OPEN ACCESS Freely available online

ISSN 2810-9279
Volume 1, Issue 1
https://www.iikii.com.sg/journal/IDC
Innovation on Design and Culture

Article

# Integrated Design Thinking to Improve Pedagogical Practices in Creative Engineering Design

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**Received:** Feb 2, 2022; **Accepted:** Mar 3, 2022; **Published:** Mar 30, 2022

**Abstract:** Repeated testing, revision, and verification make products have market value and the commercialization of creative ideas reflected in the product. In the model, product and industrial designs present actual cases so that students are trained from scratch to clarify problems, identify needs, establish functional structures, and evaluate the creative design and engineering design. A good design plan includes market and user demand analysis, creative thinking, concept formation, and actual prototype making. Thus, students need to learn how to simulate the actual product design and development process through design protection and complete design planning. Therefore, taking creative engineering design courses as an example, this study aims to introduce various design methods into interactive teaching by using the problem/project-based learning (PBL) and science, technology, engineering, arts, and mathematics (STEAM) model. In industry, the methods are expected to simulate how a product design engineer faces the market and consumers. The results reveal the following. Students prefer to focus on hands-on practice and ask for examples and supplementary reference materials and a diversified interactive learning model. They like to work in groups and interact with peers and teachers to learn in real-time, hoping to know their levels and thoughts. They hope to apply what they learn for future career development. The education model integrates academic theory and industrial practice to reduce the gap between learning and practice in the industry.

**Keywords:** PBL (Problem/Project-Based Learning), STEAM, Design Thinking, Creative Engineering Design, Pedagogical Practices

## 1. Introduction

The industry integrates multiple and cross-domain technologies, but most students are accustomed to studying in a single subject course and one-way teaching dominated by teachers. As professional subjects require interaction between teachers and students and participation in industry practice, the subjects also demand cross-disciplinary technology integration and team interaction in learning motivation and arousing interest.

The teaching objective is to give learning motivation and improve the learning effect of the course, change the teaching method, and innovate and develop teaching materials and aids. The industry-university co-teaching to improve the gap between learning and use is also one of the objectives. As learning together as a team simulates industrial fields, team projects are also included in teaching. The actual skill that is required in the industry needs to be included as a core feature to understand how a product designer understands the market and consumers. The product must have market value through repeated tests, corrections, verifications, and the commercialization of creative ideas. Thus, in the course, actual cases are introduced for learing product and industrial design to train students in clarifying problems, confirming requirements, establishing specifications, functional architecture, and evaluating engineering design capabilities. A good design contains market and user demand analysis, creative ideas, concept design, and actual hands-on prototypes. Moreover, it is necessary to learn how to simulate the actual new product design and development process through design protection and complete design.

Therefore, this research attempts to integrate the problem/project-based learning (PBL) and science, technology, engineering, arts, and mathematics (STEAM) model into teaching, emphasizing hands-on and problem-solving skills to design thinking in problem-solving and integrating knowledge in different fields such as science, technology, engineering, aesthetics, and mathematics. Through problem- or project-oriented teaching, the core values of technical and vocational education enhance students' interest in learning effectively. Design thinking is an analytical and creative process to experiment, create prototype models, gather feedback, and redesign. From the literature review, it is found that a good designer has an ability of visualization and creativity. Design thinking and its implementation present the differences between novices and experts. Students' creative thinking gradually improves through practical training (Razzouk and Shute, 2012).

