STEAM Education for Enhancing Creativity in Packaging Design

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Abstract

Background The creative development of packaging design, using the STEAM teaching method and combined with Guilford (1950)'s creative design, was synthesized into a teaching model named "CREATE." Each stage of the model included learning management, following the STEAM Education ideas (Yakman & Lee, 2012) that integrated science, technology, engineering, mathematics and arts links in each step. The principles of Structural Packaging and Creating Packaging with this system enabled students to design packaging with an imaginative form, an exotic shape, which required bending and deforming at various angles. The integrated design technique, allowed designers to develop a large variety of shapes. For packaging, this developed the ability for design in the long-term.

Methods The population consisted of 120 second-year students of the Industrial Craft Design Program at Thammasat University, Thailand. We used purposive selection to sample 30 subjects. In the experiment, we used these tools: 1) CREATE model for teaching in the subject of "Creative Packaging Design" 2) Lesson Plan 3) Test of Creative Thinking. Data was collected three times - before studying (Pretest: 1), after studying (Posttest: 2) and in a follow-up phase (Follow up: 3) - to study the effects of creativity with repeated measure ANOVA.

Results The mean of the repeated measurements for the creative score of packaging design from the ANOVA multivariate test was significantly less than the target significance level ($p<0.05$). This showed that the independent variable (i.e., the practice score from using our STEAM method) affected the dependent variable (i.e., the score assigned for creativity in the student assignment) submitted in the Packaging Design course. The posttest (Posttest: 2) scores were significantly higher than the pretest scores ($p<0.05$) and the scores two weeks after graduation (Follow up: 3) were also higher than the pretest scores ($p<0.05$). Thus, retention of the key ideas taught in the course, was high. Furthermore, the posttest and follow up phase scores were not significantly different, thus confirming good retention.

Conclusions We studied creativity in packaging design of students using our CREATE Model for teaching in computer graphic design courses. Each step of the teaching model applied STEAM Education for students to use the concepts in a scientific process, combined with the theory of packaging design. Key aspects of our approach were the exchange of ideas among students, the activities designed to encourage creativity and generally enjoying 'thinking outside the box'. so that learners strengthened their ability to design creative packaging, could develop packaging designs in a variety of formats and retain learned concepts.

Keywords Instructional Design, STEAM Education, Creative Thinking, Package Design

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1. Introduction

Creativity is essential in the development of innovative designs. There are many important factors, for example sensitivity to problem, awareness and quick solutions Crilly (2015). Guilford (1950) stated that a person who wants to know or find a problem needs to be active and different. Gruber (1981) emphasized that resolute determination will lead to discovering the real problem.

Natural factors, in many ways, affect creativity, for example - genetics or different species. Creativity can be inherited, but Eysenck (1979) found that blood relatives differed in creativity. Cole (1979) reported that a significant factor is an environment, in which children grew up, which can make the creativity of each child different. Thus, one of the factors that cause personal differences in creativity from an interactive perspective are personality, social demeanor and intellectual ability.

In addition to natural factors, that make each person different, creativity also can be practiced and learnt. Gestalt psychologists (e.g. Henle, 1962, 1974; Wertheimer, 1959) state that stimulating good creativity is to put questions into the right position. The techniques that have been used include:

1. Conflicting questions.
2. Unexpected questions, not related to other questions.
3. Questions that make new phenomena.
4. Questions based on scientific assumptions.
5. Questions that science finds difficult to explain.
6. Questions that cause thinking.

More detail for each of these techniques follows:

1. Conflicting questions train us to choose one of the answers for a question with good supporting reasons. An example question might be: “if two people in the water are drowning and you have reason to be grateful to both, who will both choose to help? Why?”
2. Unexpected questions are unrelated to other questions and are questions, that stimulate thinking, where we were not personally involved or predicted in advance. For example: “What kind of pet and why?”, where pets have not been previously mentioned in this context.
3. Questions that are related to new phenomena or drive innovation, changes in behavior and in mind sets. For example: “If no Covid vaccine is found, how can we spend our lives and travel?”.
4. Questions based on scientific hypotheses that form the basis of questions, for example: "How can I create an automatic device that can cleans used transparency sheets?" and “How is it most effective?”
5. Questions that science finds difficult to explain are ones that are independent of scientific theory or simply cannot be explained by science. For example: “Do black holes exist?”
6. Questions that cause thinking make the respondent think to explain the answer. Use meditation and wisdom as a way of asking students to think about creating new, unique ideas. Example questions might be: “Unused newspaper - what toys can be crafted from it?” or “How old boxes or crates can be reused?”

