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Application of multi-level integrated projects to meet the achievement of learning special skills in mechatronics vocational education

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Application of multi-level integrated projects to meet the achievement of learning special skills in mechatronics vocational education

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Abstract. One of the special skills learning outcomes in Mechatronics Study Program referring to fifth level of KKNI is being able to design, analyse, improve design performance, and realize the design parts in the maintenance and repair process, operation, and assembly of automation machines, with proper consideration of occupational safety, health and environmental issues. Fulfilling this learning outcome is not easy. This paper presents learning experiences in Mechatronics Study Program of Politeknik Mekatronika Sanata Dharma in an effort to fulfil it. The effort made is to carry out project-based learning in the form of workshop lectures, called "Mechatronics Workshop". These workshops held in second to fifth semester, and each project was an integration of all lecture material in that semester and before. The project results from workshop will be used in the next workshop, therefore the project is called a multilevel integrated project. Student assessments are determined by giving a checklist on the rubric of assessments, which include the ability to design, manufacture, operate, assemble, design improvement, and performance, in accordance with predetermined learning outcomes. Until now, the results of this workshop lecture have met the learning outcomes, and show high satisfaction scores, both from the perspective of teachers and students.

1. Introduction

Indonesian Qualification Framework (KKNI) is a framework for qualifying the qualifications of Indonesian human resources that matches, equalizes, and integrates the education sector with the training sector and work experience in a work skills recognition scheme adapted to structures in various employment sectors. The basic principle developed in KKNI is to assess a person's performance in scientific aspects, expertise and skills in accordance to the learning outcomes obtained through the process of education, training, or experience that has been exceeded, which is equivalent to qualification descriptors for a certain level [1].

Diploma-3 Mechatronics Study Program of Politeknik Mekatronika Sanata Dharma (PMSD) has implemented KKNI in its educational curriculum since 2017. In accordance with the Decree of the Minister of National Education RI No. 232/U/2000, regarding guidelines for the preparation of tertiary education curricula, qualification levels that must be possessed by graduates of Diploma-3 Study Program is at level 5 [2]. Achievement of special skill learning for the 5 levels of Mechatronics Study Program [3], are:

a. Able to apply mathematics, natural science, and engineering principles into technical procedures and practices to solve engineering problems in the field of mechatronics that are well defined;

b. Able to identify and solve engineering problems in the field of mechatronics that are well defined by using analysis of relevant data from codes, databases, and references as well as choosing methods by taking into account economic, health, public safety, and environmental factors;
c. Capable of designing, analyzing designs, and realizing parts of a well-defined mechatronic system design that meets specific needs with proper consideration of occupational safety and health issues and the environment;
d. Able to maintain a mechatronic system on an ongoing basis;
e. Able to test and measure mechatronic systems based on procedures and standards, and be able to analyze, interpret, and apply according to their designation;
f. Able to use and utilize modern technology in designing, realizing designs, and maintaining mechatronic systems.

All six achievements above are not easy to achieve. Adequate practice equipment is needed, qualified teaching staff, and long practice hours to support the above achievements. However, if these three things are difficult to fulfill, then the effort that can be done is to use innovative and challenging learning methods. As Kuzlyakina mentions, the process of organizing of the course design is important to form a comprehensive approach for solving engineering tasks for trainees [4]. One of them is to implement project-based learning, with projects that are designed in a systematic, gradual and integrated manner, as has been implemented in the Mechatronics Study Program, PMSD. The courses done in multi-level integrated projects methodology. Multi-level integrated projects means each project was an integration of all lecture material in that semester and before. The project results from workshop will be used in the next workshop, and the higher the level, the higher the task.

The purpose of this paper is to share learning experiences in the Diploma 3 Mechatronics Study Program, PMSD, in an effort to achieve the fulfillment of the learning outcomes of special skills in the field of Mechatronics and the results of their achievements.

2. Literatur Review

In recent years, project-based learning (PBL), has been widely applied in technical education, because it is considered quite effective [5]. Project-based learning becomes the preferred learning method especially in learning that involves several fields of science, such as mechatronics [6]. Project-based learning provides opportunities for students, teachers, and community members to collaborate with each other to investigate questions and ideas. Project-based learning also builds student confidence and allows them to think, develop and design new ideas and approaches through their teamwork [7].

Project-based learning transforms traditional approaches, which are teacher-centered, and based on knowledge, into contextual, student-centered, and based on complex understanding of technological knowledge. An innovative concept in project-based learning is to shift from teaching to learning, the task of the instructor is no longer transferring knowledge, but facilitating the learning process of the students [8].