### *1.1. PBL and STEAM Education*

PBL and STEAM are beneficial teaching strategies for helping students understand the curriculum, improve communication and soft workplace skills, and improve leadership and creativity (Hawari and Noor, 2020; Cheng and Lin, 2020; Domenici, 2022). In STEAM education, students need to (1) participate in projects, (2) provide logical reasoning, (3) collaborate, and (4) make decisions and analyses. Students are empowered to receive higher education and contribute to society. Its instruction conceptualizes solving a problem by using (1) problem/project-based learning, (2) technology to some extent for creativity and design, (3) an inquiry approach, allowing multiple paths to problem-solving, (4) science, technology, engineering, arts/humanities, the mathematics required by the problem, and (5) collaborative problem-solving. Teachers use an interdisciplinary approach holistically and develop overarching ideas or issues relevant to the student's area and life, in which students form collaborative groups to explore and design solutions to open-ended problems (Herro, Quigley, Andrews, and Delacruz, 2017). Traditionally, engineering education in technical and vocational schools provides knowledge of professional disciplines to solve real problems. However, if students can integrate through PBL and STEAM interdisciplinary, the teaching and learning of the overall curriculum become more effective. This student-oriented teaching is usually implemented collaboratively by a small group, with the teacher acting only as a consultant to the team or guiding students to produce the final result. In this way of teaching, skills of different natures, such as critical thinking and reflection, problem-solving, teamwork, and oral and written reporting, are enhanced (Ubben, 2019). However, there are problems with the PBL method such as (1) difficulty in finding suitable teaching strategies, (2) selection of appropriate items, (3) selection of relevant measurement tools or rubrics, and (4) development of appropriate curriculum objectives and primary purposes learning content.

### *1.2. Pedagogical Practice Evaluation*

The number of STEAM courses and STEAM-themed schools has increased worldwide. They have provided educators with a new opportunity to improve teaching field problems by exploring this innovative pedagogical practice model (Quigley and Herro, 2016). Currently, there are various theories and design models for developing STEAM courses, such as problem/project-based learning (PBL), design-based learning (DBL), and 6E learning. They focus on students with special educational needs due to PBL flexibility and allow researchers to modify it to suit the student's ability easily (Ledford, Lane, and Gast, 2018). In terms of PBL and STEAM pedagogical practice evaluation, the educators generally agree that STEAM improves creativity and thinking skills, the creativity is rarely measured or assessed as part of STEAM education, and often overlooks the creative process of the final product (Perignat and Katz-Buonincontro, 2019). Thus, it is necessary to ensure that all curricula are well designed. Teachers and students participate in each PBL and STEAM education. Educators usually conduct the teaching design mainly based on experience and assumptions for students' teaching evaluation methods, including learning objectives, learning experience, and techniques.

However, most of the existing teaching evaluation model is descriptive, and there is limited attention to the pedagogical research of specific evaluation to confirm the effective practice of teaching evaluation. Therefore, evaluation thinking, critical thinking, and learning principles must be adopted in the teaching practice evaluation. Through teaching and learning, the teaching methods and their differences are explored at different levels of education (LaVelle, Lovato, and Stephenson, 2020). In addition to the effectiveness of interdisciplinary and teamwork learning implementation, it is necessary to use reasonable and objective methods in the PBL environment to see the actual learning effect on students. The effect includes content knowledge, presentation skills, teamwork, and soft skills (Quigley, Herro, and Baker, 2019). In student-oriented teaching, students take more responsibility through the self-evaluation process, whether individually or as a team, which is beneficial to teaching practice (Klenowski, 1995). Designing a self-evaluation model in teaching through questionnaires and experts' evaluations helps students clearly understand the learning effect. Through the design of teaching, the training is added to a certain degree of professional courses. Self-discipline allows students to increase from the lower limit of the medium to the upper limit to carry out self-regulating learning and effective development in teaching (Senovska and Pryshliak, 2020).

### *1.3. Design Thinking in Creative Engineering*

Creativity is characterized by fluidity, flexibility, and originality of thought an indicator to assess the characteristics of the creator. It is a complex human behavior that involves a wide range of factors. It is influenced by external social development and educational background. Different domains of expression lead to different types of creativity (Runco and Sakamoto, 1999). Teachers integrate different teaching models into academic theory and industrial practice through practical courses. The advantage of this method is that it allows students to demonstrate individual skills, knowledge, ideas, experiences, perceptions, and emotions from hands-on production and demonstrate the learning effectiveness of individuals or teams as a whole (Pöllänen, 2011). There are four factors for designing a creative curriculum: personal character, creative process, creative product, and creative environment. These metrics allow teachers to assess students' creativity. Implementing creative thinking in the classroom is to stimulate students to use their imaginations and think creatively.

