Developing Problem-Solving and Collaboration Skills of Grade 11 Students Through STEM-PjBL Using the Engineering Design Process (EDP): A Case Study of the KOSEN-KMUTT Program

Jutharat Sunprasert, King Mongkut's University of Technology Thonburi, Thailand
Natthaporn Srichaikham, King Mongkut's University of Technology Thonburi, Thailand
Tas Yusoontorn, King Mongkut's University of Technology Thonburi, Thailand
Shinichiro Mito, King Mongkut's University of Technology Thonburi, Thailand

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Abstract

Problem-solving and collaborative skills are key components of Learning and Innovation Skills essential for 21st-century careers. These skills enable learners to think analytically and systematically, coordinate tasks, and cooperate effectively in developing solutions to achieve goals. This study aims to develop the problem-solving and collaborative skills of Grade 11 students in the KOSEN program at KMUTT through the Project Work course by integrating the Engineering Design Process (EDP): Define, Design, Fabrication, Experiment, and Presentation. The study was conducted with 32 students, using a free-response problem-solving test and a collaboration satisfaction survey administered before and after the implementation of the learning model, which encouraged teamwork through brainstorming solutions, dividing responsibilities for creating a workpiece, and presenting the group work. The research results found that (1) the scores on the problem-solving test after learning were significantly higher than before learning at the .05 level, and (2) students rated their collaboration experiences as "good" to "very good," though challenges remained in allocating tasks and responsibilities within groups. Overall, the findings demonstrate that integrating STEM-PjBL with EDP effectively enhances students' problem-solving ability and promotes collaborative learning experiences.

Keywords: STEM project-based learning, engineering design process, problem-solving skills and collaborative skills

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Introduction

In an era of rapid change in technology, the economy, and society, preparing learners to cope with these changes requires an emphasis on developing creativity, analytical thinking, problem-solving, collaboration, and technological literacy—key skills for the 21st century (OECD, 2025; Rotherham & Willingham, 2010). These skills not only help learners solve complex real-world problems, but also promote teamwork and experiential learning, enabling them to apply knowledge effectively in future work (Evans, 2020).

Building collaborative networks with countries that possess globally recognized expertise and capacity is another approach to economic development and the creation of a high-quality workforce. Therefore, the Thai government has established cooperation programs with several leading countries, especially Japan—a leader in advanced technology—to develop human resources in science, technology, and innovation. These efforts aim to support economic growth in the Eastern Economic Corridor (EEC) and to develop a workforce aligned with the needs of Thai industry, representing an important investment in the future.

One major cooperation initiative of this kind is the KOSEN-KMUTT program, a collaboration between Thailand and Japan. It focuses on developing students' real-world problem-solving abilities, particularly in engineering and innovation, by emphasizing problem-solving skills and collaborative skills—core competencies necessary for learners to prepare for work in a rapidly changing world. As such, this program plays an important role in preparing learners to meet future challenges and in developing a high-quality workforce that can help drive Thailand's development on a global level (Evans, 2020; Husin et al., 2025).

Regarding teaching and learning management in KOSEN-KMUTT—especially in the Project course—the program applies the STEM-PjBL approach (Science, Technology, Engineering, Mathematics–Project-Based Learning) together with the Engineering Design Process (EDP). STEM integrates knowledge in science, technology, engineering, and mathematics, enabling students to connect and apply interdisciplinary knowledge to solve real problems (Kelley & Knowles, 2016). Meanwhile, Project-Based Learning (PjBL) is a learning model that emphasizes creating artifacts or products that address real societal problems, making learning meaningful and applicable in practice (Afriana & Fitriani, 2016; Harun, 2020). The EDP helps ensure that STEM-PjBL instruction follows clear, step-by-step procedures and can be replicated in future teaching. It also promotes problem-solving and collaborative skills, which are essential components of learning and innovation skills (learning and thinking skills) and are considered fundamental for 21st-century learners (Kelley & Knowles, 2016; Lin et al., 2021).

However, although project-based learning can produce tangible outputs, the success of developing problem-solving and collaboration as competency-based outcomes remains an issue that requires further study in order to evaluate the effectiveness of STEM-PjBL combined with the EDP. For this reason, the present research aims to examine the development of problem-solving and collaborative skills among Grade 11 students in the KOSEN program through STEM-PjBL learning using the Engineering Design Process (EDP), in order to provide an important guideline for developing an effective learning model that truly cultivates these essential skills.

Research Objective

1. To develop learning activities based on the design thinking process / engineering design process, integrated with project-based learning.
2. To evaluate students' problem-solving, communication, and collaboration skills—as well as their satisfaction—after implementing learning activities based on the design thinking process integrated with project-based learning.

