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Designing a Vocational High School Instructional Program for Enhancing Creativity: Effects on Creative Thinking and Group Process Analysis

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Abstract

Teaching students the ability to think creatively can improve a country's continuity and prosperity. However how strategies for teaching creative thinking can be efficiently applied remains unclear. This study examined the effect of a 9-week creativity curriculum on the creative thinking ability of students in an engineering program at a vocational high school. A nonequivalent, quasi-experimental design was employed. A total of 85 students were assigned to an experimental group of 41 or a control group of 44. The students in the experimental group scored significantly higher in all aspects of creative thinking ability, namely, fluency, flexibility, originality, and elaboration. The creative thinking curriculum yielded positive results; the emergent themes in the creative process included: (1) curriculum characteristics, (2) group dynamics, and (3) constraining conditions. The results imply that this 9-week creativity curriculum is efficient and can be incorporated into future research on engineering education or creative thinking.

Keywords: creative thinking ability, creative thinking instruction, divergent thinking, process analysis, vocational high school

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Introduction

Aware of the value of creativity for students' development and the need to implement activities that could nurture students' creativity, many American teachers are gradually directing their teaching strategies towards an emphasis on high-level thinking skills (Alkuş & Olgan, 2014). In view of the required abilities in today's society, students deserve training in creative thinking ability, as it could help them to contribute substantively after graduation.

Creative thinking instruction is one strategy for increasing student creativity that has been proven by many studies to be effective (Karpova et al., 2011; Nakagawa, 2011). The main purpose of creative thinking instruction is to bring out students' creativity through customized activities and dynamic learning strategies such as brainstorming and teamwork. Generally speaking, two approaches to creative thinking instruction can be conducted; one is to base teaching materials on creative thinking to design an independent course for creativity training, and the other is to implant creative thinking into preexisting course content. The latter method is usually considered more practical for regular education and thus is carried out more often. When implanting creative thinking into preexisting course content, an instructional project method is practical for regular education and is efficient for cultivating creativity (Lei et al., 2012); it was thus applied in the present study. We believe that the approach can generate insightful results when applied to a "Project Practice" course at a vocational high school because this course requires intense creative thinking since students have to design an industrial product through teamwork using their skills and knowledge.

Past research has shown that creative thinking instruction can effectively increase student creativity, but this effect has mostly been tested at primary schools, middle schools, and colleges, where creative thinking instruction was incorporated into regular curricula such as language, mathematics, art, sociology, and science (e.g., Chen & Chen, 2019; Hsiao, 2017; Wang, 2019; Wu & Pan, 2007; Yu, 2003; Yu, 2015). Very little research has been conducted to test the effect of creative thinking instruction at vocational high schools, where the instruction could be incorporated into the curriculum of a project practice course (e.g., Chao et al., 2010). Thus, the present study aims to fill this gap in the literature. In addition, past research mainly focused on the effects of creative thinking instruction on individuals' ability (e.g., Baer, 1988; Chao et al., 2010; Kabanoff & Bottger, 1991; Lancaster et al., 2017; Meinel et al., 2019; Wang, 2019; Wu & Pan, 2007; Yu, 2003; Yu, 2015), and very little research, to the best of our knowledge, has placed emphasis on how individual abilities evolve, especially through group interactions and teamwork. The present study aims to fill this gap

in the existing research in the field of creativity instruction.

Therefore, this study integrated creative thinking instructional strategies into a “project practice” curriculum at a vocational high school to examine its influence on the creative thinking ability and creative processes of information-engineering students. The following research questions were formulated: (1) What is the influence of the creative thinking project curriculum on creative thinking ability? and (2) What are the distinguishing features of the process the curriculum underwent?

Creative Thinking Ability

What is creativity? Drucker (2012) defined creativity as an ability that endows an individual with resources to create wealth through learning and training. Weisberg (2006) maintained that creativity is determined by how much one knows. The creativity research has gradually evolved from unification to pluralism, and from static to dynamic. It not only investigates the agent of creativity, but also incorporates the social environment in which the agent is situated. It views creativity as the result of the multi-factor interaction of the agent and its environment. In other words, it is a natural consequence to adopt confluence approaches to investigate creativity (Baer & Kaufman, 2008).

