

The Validation of an Instructional Design and Development Model Based on Engineering Creative Problem Solving Principles to Develop Creative Thinking Skills of Undergraduate Engineering Students

Thapanee Seechaliao ¹⁺, Onjaree Natakatoong ² and Witaya Wannasuphprasit ³

¹ Maha Sarakham, Thailand

² Faculty of Education, Chulalongkorn University, Thailand

³ Faculty of Engineering, Chulalongkorn University, Thailand

Abstract. This research study aimed to validate a model of instructional design and development based on engineering creative problem solving principles to develop creative thinking skills of undergraduate engineering students. The research methodology used was research and development approach consisted of two steps. The first step was to validate the instructional design and development for engineering creative thinking model (IDECT model). The participants who designed instructions using the IDECT model consisted of four volunteered engineering instructors at the Faculty of Engineering, Chulalongkorn University, Thailand. These four engineering instructors designed their own classes. A teaching and learning process evaluation was performed by six instructional designers and engineering instructors. The second step was to evaluate the IDECT model itself by the same six experts in instructional design and engineering. Data were collected and analyzed by using arithmetic mean and descriptive analysis. The results were as follows: the participants who designed instructions according to the IDECT model were able to improve their instructional design skills in a high level. The six experts agreed that the IDECT model was appropriate in an excellent level.

Keywords: instructional design model, engineering creative problem solving, creative thinking skills.

1. Introduction

Engineering educational curriculum of Thailand aims to enhance engineering graduates to support the industrial sector and to follow The Tenth National Economic and Social Development Plan (2007-2011). Therefore, public universities/institutions need to improve engineering educational curriculum in diverse programs and emphasize the quality of engineering graduates including skills, knowledge, and habits (Chansangavej et al. 2005; Deeya 2006, pp.60-72). The emphasis should be especially made on the skills. Engineers always use 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. Engineering programs are mostly developed to ensure that engineering students attain an ability to design and develop creative thinking skills. (Farid et al. 1993, pp.399-409; Lumsdaine et al. 1999; Holtzapple and Reece 2003; Haik 2003; Lawson 2006; Sasananan 2007; Howard et al. 2008, pp.160-180)

Earlier research concerning a creative thinking skills development in engineering education has shown that there are lots of 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 encourages thinking skills, and integrating the thinking skills in contents. Despite the emphasis, the quality of engineering graduates showed that they lacked an ability to design and develop creative thinking skills (Marzano et al. 1988; Chansangavej et al.

⁺ Corresponding author. Tel.: +66(43-711117); fax: +66(43-711117).
E-mail address: (thapanee.see@hotmail.com).

2005; Deeya 2006, pp.60-72) This problem should be solved, so that the graduates possess the creative thinking skills needed for their work.

The instructional design and development model could solve the problem stated above. This model could help instructors come up with a systematic plan to connect instructional components. There are nine crucial instructional components affecting creative thinking skills as follows: 1) Contents; 2) Learning objectives; 3) Instructional strategies; 4) Engineering instructor and student roles; 5) Activities; 6) Time duration; 7) Classroom and web media, Learning resource; 8) Learning environment; and 9) Evaluation. This model could help instructors design and develop a more efficient instructional model and this very model could also help students learn more and achieve learning objectives as expected. Instructors need to follow the process of the instructional design and development model which includes analysis, design, development, implementation, and evaluation for designing and developing their instruction.

One of the most important instructional components affecting creative thinking skills is the instructional strategies or principles. Engineering creative problem solving principles could support and develop creative thinking skills as well (Marzano et al. 1988). It was analyzed and synthesized from problem solving principles, engineering problem solving principles and engineering creative principles to support engineering learning and to develop an ability to design and think creatively (Ghosh 1993, pp.113-119; Jonassen 1997; Sasananan 2007). The step of engineering creative problem solving starts from defining the engineering problem. Next, the engineers gather pertinent information, knowledge or prior experience concerning the problem situation to solve problems appropriately. Engineers need to think creatively and find new idea to solve problems in various ways, different from previous problem solutions. Then, they decide on the best problem solution in accordance to engineering method (Wallas 1949; Guilford 1970; Jonassen 1997; Lumsdaine et al. 1999; Lawson 2006; Moshe 1975; Smith 1991; Arvid et al. 2002; Howell 2002; Voland 1999; Holtzapple and Reece 2003; Morell and Beauchamp 1995).

