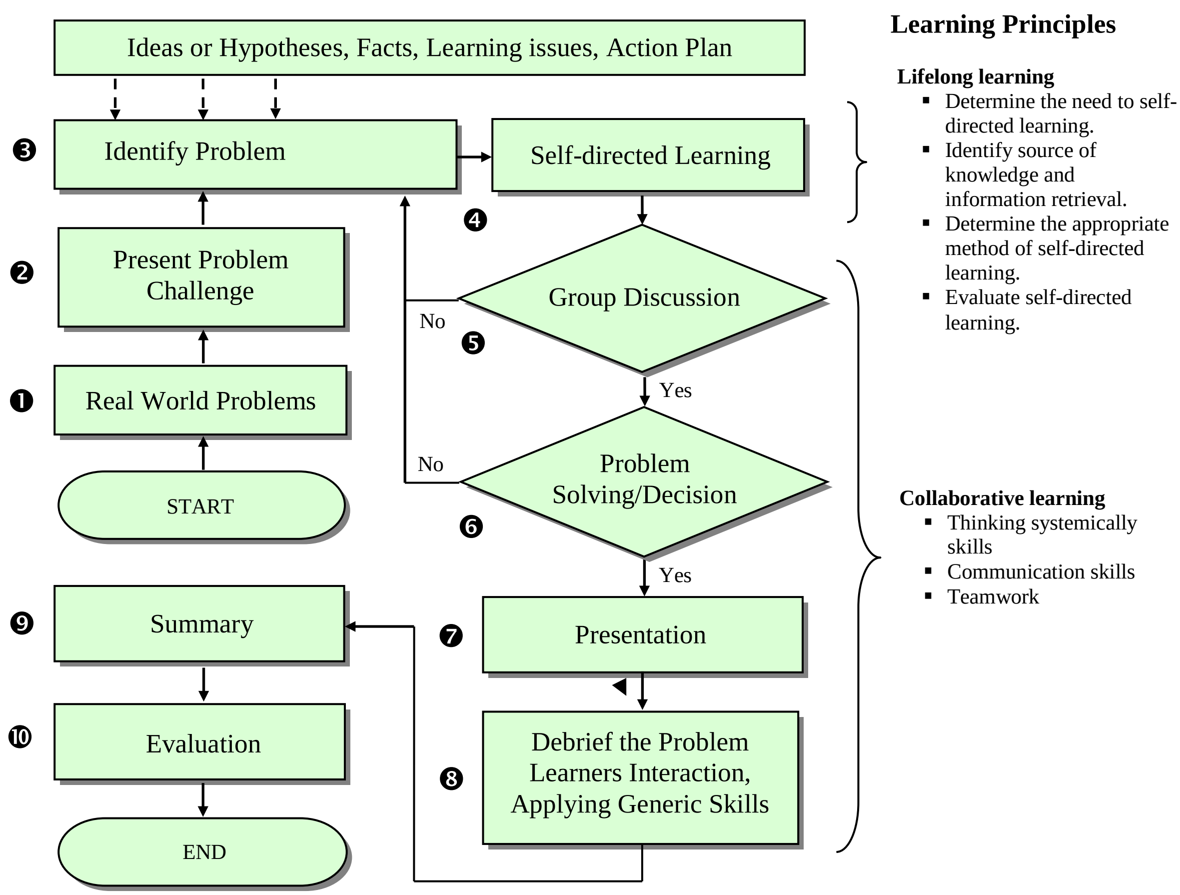

Figure 2. The problem-solving of the generic PBL model.

4 METHOD AND IMPLEMENTION

Because of the fact that, the teacher training in mechanical engineering department of KMUTNB has a memorandum of understanding (MOU) with the industry, and in this way the company offers an injection molding machine to be applied in the teaching and learning for mechatronics students. This machine is driven by hydraulic system and controlled by electrical relays. Such machine is in the old and frequent failures, thus is necessary to retrofit.