Literature Review

1) Learning and Innovation Skills in the 21st Century

Learning and Innovation Skills are fundamental competencies and essential attributes for global citizens in today's value-based economy, enabling them to cope with rapid changes in technology and society. These skills are not limited to seeking knowledge; they also encompass learners' ability to apply diverse learning methods and processes to acquire knowledge independently or to work collaboratively with others in order to achieve shared goals (OECD, 2025).

A key component of learning and innovation skills includes problem-solving skills and collaborative skills, which are basic skills learners need in order to analyze complex real-world problems (OECD, 2025). In other words, when learners can creatively integrate knowledge, this can lead to the development of innovations in the form of novel inventions. Such innovations are not only tools for solving problems but also provide a range of alternatives that support sound conclusions and reasonable decision-making that fits the situation (Husin et al., 2025; Uhame, 2020).

2) Problem-Solving Skills

Problem-solving skills are an important competency that reflects learners' ability to face and manage complex problems in authentic contexts. This ability does not rely solely on theoretical knowledge; it also includes systematic thinking, cause analysis, generating alternatives, and making decisions to select appropriate solutions. Problem-solving is widely recognized as a core element of 21st-century learning and innovation skills, and it is essential for lifelong learning and for working in the digital era (Rotherham & Willingham, 2010).

Many educational studies indicate that problem-solving skills cannot be effectively developed through one-way, transmission-based instruction alone. Instead, they require learning activities that allow learners to encounter real problems, analyze situations, and design solutions on their own. This type of learning helps learners develop the ability to identify problems, analyze root causes, and design systematic solutions step by step (Roudhotul et al., 2021; Uhame, 2020; William, 2019).

In engineering learning contexts, problem-solving skills are closely linked to the design thinking process and the engineering design process (Engineering Design Process: EDP). These emphasize a structured sequence of steps, from defining the problem, designing concepts, building prototypes, testing, and iterative improvement. Using the EDP provides a clear structure for problem solving, reduces unguided trial-and-error, and encourages decisions based on data and reasoning (Kelley & Knowles, 2016).

3) Collaboration Skills

Collaboration refers to working together in a coordinated manner within and across groups so that a team's shared main goal can be successfully completed. Research has concluded that simply giving students opportunities to work in groups does not always equate to true collaboration (Rotherham & Willingham, 2010), because in typical group work there may be "free riders" who allow the most capable peer to do most of the work (Salomon & Globerson, 1989). In contrast, genuine collaboration requires both social and cognitive processes.

Evans (2020) summarized four characteristics that indicate students are collaborating effectively:

1. **Plan and make decisions as a group (Decide):** Discuss the best way to manage and complete a task or project as a team, assign roles or tasks, and use negotiation or conflict resolution when needed to plan and decide together.
2. **Communicate thinking with the group (Communicate):** Seek clarity about one's own and teammates' thinking, respond politely to others' ideas, and propose new or different perspectives to the group.
3. **Share information, ideas, and support group members (Share):** Treat ideas and information as shared group resources that can be exchanged to accomplish the work. Members are responsible for their assigned tasks, including supporting one another.
4. **Provide feedback, monitor progress, reflect, and improve the process (Reflect & Adapt):** Reflect together on work methods and progress, and collaboratively improve the working process to reach the goal.

4) Assessment of Collaboration

Educational research shows that collaboration can be assessed in several ways, including:

1. **Self or peer reports** (questionnaires for self- and peer-assessment),
2. **Teacher ratings** (individual scoring by the instructor), and
3. **Observational measures** (teacher observation of interaction and discussion patterns within groups).

French et al. (2016) reported results from a student collaboration test using a 26-item questionnaire rated on a 1–5 scale (5-point Likert scale). The questionnaire was divided into four categories:

1. **Group Composition (4 items):** Recognizing diverse strengths that contribute to the group's overall effectiveness and performance.
2. **Interdependency (7 items):** Teamwork and collaboration through shared responsibility, compromise for the common good, and joint decision-making.
3. **Norms and Roles (6 items):** Accountability and commitment to duties and roles and maintaining preparedness according to established group standards.
4. **Goals (9 items):** Alignment of personal goals with group goals and a sense of personal responsibility for the group's success and outcomes.

5) STEM-PjBL and the Engineering Design Process (EDP)

Teaching and learning aimed at developing problem-solving and collaboration skills requires instructional models that emphasize hands-on practice and the integration of knowledge across multiple dimensions (Husin et al., 2025; Rotherham & Willingham, 2010; William, 2019), as described below.

Project-Based Learning (PjBL)

PjBL is a learner-centered approach that focuses on creating a product or artifact that addresses real societal problems. This model helps students see the meaning of learning and apply knowledge in practice. It also trains learners to ask questions, seek knowledge, plan actions systematically, share responsibility, and work as a team (Harun, 2020; William, 2019).