Creativity is essential in teaching and learning, especially in graphic design, and it requires meeting the four distinct characteristics stated by Guilford (1950): 1. sensitivity to problems, 2. active thinking, 3. thinking in a novel style and 4. flexibility. In detail:

1. Sensitivity to problems implies that a creative person is able to recognize problems, and also to reach or understand misunderstandings. A person's sensitivity to a problem is the most important thing, because he or she will not be able to solve the problem, until he or she understands what the real problem is, or, at least, knows that the problem exists.
2. Active thinking encourages students to participate in expressing their opinions independently. This will help to promote the learner creativity. Today, the subject of thinking development is widely accepted in educational institutions at all levels, from preschool to tertiary level. Although general, this applies especially for students training to be teachers, who will have to go out to teach in the future.
3. Thinking in a novel style creates images or simulates role-playing for oneself. Thinking in these visual or narrative styles, uses imagination and help significantly.

4. Flexibility A creative person is able to find multiple ways to solve problems. Rather than using a single method, he or she thinks flexibly and will remember failed solutions to previous problems, so as not to try them over and over again, but will choose a new method, that might solve the problem had it been adopted instead.

In 21st century education, educational technology to solve creative problems is not only specific to science, technology or engineering and mathematics, but they are all integrated into the instructional system called STEM (Kelley & Knowles, 2016) Now, solving problems or increasing creativity requires art to help provide flexibility and integration of each science. Boy et al. (2013), in in-depth interviews with teachers, found that art-based teaching allowed learners to truly develop creativity. Kim & Park (2012) also studied the instructional system called STEAM (Science, Technology, Engineering, Art, and Mathematics) in creating educational innovation, and they found that STEAM helped promote creativity in the design of workpieces.

Overall, we wanted to show that the STEAM instructional model helped students to develop creativity in packaging design to a greater extent. There would be development in learning, consistent with work of Shim & Lee (2019), who studied their "Multi-Converging Educational Program for Design using a 3D Printer", a course targeted for secondary school students: they showed that lessons and learning activities affected design and creative scores. Van der Lugt (2000) developed a graphic tool to solve problems by using concepts as sentences, that stimulated problem-solving in group design on sketched or mock up designs. There was a noticeable variation of brainstorming techniques, that affected STEAM education in interdisciplinary studies (Guyotte *et al*, 2014). STEAM Education was also used to organize performance events. 'Art serves society' as the activity stimulated creativity from many parties. Guyette *et al*. (2015), in a study of collaborative creativity in STEAM in an Interdisciplinary Area, found that creative storytelling in painting was driven by STEAM Education. Interdisciplinary work was better than just individual designing. Engelman *et al.* (2017), in STEAM education with 'EarSketch', found that changing the framework in EarSketch led to significant gains in computer attitudes and creativity. Also, multiple regression analyses found that the creative learning environment, driven by the EarSketch curriculum, was meaningful and personally relevant, enhancing student attitude and willingness to remain on the computer. Allina (2017) developed STEAM educational policy to promote student creativity and social empowerment. The policy recognized the importance of developing STEM to STEAM to respond to a rapidly changing world. The United States currently has a very active channel for entering the 21st century, with strong competition for labor and innovation, it is necessary to develop quality students, connecting all branches science: Allina (2017) claimed that STEAM Education is an answer for this.

In summary, previous research showed that the use of STEAM Education in teaching and learning, whether in content or learning activities, contributed to the development of creativity. Points of design and personal creativity, including helping to promote creativity in group activities, also enhanced a positive attitude in teaching and learning, that integrated various educational sciences.