Project-based learning also needs to be applied in laboratory practices. As is known, that practical or technical skills are one of the important skills in the engineering sector. Practical skills require "hands-on practice" as a key to understanding and solving some unpredictable real-world problems. This direct practice can only be done if laboratory equipment is available. However, some practices in the laboratory are stuck in experimental procedures. Students just follow the procedure and finish with a little knowledge of what is being done. With the application of project-based learning, making practice in the laboratory a focus on learning, improving practical skills and student participation in a team [9].

From the advantages of project-based learning above, making the application of project-based learning becomes necessary. Project-based learning that is planned in a systematic, integrated and sustainable manner from one level to the next, has been shown to produce better learning [5].

3. Method

3.1. Curriculum structure

Curriculum which refers to KKNI is realized in the learning outcomes of study programs. Learning outcomes is the internalization and accumulation of knowledge, skills and attitudes. Since 2017, Mechatronics Study Program, PMSD, was implemented the curriculum structure that is refers to KKNI as shown in Figure 1.

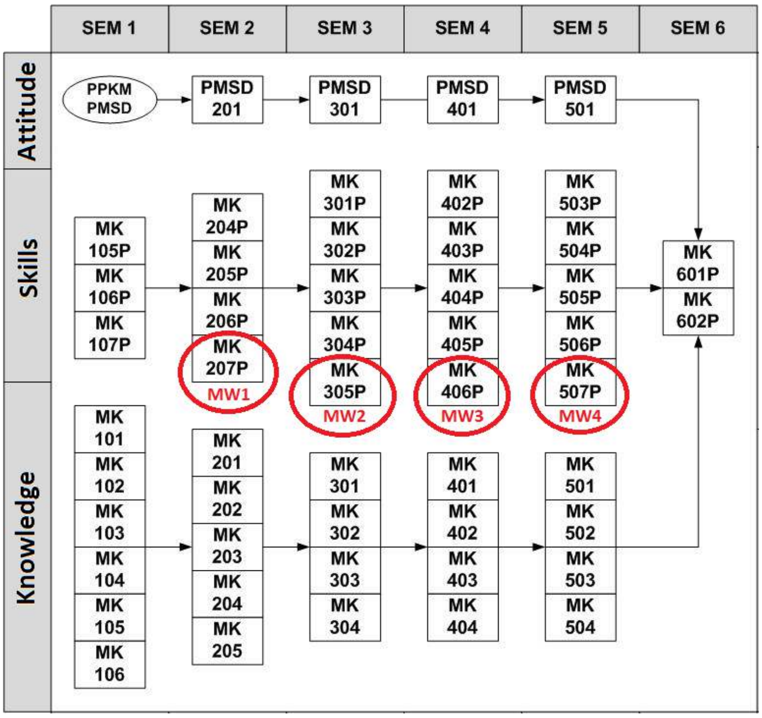


Figure 1. Curriculum structure of Mechatronics PMSD.

The course that uses the PBL method is the Mechatronics Workshop. This course is carried out in four levels, namely Mechatronics Workshop 1 to 4. The project results from the workshop will be used in the next workshop, therefore the project is called a "multilevel integrated project". Table 1 shows the distribution of Mechatronics Workshop 1 to 4 courses, with courses directly related to each level of workshop.

Table 1. Distribution of Mechatronics Workshop courses.

Semester	Workshop	Related Courses
2	Mechatronics Workshop 1 (MK207P)	Basic Mechanics (MK105P) Electronics 1 (MK106P) Mechanical Drawing (MK107P) Basic Computer (MK205P)
3	Mechatronics Workshop 2 (MK307P)	Electronics 2 (MK204P) Electrical Drawing (MK206P) Sensor (MK301P) Digital Systems (MK302P)
4	Mechatronics Workshop 3 (MK407P)	Control (MK304P) Microcontroller (MK402P)

		Electric Motor (MK403P) PLC (MK404P) Interface (MK405P)
5	Mechatronics Workshop 4 (MK507P)	Data Communication (MK504P) Mechatronics Application (MK505P) Computer Programming (MK506P)

3.2. PBL Implementations
To guarantee that the Mechatronics Workshop course can be carried out properly, the project should:

a. Be a real engineering problem;
b. Include mechatronics elements, i.e. mechanical, electronics/electrics, control, and software programming;
c. The project result from workshop will be used in the next workshop (sequence);
d. Done in student groups with 5-6 members;
e. Each group is guided by a project supervisor;
f. Course per-week: 2 credit/5 hours
g. Assessment criteria: knowledge, skill, and attitude;
h. Assessment points: work process, machine results, presentations, reports, personal reflection.

