Instructional Design and Development Activities to Develop Creative Thinking Skills of Undergraduate Engineering Students

Thapanee Seechaliao, Onjaree Natakuatoong, and Witaya Wannasuphoprasit

***Abstract*—This research paper presents the instructional design and development systematic activities to develop creative thinking skills of undergraduate engineering students. The step-by-step instructional design and development activities with outputs showing how instructors perform his role as a subject matter expert and an instructional designer. The research procedures were divided into 2 phases. The first phase was to present instructional design and development activities. The participants who designed instructions consisted of four volunteered engineering instructors at the Faculty of Engineering, Chulalongkorn University. The four engineering instructors studied and followed the instructional design and development activities for designing and developing their instructions. In the second phase, the designed instructional model was evaluated. The participants who evaluated the instructional model according to the evaluation form consisted of 6 experts in instructional design and engineering instruction. Data were collected and analyzed by using arithmetic mean and descriptive analysis. The research findings are as follows: the participants who designed instructions according to the instructional design and development activities could improve their instructional design skills in a high level. The six experts agree that the instructional model is appropriate in both a good level as well as an excellent level.**

***Index Terms*—Instructional design and development activities, instructional model, engineering creative thinking skills.**

I. Introduction

There is a general consensus that engineering problems are complicated. Therefore, engineering need knowledge, ability, experience, and creative thinking to analyze, design, and solve problems by technical process and industrial working system [1], [2]. Furthermore, engineering always applies the engineering design process or creative process to help them design and develop products and to find alternative solutions. Hence, creative thinking skills are indeed crucial for engineering programs. However, earlier research concerning creative thinking skills development in engineering education has shown that there are various engineering instructional strategies which emphasize on developing creative thinking skills of engineering students, for example, applying the instructional model that focuses on developing thinking skills, applying the instructional techniques that encourage thinking skills, and integrating the thinking skills in contents. Despite the emphasis, the quality of engineering graduates reflected that they lacked an ability to design and develop creative thinking skills [3], [4], [5]. This problem should be solved immediately.

The efficient instructional model could help students learn more and achieve learning objectives as expected. Instructional designers and engineering instructors need to revise the instructional model based on engineering educational curriculum of Thailand in order for the instructional model to be more efficient. The instructional design and development activities could help engineering instructors revise their instructional in a systematic practice. Moreover, these activities specifically aim to design and develop the instructions in order to develop creative thinking skills and to develop the engineering creative product designing skills. Therefore, engineering instructors need to study and follow the instructional design and development activities for designing and developing their instructions. These step-by-step activities consisted of 9 steps as follows: 1) Set engineering contents for developing creative thinking skills; 2) Set behavioral learning objectives to develop creative thinking skills; 3) Select and set instructional strategies for developing creative thinking skills; 4) Specify engineering instructor and student roles for developing creative thinking skills; 5) Specify and design activities for developing creative thinking skills; 6) Specify time duration for developing creative thinking skills; 7) Select classroom and web media for developing creative thinking skills; 8) Specify learning environment that supports the development of creative thinking skills; and 9) Specify tools for evaluating creative thinking skills. This research paper presents the step-by-step instructional design and development activities with outputs showing how instructors perform his role as a subject matter expert and an instructional designer.

II. Research Methodology

The research methodology uses research and development approach consisted of two phases as follows:

Phase 1: present instructional design and development activities to develop creative thinking skills of undergraduate engineering students as follows:

Participants: The volunteered participants performed the instructional design and development activities for designing and developing their instruction. The participants were made

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up of 4 engineering instructors who were from 3 different departments in the Faculty of Engineering, Chulalongkorn University. One engineering instructor was from Electrical Engineering, one from Water Resources Engineering, and two from Mechanical Engineering. All of them needed to have at least 1 year of teaching experience.