Creative thinking, aside from being based on various natural fundamentals, can be encouraged and designed by using teaching methods, that stimulate learner curiosity. The teacher can reduce the gap in inherent differences, by using teaching styles that integrate a variety of learning sciences, applied in the form of STEAM Education. Previously, we created the teaching model, "CREATE Model" (Sakon, 2019), which created a STEAM study model with Web apps, that used internet technology, to promote creativity in graphic computer design. In phase 1, we examined the problems of teaching and learning management for computer graphic design courses and showed that learners lacked creativity in packaging design. In response, here, we created a teaching and learning model, based on the principles of STEAM education and creative development, to promote creativity in these design courses, and presented it to seven education experts, who added some suggestions to improve it. The improved model had six processes: 1. Create, 2 Refine, 3 Experience, 4 Art, 5 Technology, and 6 Evaluation. It was tested with a group of students at a Thammasat University (Lampang Campus) to determine whether their creativity in packaging graphic design would actually be enhanced.

Creative thinking was evaluated on four basic metrics: originality, fluency, flexibility and elaboration, used in The Thai context. Although other metrics - problem sensitivity, curiosity, risk-taking, complexity, and imagination – have been used, we focused on the four used in Thailand, because most Thai contexts focus on these four metrics and our preliminary study found they were the most urgent.

We chose to use the CREATE Model, because it includes the STEAM concepts and specified the learning activities at each step.

Our research objective was to evaluate the learning model (CREATE Model) with STEAM Education, that promotes creativity in computer graphic design.

The research hypothesis was: "If we use the STEAM education (CREATE Model) system for teaching in packaging design, we will observe a difference in the creativity score in the design from the three measurements, *i.e.* there must be at least one point where the scores are different."

2. Method

We studied the effect of using the CREATE model in teaching computer graphic design in a unit of a packaging design course at Thammasat University, Thailand, in 2018.

The population was 120 second-year students of the Industrial Craft Design Program at Thammasat University, Thailand. 30 students who registered for the computer graphic design course, a unit in the packaging design course, were selected as subjects, with a purposive selection by sampling system (Bernard, 2017).

The sample group used the CREATE Model - the instructional model included STEAM education in a six-step process, summarized in Figure 1, and described in more detail in Table 1. We collected data on creative design scores three times: firstly, before the course started (Pretest: 1), then immediately following the course (Posttest: 2) and then two weeks after the course was finished (Follow up: 3). The research tools employed were 1) "CREATE" Instruction Model ; 2) Lesson Plan, and 3) Creative design tests.

2. 1. CREATE Model

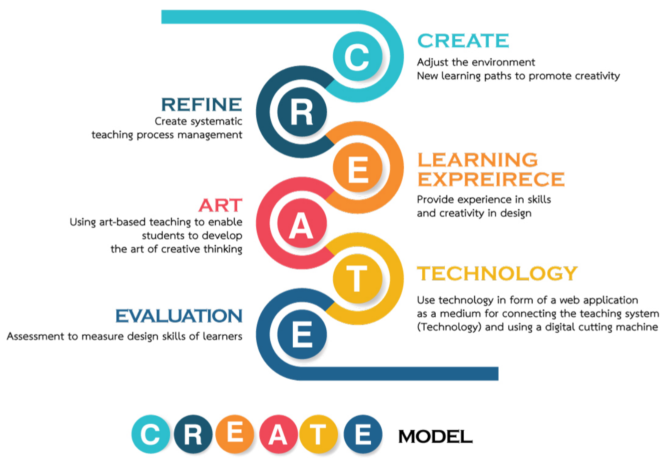


Figure 1: CREATE model used to promote creativity in packaging design

Table 1 Teaching model "CREATE" Activities in each step and roles of learners and teachers