STEM-PjBL

STEM-PjBL integrates core disciplinary knowledge—science, technology, engineering, and mathematics—with project-based learning. Its goal is to enable learners to connect theoretical knowledge from multiple fields and apply it to solving complex, real-world engineering problems.

Kelley and Knowles (2016) explained that effective STEM education is not separated into isolated subjects; rather, it uses the engineering design process as the central core that connects scientific and mathematical knowledge with the design and development of technology. This approach helps learners see the relationships among disciplines and apply knowledge systematically to problem solving.

In addition, Afriana and Fitriani (2016) showed that STEM-PjBL promotes deeper learning because learners must face real problems, plan their work, experiment, and refine solutions on their own. This process develops analytical thinking, problem-solving ability, and the application of science and mathematics in meaningful contexts.

Engineering Design Process (EDP)

The EDP serves as a scaffolded sequence that gives project work clear direction and makes it repeatable. It is used to structure instruction step by step and consists of five key stages (Kelley & Knowles, 2016; Lin et al., 2021):

1. **Define (Problem identification):** Defining a problem based on a social context (society-inspired problem)
2. **Design:** Planning and designing conceptual solutions
3. **Fabrication:** Building a real prototype
4. **Test & Evaluation:** Evaluating the prototype's performance
5. **Communication:** Communicating results and innovations to society (society-oriented invention)

Lin et al. (2021) studied the effects of integrating the engineering design process into STEM project-based learning activities for preservice technology teachers. They found that learners who learned through the EDP showed significant improvements in design thinking, problem definition, concept design, and iterative improvement through repeated testing. This research indicates that the EDP functions as a scaffolded structure that systematically guides learners' thinking processes. Additionally, Kelley and Knowles (2016) proposed a conceptual framework for integrated STEM, identifying the engineering design process as the core that links scientific, mathematical, and technological knowledge with authentic engineering practice. Using the EDP as a step-by-step learning structure helps learners solve problems with clearer direction and make better decisions based on evidence and reasoning.

Research Methodology

This study aims to develop problem-solving skills and collaboration skills. The research procedures are described as follows.

Research Design

This study is a classroom action research study (Classroom Action Research) using a quasi-experimental approach (pre-experimental design). It employs a One-Group Pretest–Posttest Design to compare the development of students' problem-solving and collaboration skills before and after the learning intervention.

Participants

The target group consisted of 33 second-year students (Grade 11) in the KOSEN-KMUTT program, Automation Engineering major (Cohort 5), who were enrolled in the Project course in the Academic Year 2024.

Research Instruments & Teaching Method

The research instruments included a **STEM-PjBL-EDP lesson plan**, with the following details:

Project Topic

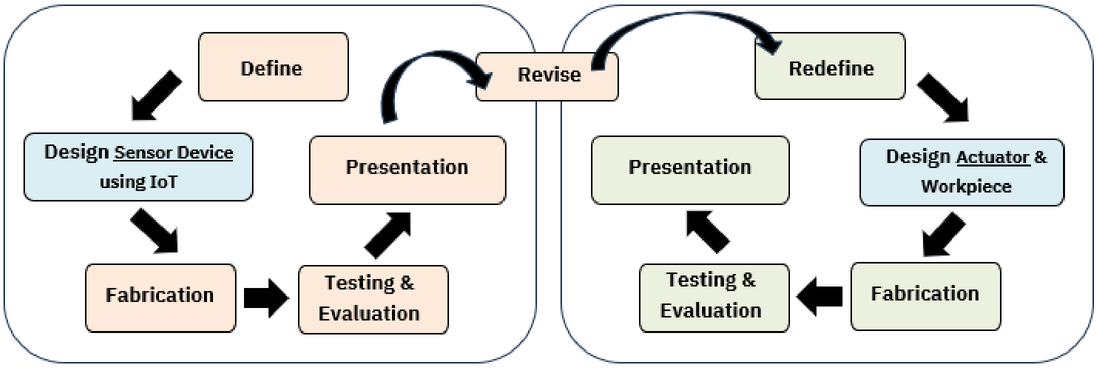
The researcher assigned students to design and build a "sensor-based detection and actuator system" to solve real problems within the school, with an emphasis on ensuring the system could be tested with real users.

Teaching Method (The EDP 2-Loop Model)

Instruction was divided into two main loops to enable continuous improvement of the project artifacts (an iterative process), as shown in Figure 1:

- **EDP Loop 1 – Sensor (Semester 1):** Students learned about IoT and sensor (sensing device) design, emphasizing rapid **fabrication** and **testing & evaluation** to ensure accurate sensor performance.
- **EDP Loop 2 – Actuator (Semester 2):** Students used the outcomes from Loop 1 to **redefine** the problem and then design and build an actuator system and the workpiece, resulting in a complete innovation.