Research instrument: The research instruments were the instructional design and development activities to develop creative thinking skills of undergraduate engineering students as follows:

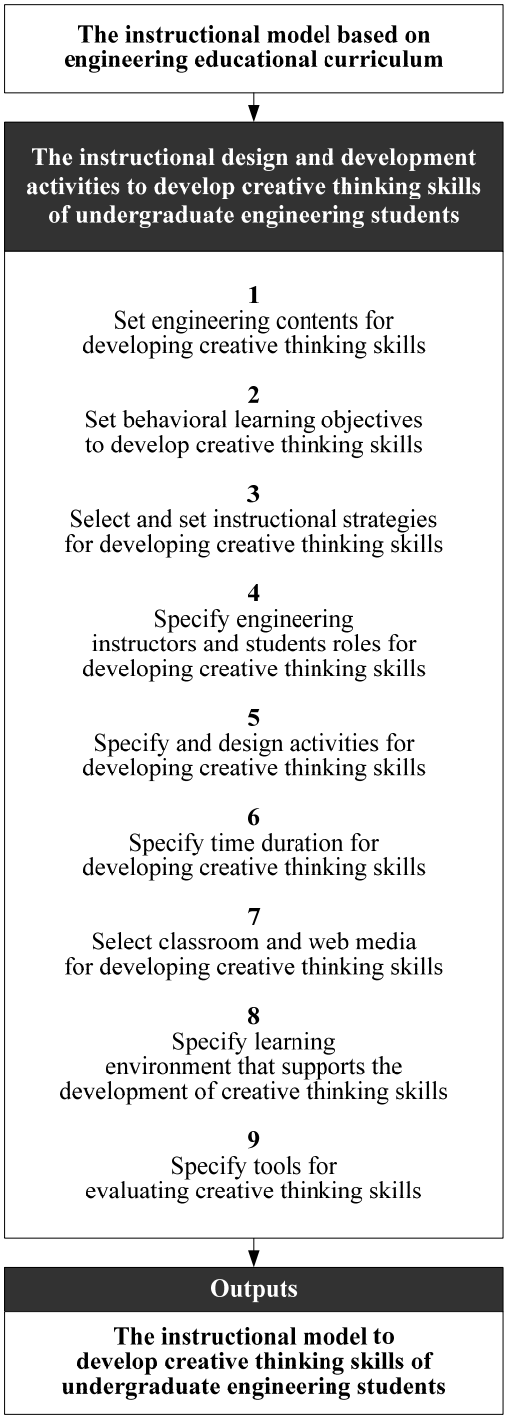

Fig. 1. The instructional design and development activities to develop creative thinking skills of undergraduate engineering students.

The instructional design and development activities to develop creative thinking skills of undergraduate engineering students are as follows:

Engineering instructors need to study and follow the instructional design and development activities for designing and developing their instruction consisted of nine steps as follows:

Step 1: Set engineering contents for developing creative thinking skills. Engineering contents focus on engineering synthesis and design. It should be problem-based learning to encourage students to think creatively in engineering problem solving.

Step 2: Set behavioral learning objectives to develop creative thinking skills. Behavioral learning objectives to develop creative thinking skills compose of 11 items:

2.1) Behavioral learning objectives to develop creative thinking skills and to have the following abilities:

2.1.1) Define engineering problems

2.1.2) Gather pertinent information

2.1.3) Write engineering problem solutions

2.1.4) Analyze each potential engineering problem solutions

2.1.5) Evaluate each potential engineering problem solutions against the criteria set

2.1.6) Make prototype to test the engineering problem solutions under the conditions set

2.1.7) Evaluate prototype

2.1.8) Modify and develop prototype under controlling errors

2.1.9) Implement prototype

2.1.10) Write and present engineering problem solutions

2.2) Behavioral learning objectives to develop the engineering creative product designing skills and to have the ability to design the engineering creative products

Step 3: Select and set instructional strategies for developing creative thinking skills. Instructional strategies based on engineering creative problem solving principles to develop creative thinking skills consist of 13 steps:

3.1) Establish and present engineering problem situations

3.2) Define the engineering problems

3.3) Gather pertinent information

3.4) Connect relation between engineering problem and pertinent information to plan engineering problem solutions

3.5) Define goals of engineering problem solutions

3.6) Write engineering problem solutions

3.7) Analyze each potential engineering problem solution

3.8) Evaluate each potential engineering problem solution against the criteria set

3.9) Make prototype to test the engineering problem solutions under the conditions set

3.10) Evaluate prototype

3.11) Modify and develop prototype under controlling errors

3.12) Implement prototype

3.13) Write and present engineering problem solutions

Step 4: Specify engineering instructors and students roles for developing creative thinking skills. Engineering instructors and students roles based on instructional strategies. Both of them should follow all steps of instructional strategies based on engineering creative problem solving principles for developing creative thinking skills.

Step 5: Specify and design activities for developing creative thinking skills. Activities for developing creative thinking skills are divided into 2 types:

5.1) Activities in class consist of 5 activities:
5.1.1) Case study
5.1.2) Questioning: 5W1H
5.1.3) Inventive thinking
5.1.4) Mind mapping
5.1.5) Brain storming
5.2) Activities on web via web tools consist of 10 web tools:
5.2.1) Chat room
5.2.2) Video conferencing
5.2.3) Instant messaging
5.2.4) Web conferencing
5.2.5) Electronic mail: E-mail
5.2.6) Web boards
5.2.7) Blog
5.2.8) Group announcements
5.2.9) Wiki
5.2.10) Facebook

Step 6: Specify time duration for developing creative thinking skills. Time duration for developing creative thinking skills takes approximately 6-8 weeks or 10-15 periods in a semester.

Step 7: Select classroom and web media for developing creative thinking skills. Classroom and web media for developing creative thinking skills consist of 4 media:

7.1) Documents, books and textbooks based on self learning
7.2) Slides with description
7.3) Pictures and videos focusing on engineering creative problem solving presentation or creative product design
7.4) Practices focused on questions and answers concerning problem situation and practice as well as learning resources from a reliable data source.

Step 8: Specify learning environment that supports the development of creative thinking skills. Learning environment that supports the development of creative thinking skills are grouped into 3 types:

8.1) Physical environment
8.2) Psychological environment
8.3) Sociological environment

Step 9: Specify tools for evaluating creative thinking skills. Tools for evaluating creative thinking skills consist of 2 tools:

9.1) Engineering creative thinking test for undergraduate engineering students
9.2) Engineering creative product evaluation for evaluators

Procedures: The data was collected through the instructional design and development activities including the steps for designing and developing instructions in a systematic practice. All steps integrated the crucial instructional components affecting creative thinking skills. Moreover, all steps show the examples that could help engineering instructors design their instructional model easier. The participants who designed instructions according to the instructional design and development activities consisted of 4 engineering instructors.

Data analysis: The data of the questionnaire in check list form were scored by asking experts' opinions and were analyzed by using arithmetic mean. The data of the questionnaire, the evaluation in open-ended form and the individual interviews were analyzed by using descriptive analysis.

The results of the first step showed that the instructional model which was designed by the instructional design and development activities consisted of 4 subjects. The 4 instructional models were different based on each subject characteristic.

Phase 2: evaluate the instructional model to develop creative thinking skills of undergraduate engineering students as follows:

Participants: The participants evaluated the instructional model that was selected through the snowball sampling technique. The participants consisted of 6 experts. There were 3 experts in instructional design and 3 experts in engineering instruction. All of them need to have experience at least 5 years or have conducted a research with educational acceptance.

Procedures: The data was collected through the questionnaires on the expert evaluation of the overall instructional model. There were 2 sets of questionnaires for each group of experts. The participants who evaluated the instructional model according to the evaluation form consisted of 6 experts from 4 different public universities/ institutions in Thailand. There were 3 experts in instructional design and 3 experts in engineering instruction using IOC index of congruence, alongside individual interviews.