The instructional design and development for engineering creative thinking model (IDECT model) was constructed to be as a guideline as well as a tool of the instructional design and development model based on engineering creative problem solving principles to develop undergraduate engineering students' creative thinking skills in systematical practice. It reveals components that obviously affect creative thinking skills and steps for designing and developing instructions to develop creative thinking skills. It could help engineering instructors design and develop more efficient instructional models. However, the IDECT model does not ensure whether engineering instructors can design instructions according to the IDECT model or not.

From the problem stated above, the IDECT model should be undoubtedly validated. The literature review of validating instructional design and development model showed that there were lots of validating strategies, for example, 1) expert review, 2) usability documentation, 3) component investigation, 4) field evaluation, and 5) controlled testing (Davis et al. 1974; Weston et al. 1995; Rusameprome 1999; Gustafson & Branch 2002; Richey 2005; Tracey and Richey 2007, pp.369-390; Jeerungsuwan 2006). Furthermore, the opinions of experts in engineering instruction regarding validating the IDECT model showed that this model should be validated through 1) controlled testing, and 2) expert review. Therefore, firstly, engineering instructors should design and develop their instructional model according to the IDECT model. After that, their instructional model should be reviewed and evaluated through the questionnaires concerning the evaluation of overall instructional model by experts. Secondly, the IDECT model should be reviewed and evaluated through the evaluation form by experts. This research aims to validate the IDECT model.

2. Research methodology

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

Step 1: Validate the model of instructional design and development based on engineering creative problem solving principles to develop creative thinking skills of undergraduate engineering students as follows:

Participants: The volunteered participants designed instruction according to the IDECT model. They consisted 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 for engineering creative thinking model (IDECT model) as follows:

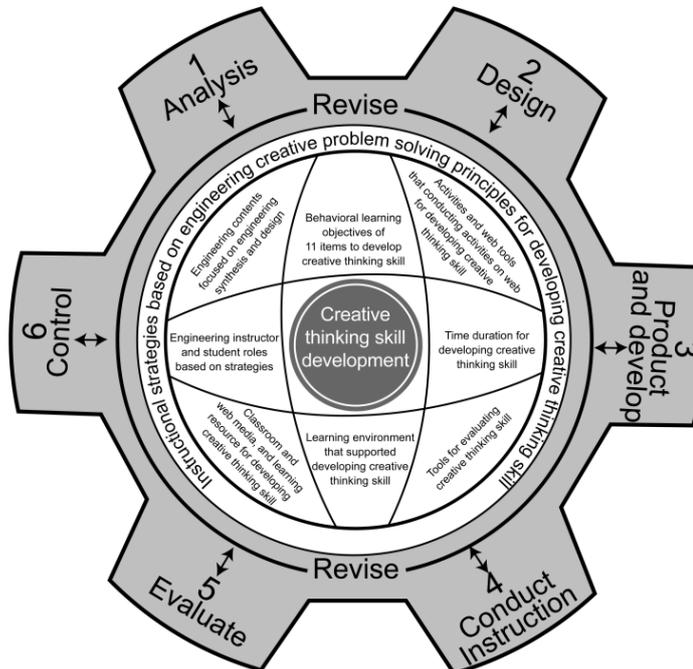


Fig. 1: The instructional design and development model based on engineering creative problem solving principles to develop creative thinking skills of undergraduate engineering students

This model is comprised of three parts as follows:

Part 1: Objectives of this model

1. To be a tool of instructional design and development model based on engineering creative problem solving principles to develop creative thinking skills of undergraduate engineering students in systematic practice. It could help engineering instructors to design and develop more efficient instructional models.

2. To increase engineering instructors' ability in instructional design and development.

Part 2: Components of this model

This model consists of 9 components which obviously affect creative thinking skills as follows:

1) Engineering contents which focus on engineering synthesis and design. It should be problem-based learning to encourage students to think creatively in engineering problem solving.

2) Behavioral learning objectives to develop creative thinking skills consisted of 11 items:

2.1) Behavioral learning objectives to develop creative thinking skills and to have abilities as follows:

- 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

3) 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 an engineering problem solutions 3.5) Define goals of engineering problem solutions 3.6) Write engineering problem solutions 3.7) Analyze each potential engineering problem

solutions 3.8) Evaluate each potential engineering problem solutions 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.