Design thinking is an analytical and creative process that allows people to experiment, create and prototype models, gather feedback and redesign. From a literature review, it is determined that a good designer has the ability of visualization and creativity. Design thinking and implementation are presented by the differences between novices and experts, and students' creative thinking ability gradually improves through practical training (Razzouk and Shute, 2012). Creativity is essential for engineering innovation. Scholars compare general creativity and creative engineering design ability between first-year engineering and non-engineering background students in the course of a creative engineering design through five weeks of training. Overall, both male and female students significantly improved their learning outcomes when they first learned. However, the content of creative engineering design courses did not impact on creativity. Engineering and non-engineering background students showed a difference in advanced engineering innovative design (Charyton, Merrill, 2009). Kim and Park (2012) used an activity-specific Rube Goldberg Machines as a construct for STEAM and then examined the effect on the creativity of elementary school students. The Rube Goldberg machine was an invention to find the most straightforward problems for complex engineering problems. For example, if the goal is to turn on a light switch, the Rube Goldberg machine creates a chain reaction, such as rolling a ball down a ramp, hitting a lever, triggering a domino to fall in a series of waves, and then hitting a spring-loaded sign to click a button to turn on a light. In their study, students in groups solved a predetermined problem but were encouraged to use other methods to solve the problem.

## 2. Materials and Methods

### *2.1. Course Plan*

We used innovative teaching methods to help students design think, research, and solve problems. The methods focused on the actual problems. The process included how to clarify problems, confirm needs, establish specifications, functional structures, creative design, and engineering design evaluation capabilities. It also teaches students to complete a design proposal through market and user demand analysis, creative thinking, concept formation, and actual prototype making. Students learned how to simulate the actual new product design and develop a process through design planning for commercial marketing. This improved students' learning motivation and effectiveness. The creative engineering design course introduced various creative design thinking methods and generated conceptual designs. In product definition and function analysis, DFM (design for manufacturing) and DFA (design for assembly) were taught along with industrial design communication methods, and rapid prototyping technology. The design protection process includes the patented TRIZ method, design feasibility evaluation, and design risk management with the creative commercialization and present design results. To combine theoretical and practical applications, the course introduced PBL and STEAM's interdisciplinary teaching methods. Design thinking was carried out through teamwork, and concepts and ideas were developed. The course provided the opportunity to participate in various creative entrepreneurship competitions and a pre-training for product designs. The detail of the course plan for creative engineering design is shown in Table 1.

**Table 1.** Course Plan of the creative engineering design.

| Weeks | Course Content | Remark |
|---|---|---|
| 1 | Introduction to Creative Engineering Design Courses | Team work |
| 2 | Product design and industrial design:<br>Product design: starting from nothing, taking mass production as the premise, and integrating the concrete design of engineering technology.<br>Industrial design: A conceptual design with design aesthetics, based on the user's premise, integrating user experience and human factors engineering. | Case study 1: Four major international design awards: winning works of student conceptual design and mass production product design (iF, Red Dot, Good Design, IDA Award) |
| 3 | Creative thinking and design methods: design thinking, brainstorming and etc. | Case study 2: Use the design method have learned to illustrate with an example. |
| 4 | Design concept and engineering realization: new product design and development process (NPD) | Case study 3: Create a schedule with selected topics. |