Many scholars have proposed diverse theories to describe the process of how creative ideas are generated. The four-stage model of creative process (Wallas, 1926) indicated that the process comprises four stages: preparation, incubation, illumination and verification. Basadur (1995) regarded creative problem solving as a cycle of concept formation-evaluation. The geneplore model proposed by Finke et al. (1996) suggested the generative stage and the exploratory stage as the two stages involved in creative processes. In the generative stage, individuals identify, connect, analogize, and transform various components in a pre-existing knowledge structure in order to establish representations of a pre-inventive structure. The exploratory stage, on the other hand, is where individuals consult the characteristics of a pre-inventive structure in order to make inferences and explore. This stage is also where they compare those inferences and explore the limits of the constraints imbedded in an end product. Most scholars seem to have reached a consensus on the significance of the generation and evaluation processes in creativity. The process of idea generation involves the functioning of divergent thinking, while the process of idea evaluation calls for exploring, assessing, and critiquing all of the responses through logical analysis, convergent thinking, and critical thinking (Cropley, 2006; Runco, 2003). The ongoing and continuous interaction among the above processes leads to the eventual production of creative ideas or solutions.

Previous studies have proposed detailed taxonomies of creative thinking ability. Sternberg and Lubart (1995) contended that creativity at least comprises synthetic ability (e.g., combine, generalize, integrate, design, summarize), analytic ability (e.g., compare, enumeration, categorize), and practical ability (e.g., operate, utilize, discover, correct). Only when the above three abilities are developed in balance and there is proper coordination could creative activities occur. Another school of scholars comprehend creative thinking ability from a pure test perspective. Torrance (2008) assessed creative thinking along dimensions of fluency, originality, elaboration, etc. He designed the TTCT (Torrance Tests of Creative Thinking), commonly used for creativity assessment (Kim, 2011b; Shamay-Tsoory et al., 2011). Kim (2011a) and Yoon et al. (2015) found that TTCT was effective when it comes to identifying highly creative students and fostering their creative thinking skills.

Creative Thinking Instructional Project

Many researchers have pointed out that creativity could be elevated through creative thinking training (e.g., Mumford et al., 2012; Parnes, 1967). Piirto (2004) indicated that creativity training has developed prominently in many schools, and there are many curricula that it can be applied to. Csikszentmihalyi (2014) believes that, to have creativity, one must internalize overall knowledge or messages to enable creativity to become a possible system. Therefore, further investigation is needed to understand how to employ different creative thinking strategies to facilitate students' high-order thinking, strengthen their mental operation processes, and implement abstract thoughts in concrete teaching materials of a discipline.

Scholars have offered several categorization methods for creative thinking teaching models. Guilford's (1968, 1977) Structure-of-Intellect (SOI) model, Williams's (1970) Cognitive-Affective Interaction Model (CAIM), and the Creative-Problem-Solving (CPS) model (Parnes, 1967) are among the most famous. Guilford's (1977) SOI model suggests that, to stimulate creativity, divergent and convergent thinking practices and training should be incorporated into the instruction. Williams's (1970) CAIM highlights the importance of instructors incorporating creative thinking strategies to improve students' cognitive and affective creativity. The CPS model comprises five stages of creative thinking and problem solving, namely fact-finding, problem-finding, idea-finding, solution-finding, and acceptance-finding. The model suggests that, at each stage, divergent thinking should take place before convergent thinking, in order to first exhaust all possibilities before deciding an optimal solution (Parnes, 1967). Building on the CPS model, Treffinger and Isaksen (1992) proposed an additional sixth stage, mess-finding. Some other models have been constructed by Taiwanese scholars, such as the ATDE (Asking, Thinking, Doing, Evaluation) (Chen, 2006) and

the Creative Thinking Instruction Model (CTIM) (Cheng et al., 2003).

Research has shown that these teaching models are effective, in that creative thinking courses based on these models have been found to increase creative thinking abilities (e.g., Baer, 1988; Kabanoff & Bottger, 1991; Lancaster et al., 2017; Meinel et al., 2019; Wang, 2019). For example, in the study by Wang (2019), it was found that high school students' divergent thinking ability and English writing skills improved after taking an English course that incorporated a 340-minute session that involved four types of creative writing practices, designed based on the six stages of the CPS model.

An overview of the existing literature shows that most of the studies on creative thinking teaching models were conducted to see whether courses designed based on the models can enhance individual abilities (e.g., Baer, 1988; Chao et al., 2010; Kabanoff & Bottger, 1991; Lancaster et al., 2017; Meinel et al., 2019; Wang, 2019; Wu & Pan, 2007; Yu, 2003; Yu, 2015). Very little research has been done to show how these courses affect creativity through the students' participation in group interactions and teamwork. In the present study, we applied Guilford's SOI model and categorized creative thinking strategies into divergent and convergent production, which we used to enhance students' unique performance. While divergent thinking strategies are to generate numerous ideas and trigger various ways of thinking, convergent thinking strategies are methods that are for systematically summarizing information, analyzing, synthesizing, and selecting (Chen & Ju, 1998). Guilford's SOI model is problem-solving oriented. When SOI is applied, learners' knowledge and experience are valued; they process and filter new information based on their pre-existing knowledge. Through cognitive processes, learners come to understand the nature of problems, and use either divergent or convergent thinking to solve the problems.