4) 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.

5) Activities for developing creative thinking skills 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

6) Time duration for developing creative thinking skills (approximately 6-8 weeks or 10-15 periods in a semester)

7) Classroom and web media for developing creative thinking skills consisted 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 question and answer concerning problem situation and practice as well as learning resources from a reliable data source.

8) Learning environment that supports the development of creative thinking skills consisted of 3 types: 8.1) Physical environment 8.2) Psychological environment 8.3) Sociological environment

9) Tools for evaluating creative thinking skills consisted of 2 tools: 9.1) Engineering creative thinking test for undergraduate engineering students 9.2) Engineering creative product evaluation for evaluators

Part 3: Steps of this model

The instructional design and development model consist of 6 steps:

1) Analysis: analyze all components that effect the development of creative thinking skills. The result of this step is that instructional components affect creative thinking skills.

2) Design: design instructions to develop creative thinking skills. The result of this step is the instructional model based on engineering creative problem solving principles to develop creative thinking skills for undergraduate engineering students.

3) Product and development: produce and develop classroom and web media, and evaluate tools that they designed in the previous step. The result of this step is classroom and web media for developing creative thinking skills. Also, tools for evaluating creative thinking skills are the consequence of the step.

4) Conduct instruction: conduct instruction based on instructional model. The result of this step is the report of instructional conduction.

5) Evaluation: evaluate the creative thinking skills. The result of this step is the report of engineering creative thinking test and the report of engineering creative product evaluation.

6) Control: controlling instructional conduction based on the instructional model. The result of this step is the report of instructional conducted control. It would be more efficient if the instructional conduction is completely based on instructional model.

Procedures: The data were collected through the IDECT model. It is a guideline as well as a tool of an instructional design and development model based on engineering creative problem solving principles to develop undergraduate engineering students' creative thinking skills in a systematical practice. It reveals components that obviously affect creative thinking skills and the steps for designing and developing instructions to develop creative thinking skills. Furthermore, all steps show the example that could help engineering instructors design their instructional model easier. The participants who designed instructions according to the IDECT model consisted of 4 engineering instructors. After that, 4 instructional models were

evaluated through the questionnaires concerning the evaluation of overall instructional model by experts, alongside individual interviews.

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

The results of the first step showed that the instructional model which was designed by the IDECT model consisted of 4 subjects that were evaluated through the questionnaires concerning the evaluation of overall instructional model by experts. The evaluation comprised of the engineering creative thinking skill test and the engineering creative product evaluation.

Step 2: Evaluate the model of instructional design and development based on engineering creative problem solving principles to develop creative thinking skills of undergraduate engineering students. This step was reviewed and evaluated by experts.

Participants: The participants were reviewed and evaluated the IDECT 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 needed to have at least 5 years of experience or have conducted research with educational acceptance.

Research instrument: The research instruments were the questionnaires concerning the evaluation of overall the IDECT model for expert. There were 2 sets of questionnaires for each group of expert.

Procedures: The data were collected through the questionnaires concerning the evaluation of overall the IDECT model for expert. There were 2 sets of questionnaires for each group of expert. The participants who evaluated the IDECT 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 questionnaire and the individual interview in open-ended form were analyzed by using descriptive analysis.

The results of the second step showed a reviewed and evaluated IDECT model through the questionnaires concerning the evaluation of overall instructional design and development model for experts.

3. Results

The results of this research were the validation of the IDECT model that consisted of two parts as follow:

Part 1: Validate the IDECT model as follows:

1) Implement the model of instructional design and development according to the IDECT model