Applying the ROMBL is to take each step of retrofitting in questioning and assessment through the process of PBL. Then, it can be said that using procedure arranged as a systematic process can be used throughout the course. The implementation will be applied to the 20 third-year mechatronics students that enrolled PLC course and passed pneumatics and hydraulics (fluid power) course already. The main objectives of this course requires [18] the students to have knowledge, understanding and skills on the meaning, structures and components, functionality, language and programming, design and applications of PLC. Procedures in the implementation will take 16 weeks and 4 hours per week (1 semester). The flowchart of implementation is shown by Fig.3, that details will be discussed in the following order.

The first week, teacher will introduce the PLC such as the meaning, structures and components, and working principle to students. The second week, teacher will introduce the language and the programming of the PLC to students. Next week, teacher will brief on PBL process to students, as had been mentioned in Fig. 2, in the meantime, teacher will divide 20 students were split into 4 groups and each group have 5 members. The fourth week, teacher will present the key problems to students. The problematical injection molding machine that is controlled by the electrical relays is shown in Fig.4 and placed in the workshop of the department. Such machine is in the old and frequent failures, thus is necessary to retrofit. “*How would you replace the electrical relays with PLC to control the injection molding machine?*” Students will use problem-solving process of PBL, which has been discussed in section III. During the period from the fourth to fifteenth week is the implementation stage of the retrofitting of machine (6 steps) as the main approach in questioning and assessment in accordance with the process of PBL. Then, throughout the course, it is using process of PBL repeated 6 times according the steps of the retrofitting. Last week, a summary and evaluating of applying the ROMBL through PBL in PLC course, as well as inquiries the opinions of students on how this instructional approach.

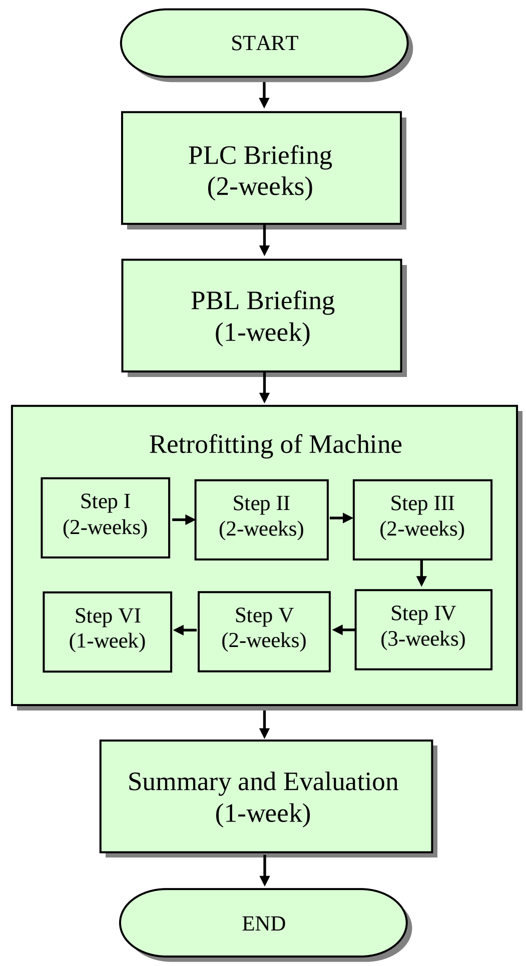

Figure 3. Step in the implement of the PLC course.

4.1 Step I: analyze existing design and review document

The teacher presents a problematical machine to students as shown in Fig. 4 “*What is this machine and how it works and designs?*” The objective of this step is analyzes existing design and reviews documentation. The problem-solving process of students is based on the PBL model. Fig. 5 shows the main components of the machine is a hydraulic system that are explored and investigated from real-machine and related documents by the students.

Figure 4. The machine that has been used in the ROMBL.

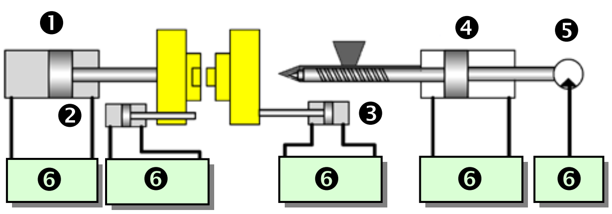

Figure 5. Main components of the machine.