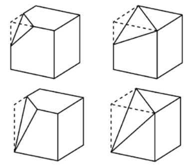
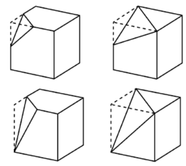
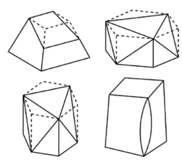
CREATE Process	Learning activities	Learner Role	Teacher Roll
1. Create Create systematic teaching process management	Define content and goals, set problems, and make assumptions (science). Specify package design.	Use science to form hypotheses in the form of mind maps.	Organize a systematic teaching process.
2. Refine Adjust the environment New learning paths to promote creativity	Adjust room layout to be wider to increase design space, arrange a flexible class in a design studio	Organize the classroom in a studio style. Decorate a room with ideas and examples of packaging design.	Prepare for packaging using computer controlled cutting machine
3. Learner Experience Provide experience in skills and creativity in design	Organize activities to improve design streamline in due time. Organize activities to reinforce detailed ideas in calculating the size and design proportions. (mathematics) Uses engineering methods, design training, problem-solving in package design, solution design by drawing sample samples, testing, and solving workpiece problems. (engineering)	Skate design. Package design by using the basic square shape in the design; Forming with the illustrator program; Cutting piece; Basic introduction to the packaging design process.	Advice on how to solve the problem.
4. Art & Design Using art-based teaching to enable students to develop the Art of creative thinking	Design and build packages with the structure of packaging theory.	Create packaging from packaging design theory. Design with Abode Illustrator.	Teaching with packaging design theory about the structure of packaging using the creative system.
5. Technology Use technology in the form of a web application as a medium for connecting the teaching system (Technology) and using a digital cutting machine	Use web application as an intermediary for data linking and receiving workpieces File information must be sent into a system for instructor	Use the web to submit work for the instructor to give advice. Use a chat system to ask, suggest solutions, including using the scalable vector graphics (SVG) file transfer system to connect to a digital cutter.	Advising students in all areas related to the design of the work, including allowing students to use the cutting machine according to the sketch design.
6. Evaluation Assessment to measure the design skills of learners	Assign three project packaging design projects to observe the development of creativity in packaging design.	Follow teacher instructions carefully Ensuring evaluation at each step	Observe and evaluate teaching - before teaching, during instruction and after following the lesson by adhering to the objective specified learning criteria and objectives.

In using the CREATE Model teaching model for teaching computer graphic design courses, we found that, after teaching structural packaging, learners could create a creative packaging form, they could apply various shapes, modified using bending, collapsing, combining or toning, to develop new creative packaging design shapes by using the system techniques (Jason, 2012).

1. Single Deformation: basic shape changes, for example shaving a face, shaving an edge, shaving a corner, twisting a 3-D form, compressing or stretching a 3-D form.
2. Multiple Deformations: techniques that change shape more than once, for example, repeating the form shaving, not just one edge off the cube, but shaving two opposite edges from the top face of the cube to create a form reminiscent of a gable-roofed house, shaving two adjacent edges from the top face of the cube to leave only a small square face on the top. The fourth example shaves three sides from the top face to create a hip roof.

3. Combinational Deformations: Bring together a variety of techniques, allows designers to develop unrestrained shapes for the package.

Table 2 Create Structural Packaging with system taken from Jackson (2012)

Create with System	
1. Single Deformation – Shaving a face – Shaving an edge – Shaving a corner – Twisting a 3–D form – Compressing or stretching a 3–D form	
2. Multiple Deformation – shaving just one edge off the cube – shaves off two opposite sides from the top face of the cube to create a form reminiscent of a gable–roofed house – shaves off two adjacent edges from the top face of the cube to leave only a small square face on the top – shaves three edges of the top face to create a hip roof.	
3. Combinational Deformation – shave just one edge off the cube – shave two opposite edges from the top face of the cube to create a form reminiscent of a gable–roofed house – shave two adjacent edges from the top face of the cube to leave only a small square face on the top – shave three edges from the top face to create a hip roof.	

1. Structural Packaging

We used the polygon shape as a guideline for creating a package with the system, since these forms can be twisted, bent and the angles changed, to create forms in multiple dimensions.