**Table 1.** *Cont.*

| Weeks | Course Content | Remark |
|---|---|---|
| 5 | Analysis of external design requirements: market analysis and user requirements (SWOT analysis, QFD quality function deployment 1) | Case study 4: Practice SWOT analysis and QFD planning with selected topics. |
| 6 | Internal engineering technology development: product positioning and functional specification (QFD quality function development 2) | Case study 5: Practice QFD method expansion with selected questions. |
| 7 | Design communication method: product conceptual design (expression techniques, hand-drawn idea sketches, rendering, product rough schematics) | Case study 6: Hand-drawn sketches and product design schematics on selected topics. |
| 8 | Rapid prototyping: 2D/3D modeling, hand-make mockup samples, paper models, 3D printing prototyping | Case study 7: 2D/3D modeling proofing with selected topics. |
| 9 | Midterm | Midterm presentation |
| 10 | Creative Problem Solving Theory of Engineering Design (TRIZ): Contradiction Matrix, 39 Engineering Parameters, 40 Invention Principles | Case study 8: Practice TRIZ method with selected topics. |
| 11 | Product design protection: patent requirements (novelty, advancement, industrial applicability), patent search, patent application process, and design around methods | Case study 9: Practice patent searches on selected topics. |
| 12 | Product feasibility evaluation and design modification: DFM/DFA easy-to-manufacture and easy-to-assemble design (product appearance, dimensional tolerances, material selection, machining methods, mold engineering, manufacturing procedures, quality management, etc.) | Case study 10: Practice DFM/DFA design feasibility evaluation with selected topics. |
| 13 | Product design risk assessment and design quality: FMEA, mistake-proof design (Poka-Yoke), robust design | Case study 11: Practice product design and design risk assessment with selected questions. |
| 14 | Commercialization planning from idea creativity, innovation, to entrepreneurship: team, capital, technology, startup, crowdfunding and etc | Case study 12: Practice the creativity, innovation, and entrepreneurship planning proposals on selected topics. |
| 15 | Design presentation: design proposal, conceptual drawing, project & engineering deployment, cost and manufacturing process analysis, marketing planning, presentation and oral skills | Case study 13: Practice design presentation with the design proposal, presentation, and oral skills. |
| 16 | Design presentation practice | |
| 17 | Prepare final report and video | |
| 18 | Final Presentation | |

### *2.2. Procedures*

This course was designed based on a student-centered and interdisciplinary teaching model to introduce the industrial practice. In terms of the spillover effect, the following was considered: improving students' learning effectiveness, class management, teaching materials, and teaching plans, student competition, awards, and other teaching and learning outcomes. The purpose was to have students practice for the industry. To understand the learning effect, students were surveyed about their learning motivation and learning goals before and after learning. The questions included: 'why do they want to take this course?', 'what do they hope to learn in this class?', and 'are they confident that they will complete pre-set goals by the end of the semester?'.

The lesson plan for theoretical and practical teaching contained the following:

(1) Product design and industrial design: mass production as the premise, integrated engineering technology-specific design; industrial design: with design aesthetics, based on the user, integrating user experience and human factors conceptual design of the project
(2) Creative ideas and design methods: design thinking, brainstorming, and other creative ideas and design methods.
(3) Design concept and engineering realization: new product design and development, from design concept to engineering realization

(4) Analysis of external design requirements: market analysis and user requirements, including SWOT analysis, QFD quality function expansion method
(5) Internal engineering technology development: product positioning and function specification formulation and precise QFD quality function development method
(6) Design communication methods: conceptual product design, from performance techniques, hand-painted sketches, painted detailed drawings, to product schematics
(7) Rapid prototyping: Introduce rapid prototyping methods such as 2D/3D modeling, hand-made prototype samples, paper models, and 3D printing

After the midterm presentation, a group practice in PBL and STEAM included the following theoretical and practical applications.

(1) Theory of creative problem solving for engineering Design (TRIZ): the contradiction matrix, 39 engineering parameters, and 40 invention principles

(2) Product design protection: patent requirements (novelty, non-obviousness, industrial applicability), patent search, patent application process, and design avoidance methods

(3) Product feasibility assessment and design revision: DFM/DFA design for easy manufacturing and assembly, from product appearance, dimensional tolerance, material selection, processing methods, mold engineering, manufacturing procedures, quality management, Etc, product feasibility assessment, and design correction method
(4) Product design risk assessment and design quality: FMEA, mistake-proof design (Poka-Yoke), robust design, Etc, product design risk assessment, and design quality methods
(5) Commercialization planning from creativity, innovation to entrepreneurship: team, capital, technology, new ventures, crowdfunding
(6) Design presentation: design proposal, concept drawing, project development, cost and process analysis, marketing planning, production and presentation skills