Figure 1
The EDP Loop 1 Process Focuses on Teaching Sensors, and EDP Loop 2 Focuses on Teaching Actuators



Class Activities (Following EDP Steps)

Teaching and learning activities followed the EDP steps as described below.

Define included:
1. Identifying problems through user interviews and analyzing causes using a Fishbone Diagram to find the root cause, leading to the selected focus problem. This step was called the **Problem Statement** stage.
2. Brainstorming within the group and selecting 3–4 possible approaches, referred to as the **Ideate Solutions** stage.
3. Selecting one solution by considering factors such as originality and effectiveness in solving the problem, referred to as the **Choose Solutions** stage.

Design & Fabrication

Students drafted the hardware and software design and created a simple **quick prototype** using leftover/recycled materials to obtain feedback.

Figure 2
Examples of a Workpiece Model Created in SolidWorks and the Actual Fabricated Workpiece

Presentation

Students presented their projects in a **hybrid exhibition** format and through an **oral presentation** at the end of the academic year.

Data Collection & Analysis

The researcher collected and analyzed data as follows:

1. **Problem-solving skills assessment:** An open-ended test (total 44 points) was used to measure students' ability to identify problems, analyze causes, and design solution approaches.
2. **Collaboration skills assessment:** A 26-item questionnaire based on French et al. (2016), divided into four dimensions: Group Composition, Interdependency, Norms & Roles, and Goals.
3. **Data analysis:** Mean and standard deviation (S.D.) were calculated, and a paired-samples t-test was used to compare differences between pretest and posttest scores.

Results and Discussion

From implementing the STEM-PjBL learning model together with the Engineering Design Process (EDP) with students in the KOSEN-KMUTT program, the data analysis can be summarized as follows:

Results of Problem-Solving Skill Development

An analysis of students' scores on the Problem-Solving Test before and after participating in the learning activities showed clear improvement, as presented in Table 1.

Table 1
The Score of Pretest–Posttest for Problem-Solving Skill

	Mean	N	Std. Deviation	Sig. (2-tailed)
Pretest	20.07	28	3.99	< 0.001*
Posttest	28.11	28	3.68	

Note. *Significant at the $p < 0.001$ level

Table 1 shows that the posttest mean score (Mean = 28.11) was significantly higher than the pretest mean score (Mean = 20.07) at the **$p < 0.001$** level. This supports the hypothesis that STEM-PjBL combined with the EDP enhances learners' analytical thinking, problem identification, and systematic design of solution alternatives (Husin et al., 2025; Kelley & Knowles, 2016; Lin et al., 2021).

Results of Collaborative Skill Development

Collaboration skills were assessed using a questionnaire across four dimensions. The results indicate that students demonstrated positive attitudes and group-work behaviors after the STEM-PjBL and EDP learning intervention, as shown in Table 2.

Table 2
The Score of Pretest–Posttest for Collaborative Skill

Dimension		Mean (n = 33)	Std. Deviation
Group Composition	Pretest	4.19	0.75
	Posttest	4.35	0.69
Interdependency	Pretest	4.17	0.86
	Posttest	4.45	0.62
Norms and Roles	Pretest	4.33	0.76
	Posttest	4.30	0.74
Goals	Pretest	4.41	0.63
	Posttest	4.27	0.74

Item-level analysis (sub-questions) revealed statistically significant and noteworthy findings in two key dimensions:

1. **Group Composition:** Students recognized the value of teamwork and agreed that *group work produces better outcomes than working individually* ("groups outperform individuals").
2. **Interdependency:** Students showed a clear increase in willingness to make sacrifices and to accept collective input—especially regarding *being willing to compromise on personal issues for the benefit of the group* and *consulting all members before making decisions*.

However, the posttest mean scores for **Norms and Roles** and **Goals** decreased slightly (from 4.33 to 4.30, and from 4.41 to 4.27, respectively). This suggests challenges in assigning responsibilities within groups and maintaining a balance between personal goals and group goals (Evans, 2020; Salomon & Globerson, 1989). These issues point to the need for improved task-tracking tools or closer instructional coaching and guidance in future implementations.

Conclusion

Integrating STEM-PjBL with the EDP is highly effective in developing problem-solving skills and in fostering a sense of collaboration through interdependency and recognition of differences among team members (group composition). These are key elements in developing high-quality innovators in line with the goals of the KOSEN-KMUTT program.

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

The author declares that ChatGPT, an AI-assisted software tool, was used for translation support, proofreading, and language refinement. Its use was limited to correcting grammar and spelling and rephrasing sentences to improve clarity and accuracy. The author also confirms that no other AI or AI-assisted technologies were used to generate manuscript content. All ideas, research design, procedures, results, analyses, and discussion were produced by the author and are based on the careful and systematic conduct of the study.

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