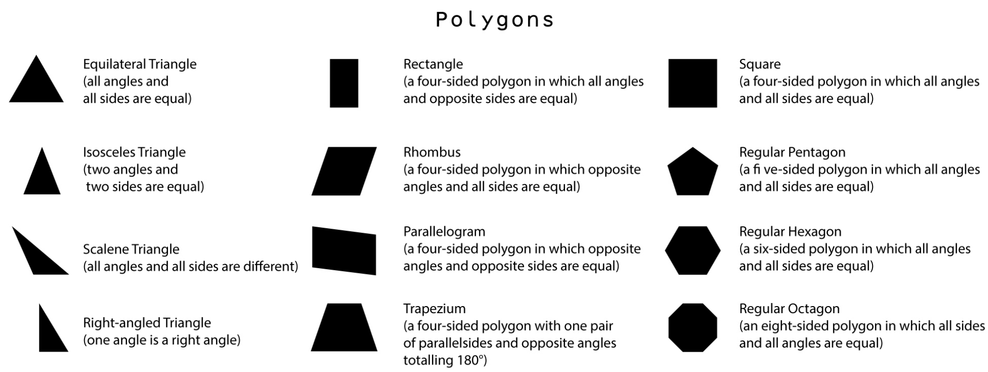


Figure 2 Polygon shapes used in the packaging design. Taken from Jackson (2012)

2. Lesson Plan

Our lesson plan used STEAM Education, especially in Art, i.e. we used art-based teaching, in combination with other sciences. Therefore, the lesson plan included art activities, that promoted creativity in packaging design. The various elements of the lesson plan, from objectives, content, activities and teaching media, including measurement and evaluation, encouraged students to develop real creativity in package design.

3. Test of Creative Thinking

A measure was created to score the packaging design covering four areas:

1. Originality
2. Fluency
3. Flexibility
4. Elaboration

using a Rubric Score. After evaluating the inter-rater reliability for the test of creative thinking (Jonsson & Svingby, 2007), we found that the average scores of the five instructors, who had experience teaching package design courses for more than ten years, were highly reliable: the confidence interval was between 0.956 and 0.975 at 95% confidence.

Assessment	Rating criteria			
	4 Very good	3 good	2 fair	1 should improve
1. Fluency in packaging design sketch	Completed in 40 minutes	Completed in 50 minutes	Completed in 60 minutes	〉60 minutes
2. Flexibility in use of design elements in the design sketch	Highest flexibility	High flexibility	Some elements used in graphic design.	Did not use elements in
3. Originality in the design sketch	Very attractive and interesting in overall appearance	Sketch modified and applied new design for overall interesting appearance	Sketch complied with standards	Sketch uninteresting
4.Elaboration in the design sketch	Explained ideas in sketch and connected	Explained ideas for sketch and connected almost all elements correctly	Explained ideas for sketch and partially connected elements correctly	Did not explain sketch and connected some elements incorrectly

Figure 3 Evaluation criteria (Creativity in packaging design sketch)

4. Experiment and data collection

Steps in the experiment were:

1. We assigned the packaging design work, before using the teaching model. Then we rated the workpiece for creativity in the design from the created test form (Pretest: 1).
2. By using the CREATE Model instruction, we taught packaging design theory (structural packaging). At the end of the formal teaching, we graded from the original test form (Post-test: 2). Two weeks later, we assigned another simple packaging design task and assessed it (Follow up test: 3).