### *2.3. Effectiveness Evaluation Tools*

The learning effectiveness evaluation tools include questionnaires (beginning, mid-term, and end-of-term) to compare the differences between before and after learning and 360-degree evaluation (self-evaluation, other-evaluation, and industry-teacher co-evaluation). The learning evaluation method is divided into quantitative and qualitative evaluations. Quantitative evaluation measures academic learning effectiveness, active learning motivation, learning attitude and interest, and problem-solving ability. Qualitative evaluation includes in-depth interviews with students as one of the indicators of teaching effectiveness. Since this course adopts a 360-degree evaluation method, teachers tried to make the most objective evaluation results after considering the overall learning effect of students through students' self-evaluation, peer evaluation of group members, and evaluation of other groups. In learning, each group member thought, reflected, and suggested. The communication and interaction between group members affected the students' objective learning motivation in peer evaluation and adjustment. After the group members assign work tasks, each student's self-competence improved. Through a multi-dimensional evaluation method, teachers analyzed and countermeasured the problems raised by each group and suggested the expected learning outcomes in terms of creativity. In addition to strengthening students' academic abilities, cross-disciplinary professionalism was cultivated for related industries by establishing an interactive mechanism.

From the practical courses, it was also possible to observe and discover students' specialties. The learning ability was assessed in six dimensions: shape design, mechanism design, electronic control, programming, communication, and artificial intelligence. The degree of difficulty changed to cultivate students' logical thinking and hands-on learning ability, emphasizing the diversified learning effect. In terms of qualitative evaluation, radar chart diagnosis helped students explore their careers and diagnose the effectiveness of their learning process. In terms of qualitative evaluation, the data of the final work was scored. Students were provided with diversified learning or focused learning and a reference for future career development. Co-teaching of industry-university cooperation was recommended to develop the curriculum and learning content according to the needs of the industry. To quickly and accurately be integrated into the industry, the gap between learning and use needs to be overcome. The executive photos in the creative engineering design course are shown in Fig. 1.

(a) (b) (c) (d) (e) (f)

**Fig. 1.** Creative engineering design: (**a**) PBL & STEAM introduction, (**b**) Brainstorming practice, (**c**) Design thinking practice, (**d**) Weekly course practice and teacher-student discussion, (**e**) Weekly practical exercises and present instantly, and (**f**) Result presentation of mid-term and end-of-term.

## 3. Results

30 students (27 males and three females) participated in the course, of which 25 were university students (fourth grade), and 5 were college students (first grade).

### *3.1. Learning Confidence and Effectiveness*

Questionnaire surveys were carried out at the beginning, mid-term, and end-of-term (Table 2) to analyze students' learning confidence. Before learning, for the question to ask if they had the basic knowledge required for this course, 19.4% strongly agreed, 32.3% agreed, 35.5% neither agreed nor disagreed, and 12.9% disagreed. In the mid-term questionnaire, the ratio of the students with strong agree increased to 38.2%. 44.1% agreed, and 14.7% neither agreed nor disagreed. Only 2.9% disagreed. At the end-of-term, the ratios were 51.7, 41.4, 6.9, and 0%. The students were not confident at the beginning of learning, but after the course, the students' learning confidence and self-affirmation of learning results significantly improved. For learning objectives, before learning, 35.5% strongly agreed, 61.3% agreed, and 3.2% neither agreed nor disagreed with that there would be a place to apply what they learned in the future. In the mid-term, the ratios changed to 47.1, 50.0, and 2.9%. An the end-of-term, 58.6 and 41.4% of the student strongly agreed and agreed.

At the beginning of learning, the students were not sure if they could apply what they have learned in their future career development. However, after the course teaching, students' learning effectiveness has been improved, and they were sure for future career development (Fig. 2).

