

## **Development of a STEM-PjBL Teaching and Learning Process Using the Engineering Design Process (EDP) in a Project-Based Course for Grade 11 Students in the KOSEN-KMUTT Program**

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### **Abstract**

This study aimed to develop an instructional model for the “Project” course offered to Grade 11 students in the Automation Engineering program at KOSEN KMUTT. The model integrates STEM-PjBL (Science, Technology, Engineering, and Mathematics – Project-Based Learning) with the Engineering Design Process (EDP) to establish connections between steps of the EDP and disciplinary knowledge. Through this approach, students apply STEM knowledge in Problem Definition, Data Analysis, Design, Construction, Experimentation, and Refinement. The research was first implemented with the 3<sup>rd</sup> cohort of the program, during which data were collected using questionnaires and interviews. The findings identified three major challenges: (1) project topics were too narrowly defined, limiting access to relevant information; (2) the application of classroom knowledge to project work was limited, and (3) teacher support was inadequate. Consequently, student satisfaction was rated at a moderate to good level. Based on these findings, the instructional model was revised for the 4<sup>th</sup> cohort of the program in the following year. Key modifications included: (1) adapting project topics to align more closely with students' real-life contexts, (2) aligning the teaching of prerequisite content with the project timeline, and (3) providing increased teacher support through consultation and technical guidance. The revised model resulted in significantly higher levels of student satisfaction, particularly in project process management, with ratings improving to “good” and “very good.” Overall, the study demonstrates that integrating STEM-PjBL with the EDP effectively enhances teaching and learning in the “Project” course and provides a practical framework for improving project-based education in engineering contexts.

*Keywords:* STEM-PjBL, engineering design process, project-based learning, KOSEN, engineering education

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## Introduction

Engineering Science College, in collaboration with the KOSEN Institute of Japan, has developed the KOSEN KMUTT curriculum with the objective of cultivating engineers and innovators who are socially responsible and capable of addressing real-world problems. This vision aligns with the KOSEN mission of producing “Social Doctors,” individuals who contribute to societal development through problem solving and innovation. Accordingly, the curriculum emphasizes deep learning through interdisciplinary integration, combining science, mathematics, languages, social studies, and engineering. This approach enables students to connect and apply knowledge systematically in both daily life and engineering contexts.

Within this curriculum, The Project course in the KOSEN Automation Engineering program is designed to integrate knowledge from multiple disciplines. Teaching and learning are jointly delivered by experts and instructors from both Thailand and Japan under the STEM-PjBL (Science, Technology, Engineering, and Mathematics – Project-Based Learning) approach, which emphasizes hands-on learning to develop higher-order thinking skills (HOTS), using the Engineering Design Process (EDP) as the operational framework (Harun, 2020; Kelley & Knowles, 2016; Lin et al., 2021). At each year level, students undertake projects of progressively increasing complexity and integrate knowledge gained across levels to solve problems systematically.

The STEM-PjBL learning management approach integrates STEM Education (Science, Technology, Engineering, and Mathematics)—which combines knowledge content from multiple disciplines—with Project-Based Learning (PjBL), a learning model in which learners actively solve problems derived from real-life contexts (authentic problems) in order to develop knowledge, understanding, and a range of skills in a holistic manner (Afriana & Fitriani, 2016; William, 2019). This instructional framework aims to promote analytical thinking, problem-solving, and the application of knowledge through the Engineering Design Process (EDP). EDP functions as a tool for systematically structuring the sequence of learning steps, allowing learners to practice engineering thinking in order to develop, create, or improve inventions, devices, or systems to meet real-world needs. The EDP consists of clear yet flexible stages and allows learners to return to earlier steps at any point in the process, providing opportunities to refine and enhance solutions for greater effectiveness.

This research adopted STEM-PjBL integrated with the Engineering Design Process (EDP) as the core model to develop an instructional approach for the “Project” course for Grade 11 students in the Automation Engineering program, KOSEN KMUTT (Cohorts 3 and 4). The goal was to design a learning process that supports integrating knowledge from multiple disciplines to solve authentic engineering problems (Husin et al., 2025; Roudhotul et al., 2023)—such as mechanics, technical drawing, programming, and electronic circuit design—which students then apply to develop their projects through the EDP. The EDP consists of five main stages: Define (problem analysis), Design, Fabrication (building), Experiment (testing and improvement), and Presentation. If the prototype does not meet the intended goals, students can enter a Redesign stage to refine the solution in a flexible and systematic manner (Kelley & Knowles, 2016; Lin et al., 2021).