The Present Study

Appling creative thinking strategies, we designed a project curriculum. We analyzed the practice of the curriculum, while focusing on the interaction between students and their environment. Specifically, we explored how individuals' cognitive structure (creative thinking ability) and their environment transformed while receiving creative thinking guidance.

Method

Participants

Eighty-five third-grade students majoring in information engineering at a vocational high

school in northern Taiwan, were recruited. The experimental group included 41 students, while the control group included 44. All participants were males. This school is located in an industrial area with a medium socioeconomic level.

Research Materials

Creative Thinking Instruction

The creative thinking project curriculum was designed by the authors and the instructor leading the "Project Practice" course at the aforementioned school. A project curriculum is a project-based learning environment wherein students learn procedural knowledge to solve practical problems. In this particular class, didactic teaching was applied to establish basic concepts, and then the brainstorming mode was employed among group members. The principle of "deferment of judgement" was emphasized, with the aim of fostering a supportive climate in which students' creative thinking ability would grow.

A course of 18 hours in total on a 2-hour weekly basis that lasted for 9 weeks was taught. In the first week of the course, the syllabus was introduced and students were assigned to groups. Then, starting from Week 2, theories of creativity and creative thinking were introduced every week, such that one type of divergent or convergent creative thinking strategies was introduced each week, with activities for students to practice the strategy. Brainstorming, the Phillips 66 Technique, the 635-Brainstorming Technique, the Attribute Listing Technique, and the 5W2H Technique, were introduced subsequently from Week 3 to Week 7. In Week 8, students were instructed to use divergent thinking and the strategies they had learned to brainstorm ideas for their group project and decide on a topic. Then, in Week 9, they were instructed to use convergent thinking to come up with a concrete plan for their project (see Table 1).

Classified according to Guilford's (1968) SOI model, the divergent creative thinking strategies employed in this study were brainstorming, Phillips 66 Technique, and the 635-Brainstorming Technique. These strategies help one's imagination to run wild. The convergent creative thinking strategies employed were the Attribute Listing Technique and the 5W2H Technique, which helped students develop their conceived ideas into concrete plans. The strategies used are illustrated as follows.

Brainstorming, developed by Osborn (1953), requires collective thinking aiming to generate original ideas from a chain reaction. It requires participants to defer their judgement on the ideas proposed by other members, while encouraging conceiving as many ideas as possible. Thus, it can create an environment in which students learn respectful attitudes towards various ideas and wild imagining.

Table 1

The Curriculum Design

Theme	Activity	Goal
Week 1: Forming groups	1. Ice-breaking games 2. Groups of four were formed randomly according to GPA 3. Task distribution	Cultivating a collaborative climate and triggering learning motivation
Week 2: Understanding creativity	Introduction to theories of creativity	Understanding creativity and its importance
Weeks 3-7: Understanding and practicing creative thinking strategies	Introduction to the creative thinking strategies & task practice. (Topics: Brainstorming, the Phillips 66 Technique, the 635-Brainstorming Technique, the Attribute Listing Technique, the 5W2H Technique)	Understanding & applying the strategies
Week 8: Determining the project topic	Applying the 635-Brainstorming Technique and the Phillips 66 Technique to conceive an adequate topic	Applying the divergent creative thinking strategies to determine the project topic
Week 9: Yielding a concrete plan	Applying the Attribute Listing Technique and the 5W2H Technique to evaluate the feasibility of the project plan	Applying the convergent creative thinking strategies to delineate the project plan

The Phillips 66 activity (Phillips, 1948) is a group discussion technique based on brainstorming. It aims at improving the unfavorable condition for expressing one's opinions in a group of numerous people. It divides students into groups of six, with each group generating ideas for 6 minutes. The representatives from each group then reads their group proposals to the whole class, followed by instructors' summary on those ideas.

Method 635, a variation of brainstorming, was designed to stimulate diverse solutions to a specific problem under time limits (Pahl et al., 2007). The practice divides students into groups of six, with each person writing down three ideas for solutions. Each person then passes on her/his written ideas to the next person, who revises or extends those ideas in 3 to 5 minutes. The process goes on until each person has worked on all ideas and there would be a total of 108 ideas obtained.