**Table 2.** Learning confidence and effectiveness.

| **Item** | **Questionnaire Content** | **Result** | | | | |
|---|---|---|---|---|---|---|
| | | **Strongly Agree** | **Agree** | **Neither Agree nor Disagree** | **Disagree** | **Strongly Disagree** |
| Beginning | Learning Confidence:<br>Before taking this course, they think they have the basic knowledge required to take it. | 19.4% | 32.3% | 35.5% | 12.9% | |
| | Learning Effectiveness :<br>Before taking this course, they knew that taking this course, and there would be a place to apply what they learned in the future. | 35.5% | 61.3% | 3.2% | | |
| Mid-term | Learning Confidence:<br>From the beginning of the course to mid-term, the basic knowledge they have learned before will help them take it. | 38.2% | 44.1% | 14.7% | 2.9% | |
| | Learning Effectiveness:<br>From the beginning of the course to mid-term, they know what they have learned and apply it to future career development. | 47.1% | 50.0% | 2.9% | | |
| End-of-term | Learning Confidence:<br>After one semester of study, basic knowledge previously learned will help take this course. | 51.7% | 41.4% | 6.9% | | |
| | Learning Effectiveness:<br>After one semester of study, know what they have learned and apply it for future career development. | 58.6% | 41.4% | | | |

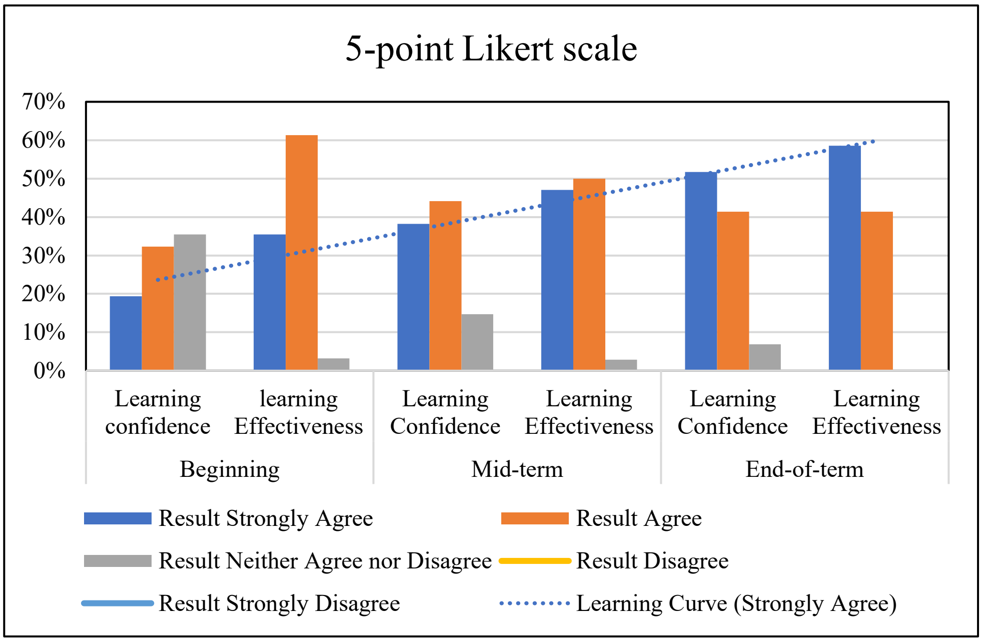

**Fig. 2.** Questionnaire results.

### *3.2 Learning and Interactive Model*

For the learning model, the students preferred to focus on hands-on practice and asked teachers to use examples and supplementary reference materials. The students preferred teaching based on examples, supplemented by reference materials, supplemented by hands-on practice. The diversified interactive learning model was favored in the beginning, 29.4% in mid-term, and 55.2% at the end of the term. 38.7% of the students preferred static learning or self-learning in the beginning. The ratio decreased to 2.9% in the mid-term and o% in the end-term. The traditional one-way teaching with textbooks was supported by 3.2% of the students in the beginning, 8.8% in mid-term reduced, and 0% at the end of the term.