To achieve the objectives of this study, the researcher implemented the “Project” course by applying STEM-PjBL together with the Engineering Design Process (EDP), designed to align with the interests and capabilities of KOSEN KMUTT Cohort 3 students. Data were collected using a researcher-developed instrument, namely a course satisfaction questionnaire, to gather

students' feedback and suggestions regarding the instructional model. The results were used to improve the teaching model for Cohort 4, after which the revised model was evaluated again to ensure it was appropriate and effective for learners in the KOSEN KMUTT context. In addition, the study aims for the developed learning model to enhance students' potential—especially engineering analytical thinking, systematic problem-solving ability, and effective teamwork.

### **Research Objectives**

The objectives of this study were as follows:

1. To evaluate student satisfaction with the STEM-PjBL instructional process using EDP among KOSEN KMUTT Cohort 4 students.
2. To refine the STEM-PjBL-EDP instructional model based on feedback from Cohort 4 and implement it with Cohort 5 students.
3. To evaluate student satisfaction with the revised instructional model among KOSEN KMUTT Cohort 5 students.

### **Literature Review**

This section presents a review of the literature on STEM, PjBL, and EDP as follows.

#### **1. STEM Education**

STEM education is an instructional approach that emphasizes the integration of knowledge in science, technology, engineering, and mathematics, enabling learners to apply knowledge from multiple disciplines to solve problems in real-world contexts. This type of learning focuses on hands-on practice, analytical thinking, and cross-disciplinary connections rather than learning in separated subject areas (Kelley & Knowles, 2016).

Research by Aguilera and Ortiz-Revilla (2021) shows that STEM education plays an important role in developing learners' creativity and problem-solving ability, especially when learning is designed to connect with authentic situations and societal challenges. At the same time, the OECD (2025) emphasizes that education in the 21st century must focus on developing analytical thinking, problem-solving, and collaboration—core competencies that STEM education can effectively support.

#### **2. Project-Based Learning (PjBL)**

Project-Based Learning (PjBL) is an instructional approach in which learners play a central role by learning through projects. It begins with meaningful problems or driving questions, followed by planning, research, experimentation, and the creation of artifacts or products to address the problem. This approach promotes active learning and helps learners effectively connect knowledge with real practice (William, 2019).

In addition, research indicates that PjBL strongly supports problem-solving skills and teamwork because learners must work in groups, share responsibilities, and communicate and exchange ideas throughout the project process. This contributes to the development of social skills and collaborative learning (Harun, 2020; Husin et al., 2025).

### **3. Engineering Design Process (EDP)**

The Engineering Design Process (EDP) is a systematic process used to solve engineering problems. It consists of clear, repeatable steps that guide learners' thinking from defining the problem, designing ideas, building prototypes, testing and evaluating, to communicating results (Lin et al., 2021).

Using EDP in learning contexts promotes design thinking and decision-making based on data and reasoning, which aligns with the goal of developing 21st-century problem-solving skills (Kelley & Knowles, 2016). Moreover, Husin et al. (2025) note that EDP can serve as a key structure linking learners' thinking processes with hands-on practice in engineering contexts.

### **4. STEM Project-Based Learning Integrated With EDP**

Integrating STEM education with Project-Based Learning and the Engineering Design Process (STEM-PjBL with EDP) is an instructional approach that combines the strengths of each concept. It uses projects as the foundation for learning and uses EDP as the primary structure for learning activities. This approach enables learners to apply knowledge from multiple disciplines to solve complex engineering problems in authentic contexts (Kelley & Knowles, 2016).

Lin et al. (2021) report that using EDP as the core of STEM-PjBL significantly enhances learners' engineering thinking and problem-solving skills. Similarly, Roudhotul et al. (2023) and Rochim et al. (2021) found that STEM-PjBL can improve academic achievement and support the application of knowledge in real situations, particularly when learners collaborate to design and develop engineering-based outcomes.