Data analysis: The data of the evaluation in check list form were scored by using experts' opinion and analyzed by using arithmetic mean. The data of the questionnaires and the individual interviews in open-ended form were analyzed by using descriptive analysis.

The results of the second step showed that the 4 instructional models which were evaluated by experts.

III. Findings

The findings of this research were the presentation of the instructional design and development activities that consisted of two parts as follow:

Part 1: Presentation of instructional design and development activities to develop creative thinking skills of undergraduate engineering students as follows:

Engineering instructors who designed their instruction according to the instructional design and development activities could improve their instructional design skills in a high level. First, they started writing engineering contents for developing creative thinking skills. Engineering contents focus on engineering synthesis and design. It should be problem-based learning to encourage students to think creatively in engineering problem solving.

Second, they set behavioral learning objectives to develop creative thinking skills. Behavioral learning objectives to develop creative thinking skills comprise of 11 items: 1) Behavioral learning objectives to develop creative thinking skills and to have the following abilities: 1.1) Define engineering problems 1.2) Gather pertinent information 1.3) Write engineering problem solutions 1.4) Analyze each potential engineering problem solution 1.5) Evaluate each potential engineering problem solution against the criteria set 1.6) Make prototype to test the engineering problem solutions under the conditions set 1.7) Evaluate prototype 1.8) Modify and develop prototype under controlling errors 1.9) Implement prototype 1.10) Write and present engineering

problem solutions 2) Behavioral learning objectives to develop the engineering creative product designing skills and to have the ability to design the engineering creative products.

Third, they selected and set instructional strategies for developing creative thinking skills. Instructional strategies based on engineering creative problem solving principles to develop creative thinking skills compose of 13 steps: 1) Establish and present engineering problem situations 2) Define the engineering problems 3) Gather pertinent information 4) Connect relation between engineering problem and pertinent information to plan engineering problem solutions 5) Define goals of engineering problem solutions 6) Write engineering problem solutions 7) Analyze each potential engineering problem solution 8) Evaluate each potential engineering problem solution against the criteria set 9) Make prototype to test the engineering problem solutions under the conditions set 10) Evaluate prototype 11) Modify and develop prototype under controlling errors 12) Implement prototype 13) Write and present engineering problem solutions.

Fourth, they specified and wrote engineering instructors and students roles for developing creative thinking skills. Engineering instructor and student roles based on instructional strategies. Both of them should follow all steps of instructional strategies based on engineering creative problem solving principles for developing creative thinking skills.

Fifth, they specified and designed activities for developing creative thinking skills. Activities for developing creative thinking skills are divided into 2 types: 1) Activities in class consist of 5 activities: 1.1) Case study 1.2) Questioning: 5W1H 1.3) Inventive thinking 1.4) Mind mapping 1.5) Brain storming 2) Activities on web via web tools consist of 10 web tools: 2.1) Chat room 2.2) Video conferencing 2.3) Instant messaging 2.4) Web conferencing 2.5) Electronic mail: E-mail 2.6) Web boards 2.7) Blog 2.8) Group announcements 2.9) Wiki 2.10) Facebook.

Sixth, they specified and wrote time duration for developing creative thinking skills. Time duration for developing creative thinking skills is approximately 6-8 weeks or 10-15 periods in a semester.

Seventh, they selected and wrote classroom and web media for developing creative thinking skills. Classroom and web media for developing creative thinking skills consist of 4 media: 7.1) Document, books and textbooks based on self learning 7.2) Slides with description 7.3) Pictures and videos focusing on engineering creative problem solving presentation or creative product design 7.4) Practices focused on questions and answers concerning problem situation and practice as well as learning resources from a reliable data source.

Eighth, they specified and wrote learning environment that supports the development of creative thinking skills. Learning environment that supports the development of creative thinking skills consists of 3 types: 8.1) Physical environment 8.2) Psychological environment 8.3) Sociological environment.