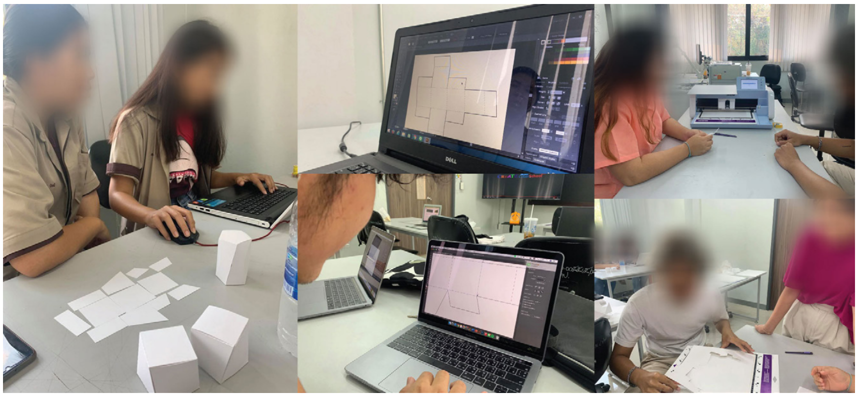


Figure 3 Learning Activities in Packaging Design Topics

3. Results and Discussion

We collected the scores of design (Packaging Design) before teaching the CREATE Model (Pre-test: 1), after learning (Post-test: 2) and in the tracking phase (Follow up test: 3). The results are in Table 2.

Table 2 Mean values from repeated multivariate test

Effect	Value	F	Hypothesis df	Error df	Sig
Time Pillai's Trace	.98	692.41	2.00	28.0	.000
Wilk's Lambda	.02	692.41	2.00	28.0	.000
Hotelling's Trace	49.45	692.41	2.00	28.0	.000
Roy's Largest Root	49.45	692.41	2.00	28.0	.000

Table 2 shows the mean values of the repeated measurement ANOVA, for the creative score in packaging design. The value from the multivariate test was insignificantly different from 0.0 ($p < 0.05$). It showed that the STEAM Education teaching method (CREATE Model) affected the dependent variables, i.e. the creative score in packaging design.

Table 3 Means of creative scores (Pre-test :1), (Post-test: 2), and (Follow-up test:3) periods.

Time (I)	Time (J)	Mean Difference (I-J)	Std.Error	Sig	95% Confidence Inter for Difference	
					Lower Bound	Upper Bound
1	2	-5.53*	.15	.00	-5.91	-5.13
	3	-5.60	.15	.00	-5.99	-5.20
2	1	5.53*	.15	.00	5.15	5.91
	3	-.06	.08	1.0	-.27	.14
3	1	5.60	.15	.00	5.20	5.99
	2	.06	.82	1.0	-.14	.27

In Table 3, we see that

1. Post-test:2 scores were higher than pretest: 1 scores ($p<0.05$)
2. Scores two weeks after the course finished (Follow up:3) were higher than (Pre-test:1) ($p<0.05$)
3. Posttest:2 scores and after the course finished (Follow up:3) were not significantly different.

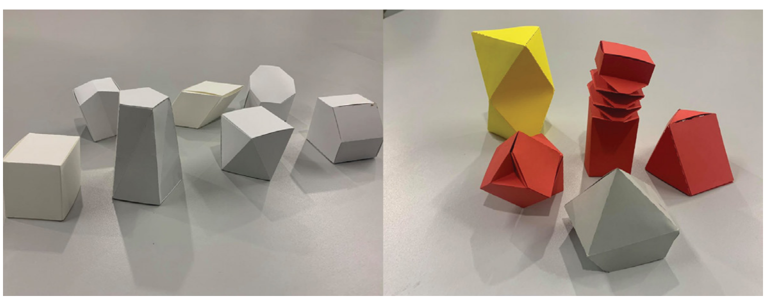


Figure 4 Packaging workpieces – using systematic design principles

From the principles of education STEAM, we developed a teaching model, the "CREATE model" Sakon (2019), which has methods from various science processes in each step:

1. Science: Students will use the scientific process to design workpieces.
2. Technology: Students will use digital cutting machines that supports files from computer graphics to cut pieces.

3. Engineering: Students will use the solution design concept to solve design problems.
4. Art: Students will have studied creating packaging with the system as part of their study. Understanding these topics will allow the student to design a package creatively and without constraints in design.
5. Mathematics: Students will use the application SCALE to calculate the proportions in the package design correctly.

Regarding creativity in design, we applied the concepts of Guilford (1950) in our study. The content and practical activities followed the worksheet. In teaching, the contents have been applied to the incorporation of creativity in four topics:

1. Originality: The instructor will quickly present the sketching activity in less than 40 minutes. This activity will train students to produce a sketch in a short time, but produce a complete workpiece, which can be developed as a prototype.