## **Research Methodology**

### **Research Design**

This study employed classroom action research using a pre-experimental one-shot case study design. The research followed the PDCA cycle—Plan, Do, Check, and Act. The first implementation was conducted with Grade 11 Cohort 4 students during the 2023 academic year, and the revised model was implemented with Cohort 5 students in 2024.

### **Participants**

The participants consisted of:

- 46 students from Grade 11 Cohort 4
- 33 students from Grade 11 Cohort 5

All participants were enrolled in the Automation Engineering program at KOSEN KMUTT.

### **Research Instruments**

#### ***1. STEM-PjBL-EDP Lesson Plans***

The learning management consists of a learning framework, the instructional process, and the body of knowledge used for project work, as detailed below.

### 1.1) *Project-Based Learning (PjBL) Framework*

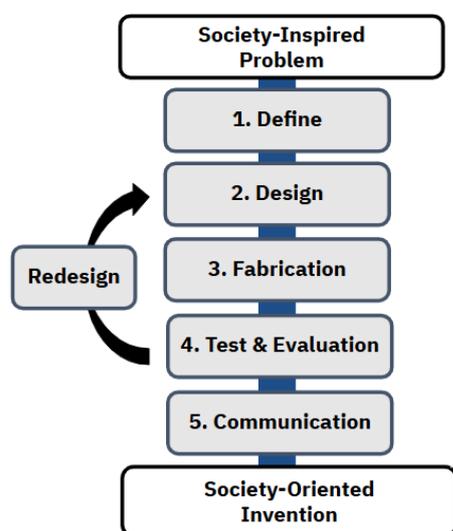
PjBL is a learning approach in which students actively work to solve problems based on real-life contexts (authentic problems) in order to develop knowledge, understanding, and various skills in a holistic manner. This learning framework aims to promote analytical thinking and problem-solving skill (Afriana & Fitriani, 2016; Harun, 2020; William, 2019).

### 1.2) *Engineering Design Process (EDP) Framework*

This serves as the process or set of steps for carrying out the work, organizing problem-solving in a logical and systematic sequence, as shown in Figure 1. The EDP includes the following steps: Define (interpreting the problem), where students are provided with a context or situation, identify the problem from the given scenario, and conduct research; Design; Fabrication (building the prototype/product); Test & Evaluation (testing and evaluating results); and Communication. This engineering design process helps students systematically transform abstract ideas into concrete outcomes (Kelley & Knowles, 2016; Lin et al., 2021).

**Figure 1**

*The Learning Management Based on the Engineering Design Process (EDP)*



### 1.3) *STEM Education Framework*

STEM Education is an interdisciplinary knowledge base (Science, Technology, Engineering, and Mathematics) that students must apply to solve problems following the steps of the EDP within a PjBL project (Kelley & Knowles, 2016; OECD, 2025).

## 2. *Duration*

The *Project* course was offered for 1 credit per semester, with two hours of instruction per week over 16 weeks, totaling 32 instructional hours.

## 3. *Data Collection*

A student satisfaction questionnaire was used to evaluate learning activities based on the STEM-PBL-EDP approach. The questionnaire items were aligned with the learning outcomes

(LOs). Responses were rated using a 5-point Likert scale, where 5 = highest, 4 = high, 3 = moderate, 2 = low, and 1 = lowest. Students were also asked to provide comments and suggestions.

#### **4. Data Analysis**

Statistical analysis was conducted by calculating the mean and standard deviation, and by analyzing students' comments and suggestions.

### **Results and Discussion**

This study is a research-and-development project focusing on improving the learning management process in the Project course. The key points of the implementation, following the PDCA research process, are summarized as follows.

Plan: Clearly defining the Course Learning Outcomes (CLOs) for the Project course is a crucial step because it sets the direction of instruction. The course has three main learning outcomes:

- CLO1: Propose a problem-solving approach in the form of an invention that aligns with the needs of, or is of interest to, a specified target group.
- CLO2: Design and construct a prototype/product or invention to meet the needs of, or match the interests of, a specified target group.
- CLO3: Prepare a report and present the work through an oral presentation and a poster presentation.