Ninth, they specified and wrote tools for evaluating creative thinking skills. Tools for evaluating creative thinking skills consist of 2 tools: 1) Engineering creative thinking test for undergraduate engineering students 2) Engineering creative product evaluation for evaluators. The results of the first part showed that the instructional model which was designed by the instructional design and development activities consisted of 4 subjects. The 4 instructional models were different based on each subject characteristic.

Part 2: Evaluation of the instructional model to develop creative thinking skills of undergraduate engineering students as follows:

Experts reviewed and evaluated the instructional model according to the questionnaires concerning the evaluation of the overall instructional model. All experts agreed that this instructional model was appropriate in a good level (for three out of four subjects) and an excellent level (for one of the four subjects). It showed that the instructional design and development activities is an efficient practice of instructional design and development to develop undergraduate engineering students' creative thinking skills. It could help engineering instructors design their instructional model easier and help engineering instructors to design and develop a more efficient instructional model.

Furthermore, regarding the satisfaction of all engineering instructors on the instructional design and development activities, it showed that they were satisfied in a high level because they can design their instructional model systematically and by themselves though the instructional design and development activities. They will continue to use the instructional design and development activities further for other engineering subjects.

IV. Discussion

According to the results, characteristic of the instructional design and development activities obviously differs from the previous instructional activities as follows:

1) The step-by-step instructional design and development activities help all engineering instructors understand how to design and develop their instructional model in systematic practice. These activities emphasize the explanation for basic instructional design or non instructional design and try to illustrate the integration of all instructional components that help engineering instructors get idea and design their instructional model more efficiently. The result shows that the participants who designed instructions according to the instructional design and development activities consist of 4 engineering instructors. All engineering instructors can completely design and develop their instructional model by themselves. Afterwards, the evaluations of their instructional model are performed by 6 experts in instructional design and engineering instruction. All experts agree that their instructional models are appropriate in a good level (for three out of four subjects) and an excellent level (for one of the four subjects). These results strongly support that the instructional design and development activities could surely help engineering instructors completely design and develop their instructional model more efficiently. These step-by-step activities is the same as the instructional design process of Kemp [6] that emphasizes on explaining all steps clearly to help instructional designers design their instruction by themselves.

Another similar instructional design process is A Multiple Intelligences Case of Tracy and Richey [7] which emphasizes on explaining all steps with the example that help instructional designers understand more.

2) The instructional model differs from previous instructional model because this instructional model specifically aims to develop undergraduate engineering students' creative thinking skills. It reveals the creative thinking skills and the engineering creative product designing skills. Both of them are essential to support the industrial sector and to follow The Tenth National Economic and Social Development Plan (2007-2011), so that the graduates possess the creative thinking skills needed for their work [3], [4], [5]. Furthermore, this instructional model integrates instructional components that truly affect creative thinking skills. This instructional model is the same as the development of teaching model which uses mind mapping to enhance nursing students' creative thinking ability [8]. This instructional model integrated important instructional components affecting nursing students' creative thinking ability, especially, by using mind mapping. Another similar instructional model is a proposed web-based instructional model based on constructivist concept using electronic portfolio for creative thinking development of undergraduate students in social sciences, Chulalongkorn University [9]. This instructional model integrates important instructional components affecting creative thinking, especially, by using electronic portfolio. One more similar instructional model is a web-based instructional model based on brain-based learning process in design course to enhance creative thinking of undergraduate students [10]. This instructional model integrates learning process affecting creative thinking, especially, by using brain-based learning process in design course.

V. Conclusion

The result of this research study is the presentation of the instructional design and development activities to develop creative thinking skills of undergraduate engineering students. These activities emphasize on the explanation for basic instructional design or non instructional design and illustrate the integration of all instructional components that help engineering instructors get idea and design their instructional model more efficiently. It confirms that these step-by-step activities can help all engineering instructors design and develop their instructional model by themselves.

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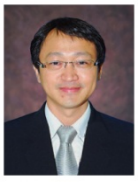

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