2. Flexibility: The teacher will introduce the shapes used in the design of all main packages, with demonstrations of how to connect each shape to the package body. Students will practice and be able to apply various shapes that come together in various ways.

3. Fluency: In creating original work, the teacher will build confidence for the students by suggesting they present their techniques in front of the class every week, allowing questions and expression of opinions from teachers and classmates. The practice of presenting design pieces every time was linked to the design theory to train them to be able to connect elements. This will promote design initiative, when a student hears comments from teachers and classmates, and sees the advantages and weaknesses of the work. The presentation will build learner confidence. Creativity in the design of a future project will be based on the experience gained in the classroom.

4. Elaboration: In designing the package, it will be reduced or enlarged by a scale ruler. The teacher will have suggested techniques for using the correct scale ruler. Calculation using mathematical methods will train prudence and verify accuracy, with the Scale application again, to enable students to calculate and draw scales accurately and precisely every time.

3. 1. Summary

Here, we used the CREATE teaching and learning model, which included in the 6-step model, process, and activity promoting creativity with elements of applied STEAM Education. It can be applied to design courses or computer graphics design. It was evident that when we used an instructional model that encouraged and stimulated creativity, learners produced better and more creative packaging designs. The ‘Creative form’ task, which required an exotic shape, including bending and deforming at various angles, used an integrated design technique, that allowed designers to develop a large variety of shapes. For packaging, this aimed to develop long-term design skills.

Here are the STEAM Education issues that help promote creativity using the CREATE model:

1. Lessons and activities

In the model, we presented natural forms of activities that promoted creativity in design These influenced the creativity score for the design work for each activity. This was consistent with Shim & Lee (2019), in their “Multi-Converging Educational Program for Design using a 3D Printer,” and we concluded that the lessons and activities fostered creativity. Further, Van der Lugt (2000) developed a graphic tool to solve problems by using concepts as sentences, that stimulated problem-solving in group design on sketched or mock-up designs, which also showed 'Arts serve society' activities, due to creative stimulation by many parties.

2. Working in cooperation

In each working activities step, cooperation was used to exchange ideas between students, *e.g.* presentation in a sketch design class to garner opinions from fellow students and teachers. The exchange of ideas improved and created better work. This follows Guyotte *et al.* (2015), who studied collaborative creativity in STEAM and found that creative stories tended to arise from storytelling in STEAM Education. In interdisciplinary work, it is better to collaboratively create design work than to work individually.

3. Different styles and variety of teaching and new learning activities: the CREATE Model has procedures and activities that have been studied and developed particularly in the context of teaching and learning of a computer graphics course. Processes and activity patterns encouraged learners to develop creativity in their designs and helped learners to persist in learning. Again note that work on 'EarSketch' (Engelman et al., 2017) showed better attitudes and higher creativity scores, where the creative learning environment powered by the EarSketch was very meaningful and relevant to drive student attitudes and willingness to use computers to produce results.

4. The Future of STEAM: In Thailand, the STEAM Education concept (STEM (Science, Technology, Engineering and Mathematics) with ART) has begun to be applied to basic education, and now to subjects related to design, because it was shown that art or ART is a the key point, that makes the students enjoy study, think outside the box and continue to develop creativity. The STEAM Education in Thailand is likely to develop more, due to 21st century attitudes: solving creative problems is not only specific to science, engineering and mathematics, but art will appear as a complement to any science. Thailand should adopt the policies, described by Allina (2017), to develop quality students who can connect all sciences.

In summary, we showed that when we combine educational technology-based teaching methods and elements and the request for creative development, students will develop a higher level of creativity and retain it. This study will be a guideline for those interested in the development of creative thinking in packaging design, that will lead to better results in the classroom results and extend to retention in external practice.

Some limitations were observed in the first trial of this approach: (a) students needed more time to understand the new activities, so in future, we need to allow sufficient time for students to understand the new activities and (b) there were some technical limitations on the size of the `ScanNCut' machine used to make prototypes, so example problems were constrained in size. We believe that (a) would be overcome by allowing additional time. Machine size was basically determined by economic constraints, but carefully planning and choice of appropriate design targets could allow use of a small machine.

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