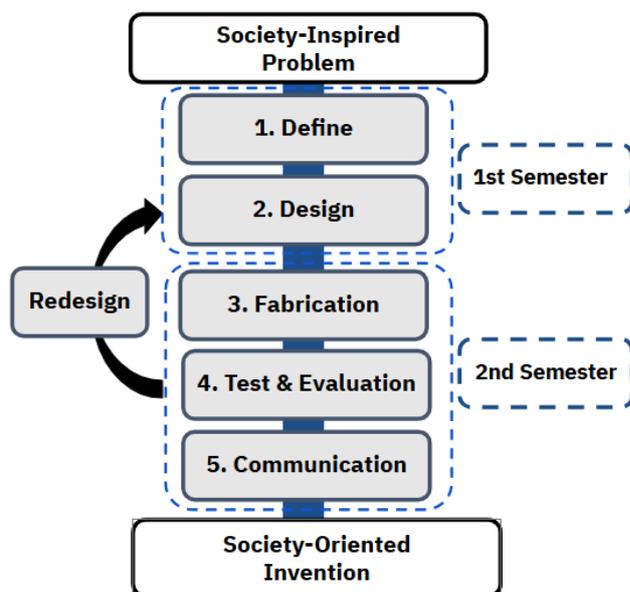
In addition, defining a problem context that aligns with CLO1 is important. During the problem-identification stage, learners must study the context and define the problem by themselves, then brainstorm and propose effective solutions. This ensures that projects do not focus only on technical problem-solving but also respond to societal needs and consider different social constraints across contexts (Afriana & Fitriani, 2016; OECD, 2025; William, 2019). For this reason, the Project course for Cohort 4 selected historical contexts, particularly The Age of Discovery, as the basis for project development because:

1. Historical contexts provide clear technical and social details that have been systematically compiled by historians, reducing the time and resources needed for additional exploration or experimentation.
2. Problems in the past are often less complex than modern problems, due to the limitations of knowledge at the time. This makes them suitable for students who are still building foundational knowledge in science and mathematics, while also allowing solutions that are not restricted to a single specialized discipline (Rotherham & Willingham, 2010).
3. Studying past contexts—developed under social and technological conditions different from those of today—helps students understand social changes driven by technological development. It also gives students an opportunity to recognize the importance of technologies that may not have been clearly visible in the past but were later extended and evolved into technologies used in the modern era.

The Engineering Design Process (EDP) used as the instructional sequence is divided into two phases by semester. In Semester 1, the focus is on helping students interpret the problem, identify solution approaches, and design the artifact. In Semester 2, the focus shifts to building the artifact, conducting experiments and summarizing experimental results, and communicating outcomes through presentations, as illustrated in Figure 2.

**Figure 2**

*Dividing the Learning Management According to the Engineering Design Process (EDP)*



Do: The teaching and learning activities were organized according to the EDP stages as follows:

### Step 1: Define

1.1) For Grade 11 students (Cohort 3), the project context was The Age of Discovery. Students conducted research and categorized problems and needs into three themes: Ships, Navigation, and Life of Seamen. They then selected a theme of interest and used a fishbone diagram to break down contributing factors and identify the root cause, leading to a focused problem of interest. This stage is referred to as **Problem Statement (problem identification)**.

1.2) Students brainstormed within their groups and selected 3–4 possible approaches. This stage is referred to as **Ideate Solutions (proposing solutions)**.

1.3) Students used various tools to narrow down to one final approach, considering factors such as originality and effectiveness in solving the problem. This stage is referred to as **Choose Solutions (selecting a solution)**.

### Step 2: Design

Students developed designs by integrating knowledge from three areas:

1. Hardware Design — designing mechanical structures and components
2. Software Design — writing programs to control system operation
3. Electronic Design — connecting sensors and motors and designing electrical circuits

Students also built a prototype using readily available materials (e.g., cardboard, straws, plastic sheets) to support understanding. They presented their ideas to classmates and the instructor during class in a **Conceptual Sharing** session, enabling them to improve the design based on feedback before proceeding to build the actual artifact.