4.2 Step II: create new design or re-engineering design

Problem presented in this step is "*How would you replace electrical relays with PLC to control the machine?*" The purpose of this step is creates new design or re-engineering design. Since the existing machine was driven by a hydraulic system and controlled by electrical relays, then it is essential that students need to be aware that there are a number of solenoid valves, limit switches, push button switches, and accessories. This is to be used in determining the number of input and output for the design of control by PLC to replace the old system. Results of student's explore and investigate found that will require 29 inputs and 14 outputs. In this stage, students have to design control with PLC.

4.3 Step III: simulate to verify functionality

Problem presented in this step is "*How would you know the machine functions that can be worked?*" The objective of this step is simulates to verify functionality. This step will be adopted conclusions drawn from steps I and II were used to simulate the working conditions of the hydraulic injection molding machine which is controlled by the PLC. The explore and investigate of students found that the basic injection molding process consists of: the raw material is fed into the machine, usually in the form of small pellets, it is then raised to a temperature whereby it will flow (plasticize) by a combination of thermal energy input and mechanical work, the plasticized material is then injected at high pressure into a two-part mold, the material is then allowed to cool and solidify, cooling is often the longest portion of the process cycle, when the part has solidified sufficiently the mold halves open and the part is ejected. Therefore in this step, the teacher will have to prepare the software for students to be applied in the simulation. Many of the software employed in the simulation such as FluidSIM hydraulics® and Automation Studio™. Fig.6 shows the example software used in the simulation. With these software, students can design and simulate the control of the hydraulic system with PLC. So at this stage, it is well-designed and simulated the functionality of the machine before actual assembly and installation.

4.4 Step IV: assemble prototype to verify design

Problem presented in this step is "*How would you know that your simulation program that you designed into a workable reality?*" The objective of this step is assembles prototype to verify design. After the conclusion of the simulation step III, this step will give all students groups helped to install the PLC to the control box and link accessories together. Why all groups of students helped install, because we have a single injection molding machine. In this step, the teacher will prepare PLC and accessories for the students to be handle.

4.5 Step V: validate through testing and demonstration of prototype

Problem presented in this step is "*How would you know that the machine is running according to function correctly?*" The purpose of this step is validates through testing and demonstration of prototype. This step provides students with the skills to explore and investigate the link between theory and reality of application of PLC. Fig.7 shows the testing and demonstration the functionality of the injection molding machine which is operated by the students, but such situation will be under the supervision of teacher and expert.

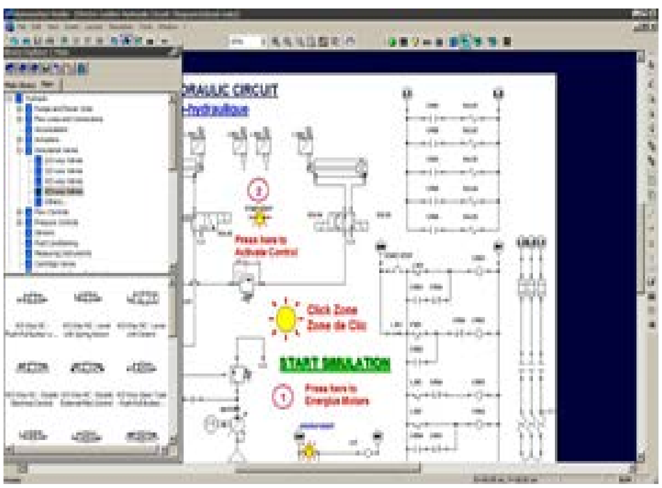

Figure 6. The example software for simulation.

Figure 7. Testing the functionality of the machine.

4.6 Step VI: generate complete technical data package to support design

After, the machine can operate functionality and achieve objective, the problem presented of the final step is "*How would engineers and others to use this machine?*" The purpose of this step is to provide students generate complete technical data package to support design. Such a step can be said that, this is a step of creating machines manual which has been retrofit already.