3.3. The project
The distribution of project material that is done are:

a. Mechatronics Workshop 1
Focus in mechanical system. The task is to build a belt conveyor with specific dimension. The work starts with the design of 2D and 3D images, machining, and assembling to produce a functioning belt conveyor.
b. Mechatronics Workshop 2
Focus in electronic system. The task is adding electronic circuit to move the conveyor. Students are asked to make 2 sensors and motor drivers to move the belt conveyor so that they can go forward and backward.
c. Mechatronics Workshop 3
Focus in control system. The task is adding a PID control to adjust the conveyor's movements according to the pattern. Students are asked to develop PID program in microcontroller to adjust the conveyor's movements.
d. Mechatronics Workshop 4
Focus in data communication. The task is adding HMI and data communication between conveyors. Students are asked to add HMI component to control and monitor the conveyor, and establish communication between the 2 conveyors.

4. Project examples and evaluation

4.1. Project examples
This section describes four PBL examples implemented in Mechatronics Workshop course.

a. Mechatronics Workshop 1

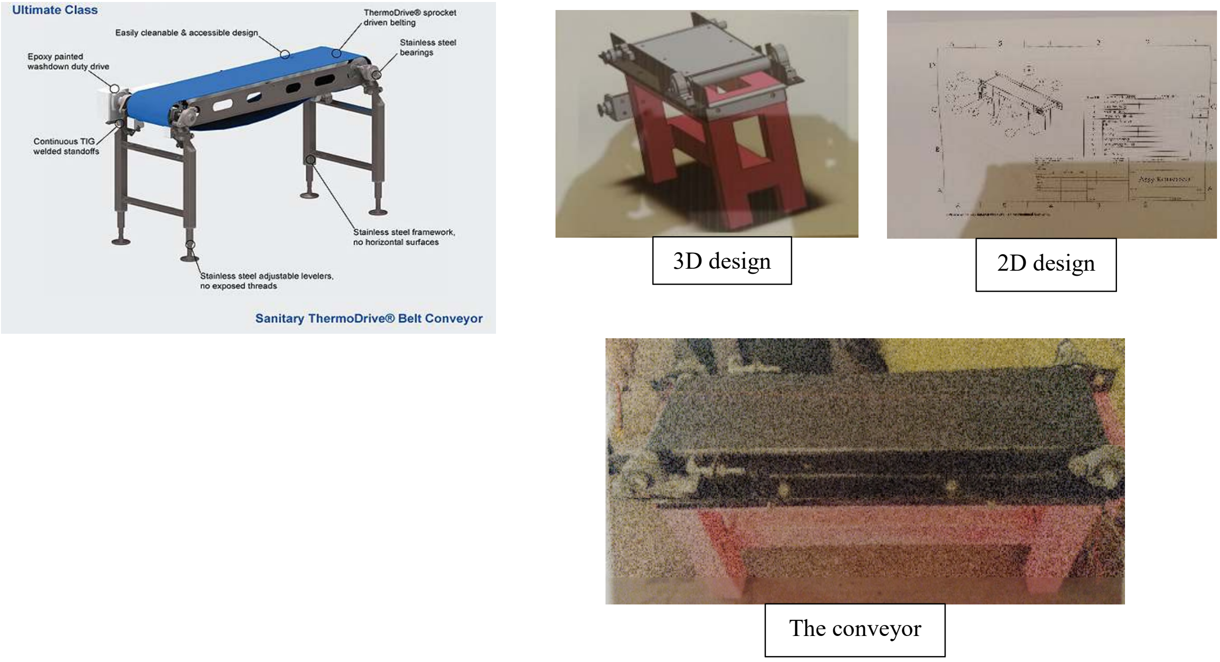


Figure 2. Example of Mechatronics Workshop 1.

b. Mechatronics Workshop 2

The task:

- Making two sensors
- Making motor driver

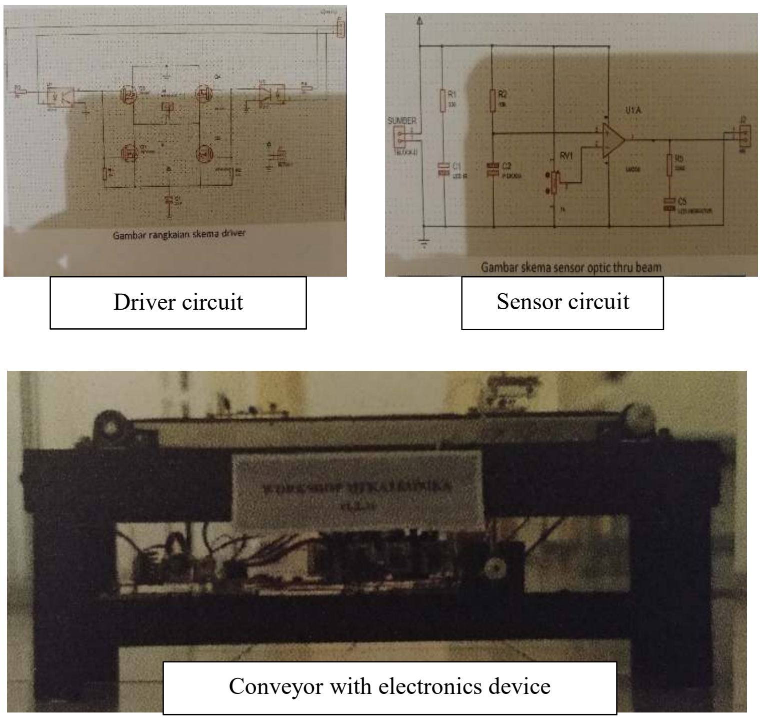
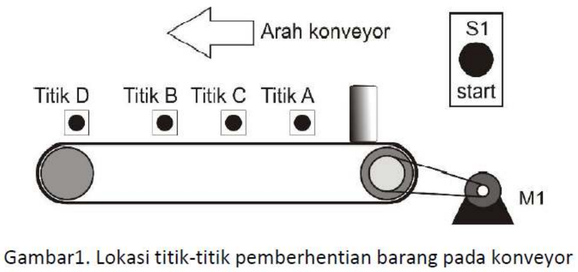


Figure 3. Example of Mechatronics Workshop 2.

c. Mechatronics Workshop 3



The task

Presentation of the student groups

Figure 4. Example of Mechatronics Workshop 3.

d. Mechatronics Workshop 4

The task:
- Adding HMI
- Communication between conveyors

Figure 5. Example of Mechatronics Workshop 4.

4.2. Project evaluation

In the first batch of Mechatronics Workshop lectures, 8 belt conveyors were produced which described the mechatronic system, which was an integration of mechanical, electrical/electronic, control and software. With the multilevel integrated project method, each group of students tries to complete the project in a structured and continuous way. Results from the beginning will be used again for further projects. With the method of each group to always improve the quality of the machine they make, if the results of the previous project are felt to be less good. This is done in order to be able to fulfill further project orders.

The assessment of this project through the process of making, demo machine, presentations and discussions, as well as report documentation. During the developing process, each group is required to consult and submit project progress every week to the project supervisor. At the end of the semester, the project results will be assessed by an assessment team of faculty members.

5. Result

In the end of this course, each student write a personal reflection to obtain the feedbacks from them. Here are excerpts from most of students:

- Gain very interesting new experiences related to this learning model.
- Increased knowledge and skills in mechanics, electronics/electricity, and programming algorithms.
- Soft skills improvement, such as cooperation, project management, discipline, and creativity.
- Group coordination is difficult because group members are not from the same class so they have different class schedules.
- Consultation schedule with the supervisor is sometimes inconsistent because there is not a daily lecture schedule.

Although most of the comments were positive, there were still some challenge to the implementation of this lecture. This is a challenge for study programs to be able to improve this learning model.

All the faculty members also gain a good experience with this multilevel integrated project method. Lecturer also have to improve their knowledge and skill in all elements of mechatronics system, not only their specialist field.

6. Conclusion

To fulfill the learning outcomes of special skills in the mechatronics fields, which involves at least 3 subsystems, i.e. mechanics, electronics/electrics, and control, it takes a learning process that can integrate all these fields in one lecture package. Lectures in the form of multilevel integrated projects become an example of a solution to meet these learning outcomes. This multilevel integrated project has been designed with targets tailored to the level of student ability. The results of implementing this multilevel integrated project are not only felt by students as participants, but also from the lecturer side, where the learning process becomes more targeted and indicators of competency targets are more easily assessed.

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