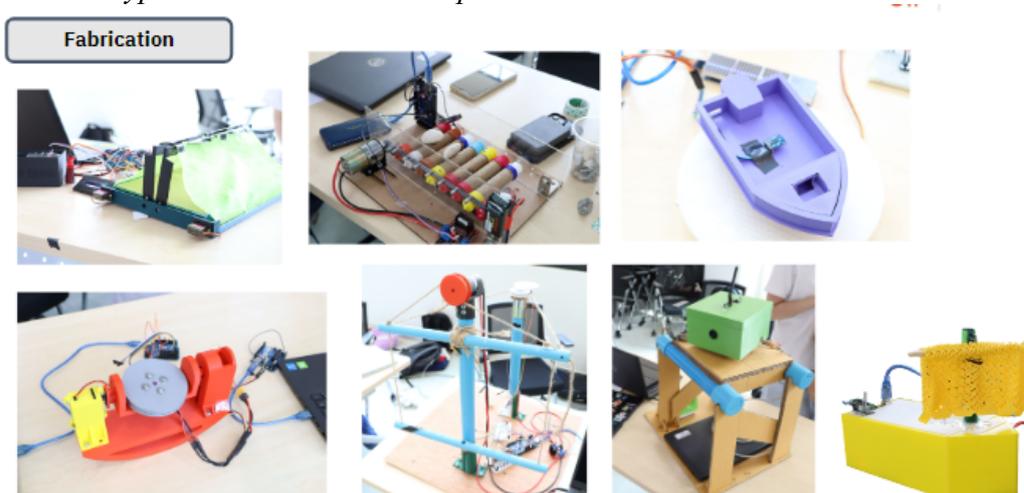
**Figure 3**  
*Prototype*



Step 3: Fabrication

After students have finalized all details and revisions, they prepare a list of the materials and equipment to be used in the **fabrication** stage of building the invention.

**Figure 4**  
*The Prototype Used in the Actual Experiment*



An example project that demonstrates the integration of all three knowledge domains is “A Wind Direction Detection Device for Navigation in the Age of Discovery.” In this project, students designed a rotating mechanism (hardware), programmed an Arduino controller (software), and connected a circuit consisting of a wind sensor and a motor (electronics) to display results in real time. This process provided students with opportunities to apply knowledge from multiple courses and develop truly interdisciplinary, in-depth understanding.

Step 4: Test & Evaluation

Students designed experiments (experimental design) to measure usability or performance of the artifact. They then conducted discussion and summarized the experimental results.

## Step 5: Communication

Students presented their work in two formats: Oral Presentation and Exhibition.

### Figure 5

*Oral Presentation and Poster Presentation*



Check: To evaluate outcomes, a post-course student satisfaction questionnaire was administered using a 5-point Likert scale. The questionnaire items aligned with the learning outcomes (LOs) shown in Table 1. The average student ratings were as follows:

**Table 1**

*Student Satisfaction Evaluation of STEM-PBL-EDP Learning Activities (Academic Year 2023)*

EDP Process	Detail	Average $\pm$ SD
Define	Problem Identification	3.54 $\pm$ 1.12
	Solution Proposal & Selection	3.57 $\pm$ 1.21
Design	Prototype & Concept Sharing	3.54 $\pm$ 1.12
Fabrication	STEM Integration & Fabrication	3.65 $\pm$ 1.08
Test & Evaluation	Experimental Design	3.35 $\pm$ 1.51
Communication	Presentation	3.82 $\pm$ 1.00

*Note.* 28 students completed the evaluation out of a total of 46 students.

Overall, Grade 11 students in Cohort 4 reported satisfaction at a moderate to good level (3.35–3.82). Students' feedback on the learning management can be grouped into three points:

1. The project topic was too narrow.
2. There was insufficient application of knowledge.
3. There was a need for more teacher consultation/advising.

Act: Based on the analysis of issues found in Cohort 4 (Academic Year 2023), the process was improved for Cohort 5 (Academic Year 2024). The results showed that students' satisfaction

increased to the highest level in every category, with average scores ranging from 4.38–4.56, as shown in Table 2. This is notably higher than Academic Year 2023 (3.35–3.82).