Engineering instructors who designed their instruction according to the IDECT model could improve their instructional design skills in a high level. First, they started analyzing all components that effect the development of creative thinking skills. They had to consider each component that was suitable for their instructional model including engineering contents focusing on encouraging students to think creatively in engineering problem solving, behavioral learning objectives to develop creative thinking skills, instructional strategies based on engineering creative problem solving principles to develop creative thinking skills, engineering instructor and student roles based on strategies, activities and web tools that conduct activities on the web for developing creative thinking skills, time duration for developing creative thinking skills, classroom and web media, learning resource from a reliable data source, learning environment that supported developing creative thinking skills, and tools for evaluating creative thinking skills. The result of this step is that instructional components affect creative thinking skills. Second, they designed instructions to develop creative thinking skills. They had to connect and select each component to design their instructional model. The result of this step is the instructional model based on engineering creative problem solving principles to develop creative thinking skills for undergraduate engineering students. Third, they produced and developed classroom and web media, and evaluate tools that they designed in the previous step. The results of this step are classroom and web media for developing creative thinking skills, and tools for evaluating creative

thinking skills. Fourth, they conducted instructions based on the instructional model. They have to explain the instructions that would be conducted both in class and on web including behavioral learning objectives to develop creative thinking skills, instructional strategies based on engineering creative problem solving principles to develop creative thinking skills, engineering instructors and students roles based on instructional strategies, activities in class and on web, time duration for each activity, creative thinking skills test, and creative product evaluation. While carrying out instructions, he could change activity to be more suitable for his course at anytime appropriate. The result of this step is the report of instructional conduction. Fifth, they evaluated the creative thinking skills. They should evaluate the creative thinking skills both creative thinking skills and engineering creative product. The result of this step is the report of engineering creative thinking test including creative thinking skill scores: defining engineering problems, gathering pertinent information, writing engineering problem solutions, analyzing each potential engineering problem solutions, evaluating each potential engineering problem solutions against the criteria set, making prototype to test the engineering problem solutions under the conditions set, evaluating prototype, modifying and developing prototype under controlling errors, implementing prototype, and writing and presenting engineering problem solutions. In addition, the report of engineering creative product evaluation includes creative product scores: 1. Novelty: 1.1 Original, 1.2 Surprising; 2. Resolution: 2.1 Valuable, 2.2 Logical, 2.3 Useful; 3. Elaboration & Synthesis: 3.1 Organic, 3.2 Understandable. Sixth, they have to control instructional conduction based on the instructional model. The result of this step is the report of instructional conducted control. It would be more efficient if the instructional conduction is completely based on instructional model.

2) Evaluate the instructional model

The four instructors from three different departments at the Faculty of Engineering, Chulalongkorn University. The evaluations showed that all engineering instructors had been enhancing their ability in instructional design and development. They could select items from each instructional component that were only suitable for their courses. All instructional models integrated engineering creative problem solving strategies in 13 steps. Engineering creative thinking skills testing was tested through the engineering creative thinking skill test in 10 skills. Engineering creative product evaluation was evaluated through the engineering creative product evaluation in 3 dimensions. All instructional models were evaluated by 6 experts. All experts agreed that this instructional model was appropriate in a good level and an excellent level. Furthermore, regarding the satisfaction of all engineering instructors on the IDECT model validation, it showed that they were satisfied in high level.

Part 2: Evaluate the IDECT model as follows:

1) Evaluate the IDECT model.

Experts reviewed and evaluated the IDECT model by answering the questionnaires on the evaluation of overall IDECT model for experts. The experts 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. The results were as follows:

1.1) Experts reviewed the IDECT model as follows:

Main point

- The framework of the IDECT model obviously aims to design and develop instruction for developing creative thinking skills and engineering creative product designing skills, especially for undergraduate engineering students. It can help engineering instructors design and develop their instructional model to be more efficient and this instructional model can help undergraduate engineering students learn more and develop their creative thinking skills as expected.
- The IDECT model consists of components and steps. All these components affect creative thinking skills and specifically aim to create creative thinking skills in engineering. These components can help undergraduate engineering students learn more and develop their creative thinking skills as expected. Furthermore, each step shows examples of how to design and develop instructional model, making it easy for instructors to understand and improve their own instructional models.

- The IDECT model is a highly flexible. Engineering instructors can select items from each instructional component that is suitable for their course. While the instructions are being carried out, the instructors could change activity as seemed fitted at anytime appropriate.
- The IDECT Model integrates motivation principles that encourage students to realize that creative thinking skills are important for them. And then, create an inner motivation to think creatively in engineering problem solution by integrating motivation principles into instructional strategy. The motivations that make students feel more confident and successful in learning.
- The IDECT model considers the learning environment that is important to encourage students to think creatively for activities both in individuals and in groups.