For the interactive model, 25.8% of the students preferred teamwork in groups to cooperate to interactively learn. The ratio increased to 35.3% in the mid-term and then reduced to 31.0% in the end-term. 67.7% preferred to cooperate and interact in groups and learn. In the mid-term, the ratio reduced to 44.1%, and in the end-term, it increased to 51.7%.

### *3.3 Learning Objective and Evaluation*

For the learning objective, 77.4% of the student were confident in achieving preset goals in the mid-term. 55.9% thought that their preset goals were not achieved but needed to be achieved. 26% did not have confidence, and 11.8% were not sure if they could achieve. 2.9% do not achieve preset goals nor are unsure of achieving them. After this course learning, they gained confidence and achieved pre-designed goals, which increased to 37.9%. Although they do not yet achieve preset goals, some can inevitably achieve them in the future is 51.7%. Even they have achieved preset goals and are unsure they can achieve them in the future reduced to 6.9%, and those not yet achieved preset goals nor can achieve reduced to 2.9%.

For the learning evaluation, 19.4% of the students graded themselves A (91–100), 54.8% graded B (81–90), 19.4% graded C (71–80), and 6.5% D grade (61–100). In the mid-term, 25.6, 44.1%, 23.5%, and 5.9% graded A, B, C, and D, respectively. After the course, 13.8, 55.2%, and 31.0% of the students graded themselves A, B, and C. The results met the pedagogical practice objectives, and 6.7 % of the students obtained A, 70.0% obtained B, and 30.0% obtained C.

## 4. Discussion

### *4.1. Discovery of Design Thinking in Pedagogical Practice*

The curriculum design with thirteen diversified creative design methodologies and case studies with PBL and STEAM included the following:

(1) Product and industrial design with four major international design awards: winning works of student conceptual design and mass production product design (iF, Red Dot, Good Design, IDA Award).
(2) The design thinking and brainstorming to illustrate with an example
(3) The design concept and engineering realization for the new product design and development process (NPD) to create a schedule with selected topics
(4) Analyzing external design requirements for market analysis and user requirements to practice SWOT analysis and QFD planning with selected topics
(5) The internal engineering technology development with product positioning and functional specification to practice the QFD method expansion with selected questions.
(6) The design communication method for conceptual product design (expression techniques, hand-drawn idea sketches, rendering, rough product schematics) to practice hand-drawn sketches and product design schematics on selected topics.
(7) Rapid 2D/3D modeling prototyping, hand-make mockup samples, paper models, and 3D printing prototyping and practice 2D/3D modeling proofing with selected topics
(8) Creative problem-solving theory of engineering design (TRIZ) with contradiction matrix, 39 engineering parameters, and 40 invention principles applications to practice TRIZ method with selected topics
(9) Product design protection includes the patent requirements (novelty, advancement, industrial applicability), patent search, patent application process, and design around methods to practice patent searches on selected topics.
(10) Product feasibility evaluation and design modification include DFM/DFA easy-to-manufacture and easy-to-assemble design (product appearance, dimensional tolerances, material selection, machining methods, mold engineering, manufacturing procedures, quality management) to practice DFM/DFA design feasibility evaluation with selected topics
(11) Product design risk assessment and quality with FMEA, mistake-proof design (Poka-Yoke), and robust design to practice product design and design risk assessment with selected questions

(12) Commercialization planning from idea creativity, innovation, and entrepreneurship includes team, capital, technology, startup, crowdfunding to practice creativity, innovation, and entrepreneurship planning proposals on selected topics.
(13) Design presentation with the design proposal, conceptual drawing, project & engineering deployment, cost, manufacturing process analysis, marketing planning, presentation, and oral skills.

After one semester of learning, 75.9% of the students showed their interest in product design protection, 62.1% in the SWOT analysis and QFD planning, 58.6% in the commercialization planning, 55.2% in the product feasibility evaluation, the product design risk assessment, and the design presentation. On average, more than half of the students were interested in the 13 types of case studies and felt they were helpful for future career development (Fig. 3).