**Table 2**

*Student Satisfaction Evaluation of STEM-PBL-EDP Learning Activities (Academic Year 2024)*

EDP Process	Detail	Average $\pm$ SD
Define	Problem Identification	4.45 $\pm$ 0.06
	Solution Proposal & Selection	4.51 $\pm$ 0.61
Design	Prototype & Concept Sharing	4.47 $\pm$ 0.73
Fabrication	STEM Integration & Fabrication	4.38 $\pm$ 0.84
Test & Evaluation	Experimental Design	4.56 $\pm$ 0.61
Communication	Presentation	4.56 $\pm$ 0.54

The improvements can be summarized in three areas:

1) Improving the project context for more meaningful learning

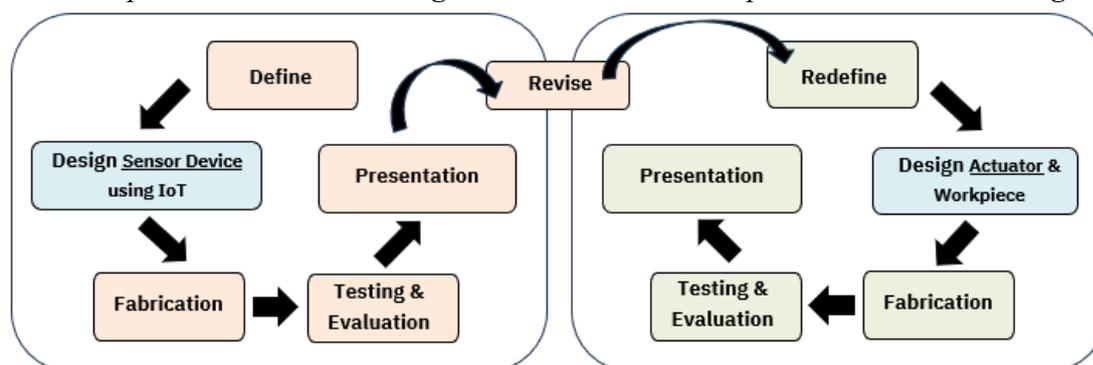
The context was changed from “The Age of Discovery” to “Dormitory Life,” which is closer to students’ real experience. This enabled students to identify problems through actual observation and user interviews (e.g., peers and teachers). As a result, the innovations created—such as a washing machine notification system and an automatic waste-sorting system—became more realistic and more responsive to societal needs. This aligns with the clearly increased satisfaction scores in the Define and Design stages (Table 2).

2) Revising the EDP instruction into a 2-loop structure

For Cohort 5 (Academic Year 2024), the instructional process was redesigned (Figure 6) into two loops: Loop 1 (Sensor) served as a foundational knowledge base that fed into Loop 2 (Actuator). This helped reduce confusion caused by receiving too much information at once, making the learning sequence more continuous and easier to understand. Consequently, satisfaction in Fabrication and Test & Evaluation improved to a very high level (Table 2).

**Figure 6**

*EDP Loop 1 Focuses on Teaching Sensors, and EDP Loop 2 Focuses on Teaching Actuators*



### 3) Strengthening the teacher's role as an advisor

To respond to students' need for more guidance, a more systematic consultation structure was added, including four advising sessions scheduled before major assessment periods throughout the academic year. This close support helped students overcome technical obstacles and maintain better continuity in project work.

## Conclusion

The evaluation in Cohort 4 showed student satisfaction at a moderate to good level, with key challenges including overly narrow project topics, limited application of knowledge, and insufficient teacher support. The researcher therefore improved the process for Cohort 5 by shifting the project context to "Dormitory Life" to make it more relevant to learners, restructuring EDP instruction into a 2-loop model by separating sensors in Semester 1 and actuators in Semester 2 to reduce complexity, and adding a clearer consultation system. As a result, Cohort 5 students' satisfaction increased to the highest level across all stages.

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## Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

The author declares that ChatGPT, an AI-assisted technologies software, was used in translating, proofreading and refining the language used in the manuscript. The usage was limited to correcting grammatical and spelling errors and rephrasing statements for accuracy and clarity. The author further declares that, apart from ChatGPT, no other AI or AI-assisted technologies have been used to generate content in writing the manuscript. The ideas, design, procedures, findings, analyses, and discussion are originally written and derived from careful and systematic conduct of the research.

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