Weak point

- The redundant steps from each step of the IDECT model should be reduced in order to help engineering instructors design and develop their instruction model in shorter time.

1.2) Experts validated and evaluated the IDECT model as follows:

- The IDECT model was considered as appropriate in an excellent level.

The IDECT model was revised so that it is more suitable for engineering instructors. The model was revised from the interview of participants concerning the validation of the IDECT model and the evaluation of experts concerning the weak point of the IDECT model.

4. Discussion

According to the results, validation of the IDECT Model obviously differs from the previous instructional design and development model as follows:

1) The IDECT Model is strongly validated through 1) implementation, and 2) expert review. The result shows that engineering instructors can completely design and develop their instructional model according to the IDECT model. Furthermore, the result of experts review shows that the IDECT model is appropriate in an excellent level. This validation of the instructional design and development model uses the same validation strategies of Davis, et al. (1974) which consists of 2 validation strategies: 1) Expert review 2) Implement instructional design model. The same validation strategies are of Richey (2005) Gustafson and Branch (2002) which composed of 5 validation strategies: 1) Expert review 2) Usability documentation 3) Component investigation 4) Field evaluation 5) Controlled testing. Another similar validation strategies are of Tracey and Richey (2007) which comprised of 2 validating strategies: 1) Expert review through Delphi technique in 3 rounds 2) Implement instructional design model with 4 instructional designers.

2) The IDECT model validation is an efficient tool of instructional design and development model based on engineering creative problem solving principles to develop creative thinking skills of undergraduate engineering students in a systematic practice. It could help engineering instructors design their instructional model easier. The result shows that the IDECT model helps all engineering instructors design and develop their instructional model by themselves because this model is constructed from self learning principles. It emphasizes on explanation for basic instructional design or non instructional design and tries to illustrate the connection of all instructional components that help engineering instructors get idea and design their instructional model more efficiently. The instructors can start learning about the IDECT model's 9 components which obviously affect creative thinking skills as follows: 1) Engineering contents focusing on engineering synthesis and design; 2) 11 behavioral learning objectives to develop creative thinking skills; 3) Instructional strategies based on engineering creative problem solving principles to develop creative thinking skills; 4) Engineering instructor and student roles based on designed strategies; 5) Activities and tools for developing creative thinking skills; 6) Time duration for developing creative thinking skill; 7) Classroom media and web media and learning resources from a reliable data sources; 8) Learning environment; and 9) Tools for evaluating creative thinking skills. Then, the instructors consider what item should be selected for their courses. They can follow 6 steps of the IDECT model to design and develop their instructional models as follows: 1) Analyze the components effecting the development of creative thinking skills; 2) Design instructions for developing creative thinking skills; 3) Produce and develop media and tools; 4) Conduct instructions based on instructional model; 5) Evaluate creative thinking skills; and 6) Control instructional

conduct based on instructional model. The result shows that the participants who designed instructions according to the IDECT model consisted of 4 engineering instructors. All engineering instructors can completely design and develop their instructional model in a high level. The participants who reviewed and evaluated the IDECT model consisted of 6 experts. All experts agreed that the IDECT model was appropriate in an excellent level. These results strongly support that the IDECT model could surely help engineering instructors completely design their instructional model more efficiently. This model is the same as the instructional design model of Kemp (Kemp 2001) that emphasizes on explaining all steps clearly to help instructional designers design their instruction by themselves. Another similar instructional design model is A Multiple Intelligences Case of Tracy and Richey (Tracey and Richey 2007 pp.369-390) which emphasizes on explaining all steps with the example that help instructional designers understand more.

3) After engineering instructors designed instructions according to the IDECT model. The result is that the instructional model differs from previous instructional model because this instructional model aims to develop creative thinking skills and to develop the engineering creative product designing skills. 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 used mind mapping to enhance nursing students' creative thinking ability (Praevanich 2000). 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 (Sujarittanatrugse 2005). This instructional model integrated 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 (Phrompan 2007). This instructional model is integrated learning process affecting creative thinking, especially, by using brain-based learning process in design course.

5. Conclusion

The result of this research study is instructional design and development model validation. The IDECT model is strongly validated through 1) implementation, and 2) expert review. It confirms that The IDECT model can help engineering instructors design and develop their instructional model in a more efficient manner.

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