5 RESULTS AND DISCUSSION

5.1 Retrofitting of machine

Applying the retrofitting of machine through PBL will be divided into 6 steps is being discussed in the past. Each step will be to evaluate and make adjustments to prevent student disorientation and to achieve defined objectives. The results of retrofit show that the students can replace electrical relays controlled by a PLC has been successful. And important, machine that has been retrofitted to be audited and approved by assessment members of the faculty and experts [19], as shown in Fig.7 and 8.

5.2 Academic achievement

The entire process ended in the last weeks of the course. Subsequently, it is an assessment of students' knowledge with an examination of PLC, which is the same as that used on the previous academic year. If adopted, the average score of students who enroll in PLC course in the past academic year which uses traditional learning compared by t-test with an average score of students who use the ROMBL, the test results are shown in Table I.

As it can be seen in the Table I, when average scores of the ROMBL group and traditional learning group were compared, it was found that the arithmetic mean of the score taken by the ROMBL group was 42.65 and the traditional learning group was 32.90 It can be seen that there is a 4.33 point difference between group mean and p value is less than 0.05. This indicates that there is a significant difference at the 0.05 confidence interval between the two groups. Thus, the results of such a comparison shows that the ROMBL group higher academic achievement than traditional learning group.

Figure 8. Results from the testing of the machine.

5.3 Students responses

At the end of the course, a survey in the form of an anonymous questionnaire was circulated amongst all the students to answer on five-point scale ranging from 1 (strongly disagree) to 5 (strongly agree), they had achieved in their respective classes. The questions [20] and the average results agree of the response received, are shown in Fig. 9. We can see that the students have responded positively to all questions. Item with highest mean responses (4.25) is "*the ROMBL provides a good learning environment*". This means that students are satisfied to have learned through the process of the retrofitting of machine through the PBL. However, most students said that the limits of this study is to have a single machine used in the experiment.

Table 1. The results of the independent sample test.

Groups	**N**	$\overline{X}$ (means)	**Standard deviation**	**Standard error**	**t-test for Equality of Means**		
Retrofitting of machine based learning	20	42.65	7.65	1.71	df	t	p
Traditional learning	20	32.90	6.53	1.46	38	4.33	p<0.05

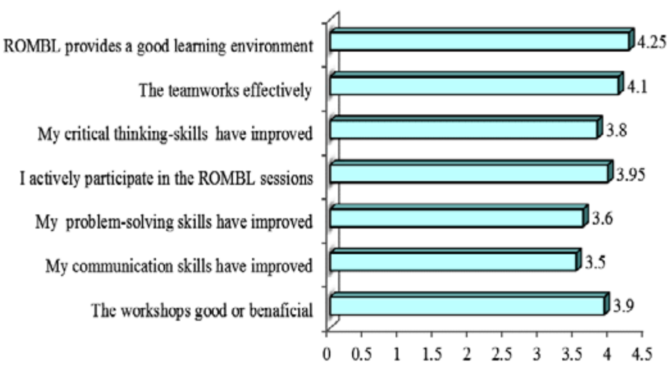

Figure 9. The student response on applying the ROMBL.

6 CONCLUSION

This paper presents the ROMBL, which study is adapt of retrofitting of machine as the main approach to the questioning and assessment. Namely, the retrofitting of machine that is divided into six steps and linked series as a story-problem to make them expedient to questioning and the assessment of PBL. Besides, such a step can be monitored and feedback before students learning disorientation. The implementation of ROMBL will be using with the 20 third-year mechatronics students that enrolled PLC course and passed fluid power course already. The results of implementation shows that the students can retrofit the hydraulic injection molding machine successfully and achieve defined objectives. In addition, the results of t-test comparison shows that the ROMBL group higher academic achievement than traditional learning group. This result accordance with the positive response to using retrofit of machinery based learning for students. Something tangible and create self-esteem for students in this applying the ROMBL is machine can be reused and stable than before the retrofitting, consistent with the results mentioned above. Then, this instructional approach is an alternative in preparing students on the according basis with the requirements of the industry**.**

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