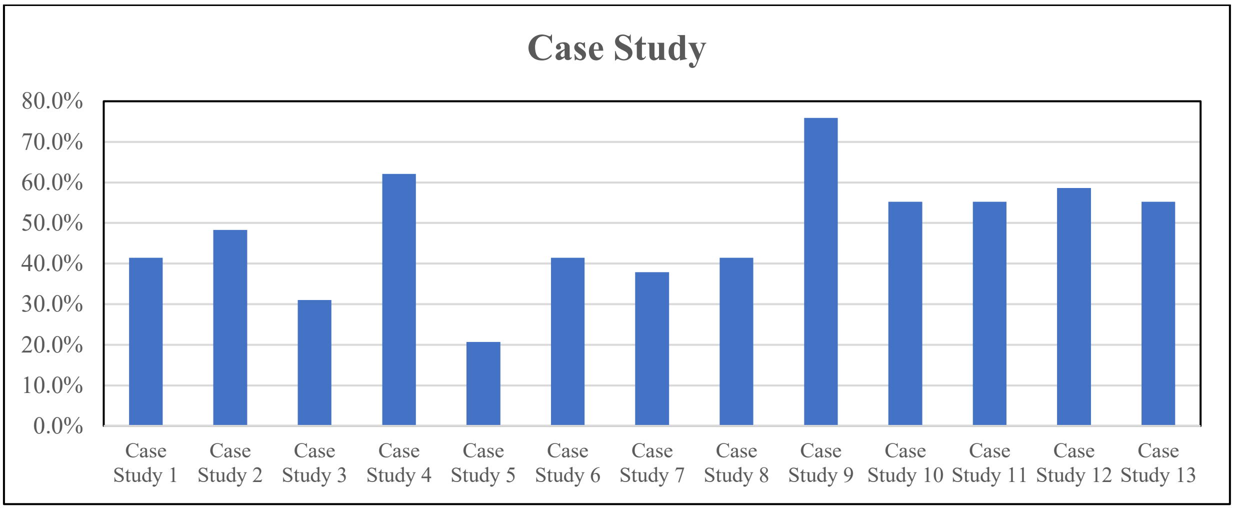

**Fig. 3.** Students prefer case studies.

### *4.2. Pedagogical Practices Improvement*

It was investigated whether the pedagogical practice enhances students' interest in learning. 82.4% of the student thought the practice enhanced their learning in the mid-term, and 96.6% thought so in the end-term. 85.3% also preferred to interact with the teacher in real-time and hoped to know their level of learning in the mid-term, and the ratio increased to 96.6% in the end-term.

### *4.3. Evaluation Tools Improvement*

For the practice learning evaluation, 77.4% of the student preferred no exams and a diversified and flexible scoring method in the beginning. The ratio reduced to 61.8% in the mid-term and increased to 75.0% in the end-term. 19.4% preferred mid-term presentations, final presentations, and regular homework to exams in the beginning. The ratio in the mid-term and the end-term was 32.4 and 75.9. The ratio of the students who preferred exams, mid-term exams, final exams, and the usual scoring method was 3.2% in the beginning, 5.9% in the mid-term, and none at the end-term. In self-evaluation, the students wanted to recall why the problem occurred, review which part of the process went wrong, and solve it. They asked team members the teacher, teaching assistant, and friends to discuss the problem.

## 5. Conclusions

The curriculum's PBL and STEAM research is to share the teaching results with students, schools, and industries. In terms of the impact and performance of pedagogical practices, integrated PBL and STEAM methods improve the effectiveness of industry-university co-teaching, overcome the gap between students' learning, and use in technical and vocational education. Then, learning motivation and direction are improved. By simulating industrial practice and situational problems in life and cooperating with teamwork to learn by doing, the course cultivates students' ability to transform knowledge into practical skills and improves students' professional skills or employment readiness for practical application. This innovative teaching method and practical experience are feasible and significantly improve students' technical and vocational education ability and professionalism.

**Funding:** This research did not receive external funding.

**Conflicts of Interest:** The authors declare no conflict of interest.

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