The attribute listing method, proposed by Crawford (1978), is to list possible attributes of a

target. The method is to look for attributes worth improving on, such as the characteristics, disadvantages, and hoped-for merits of the target, and to brainstorm on ways to improve them.

The 5W2H method allows students to list the pros and cons of their ideas and come up with possible ways to improve them with the questions of ("Why, What, Who, When, Where, How, and How much.") These strategies help students examine the practicality of their ideas.

The Torrance Test of Creative Thinking (TTCT)

TTCT's figural test (Torrance, 1966), which assesses students' creative thinking ability, includes three activities: (1) Figure Construction: participants are given a round piece of colored paper that is attached to the test sheet, and are asked to construct a figure based on the paper, (2) Complete a Picture: participants are asked to draw and name a picture based on 10 uncompleted lines, and (3) Parallel Lines: students are asked to draw a picture based on 30 pairs of parallel lines. One can obtain correlations above .90 based on the rules stated in the assessment handbook (Torrance, 1966). The test-retest reliability is between .50 and .85.

The New Creativity Test for Use

The "New Creativity Test for Use" (Wu et al., 1999), which assesses students' creative thinking ability, includes two aspects: (1) verbal creativity, and (2) figural creativity. The figural creativity test is to assess four mental characteristics: (1) fluency, (2) flexibility, (3) creativity, and (4) elaboration. The norms were developed from a sample of 2,311 students, including 516 university graduate students, 623 high school students, 600 middle school students, and 572 elementary school students from northern, central, and southern Taiwan. Assessment reviewers grade according to a guide book. The reliability is .79 to .98. The correlation between the figural creativity test and the TTCT's figural "Parallel Lines" activity is .39 to .75.

Interviews

We adopted interviews and other qualitative techniques such as a classroom observation diary to probe the process of the curriculum. Both focus group and individual interviews were conducted with the instructor and the students. Purposive sampling was applied in order to understand what the participants thought of our curriculum design. The leader of each team was required to participate in the interview because of the crucial role they played in their teams. We first conducted focus group interviews with 10 team leaders; this allows interviewees to interact with each other to generate chain reactions. Interviewees may have contradictory ideas, and a focus group interview allows them to ponder and to answer our questions. Then, we conducted in-depth interviews with four participants in order to gain a more profound understanding of their thinking. The interviewees were

also asked to check on the authenticity of their answers and to clarify any unanswered questions. Moreover, triangulation was applied to ensure dimensional counter checking that was not only carried out by the author and research participants, but also by the senior instructors of the information engineering field and creative thinking experts who were consulted at the curriculum design stage. Learning diaries kept by students, in-class observation logs, the instructor's teaching log, and qualitative data from the focus group and individual interviews were all carefully examined via the analytic induction techniques of Grounded Theory (Strauss & Corbin, 1990) to generate themes in the process.

Research Design and Procedure

A non-equivalent pretest-posttest quasi-experimental design was applied. The dependent variable was creative thinking ability. At the beginning of the course, the students in both groups were further assigned into groups randomly according to their GPA. Hence, members of the same group would have varying degrees of academic ability. Then, each group elected a leader. Neither group was taught creative thinking methods beyond the current project, and they were both taught by the same teacher at the same location. The research procedure is explained in the following paragraphs.

In the first stage, a pre-test (TTCT) was carried out for both groups a week before the experiment to have baseline control for the outcome. All 85 students took the creative thinking assessment test, and all received questionnaires were valid. In the second stage, the creativity project curriculum was carried out in the experimental group (see the section of "Creative Thinking Instruction"), and the control group was taught using traditional teaching methods. Specifically, students in the control group had learned concepts and methods through didactic lecturing. They had to apply creative thinking strategies to generate ideas (experimental group) and make practical plans for an industrial product (both groups) by building a prototype or designing the shape of a product concept at the end of the course. During the course, in-class observations were conducted as the researchers kept log records. In the third stage, post-tests were administered to both groups after the 9-week curriculum. All 85 students finished the creative-thinking assessment test (New Creativity Test for Use) and all questionnaires were valid. Finally, semi-structured focus-group interviews and in-depth interviews were conducted.

Results

Creative Thinking Ability

The reason we used two different measures for creative thinking ability was to avoid carry-over effects that can result in increased post-test performance. The measure in the pre-test, TTCT, was entered as the covariance, and the measure in the post-test, New Creativity Test for Use, was entered as the dependent variable for one-way ANCOVA analysis to examine the four aspects of the students' creative thinking ability: (1) fluency, (2) flexibility, (3) originality, (4) elaboration, and overall creativity, to see if there was any difference between the experimental group and the control group. The results are presented in Table 2, and suggest that the creative thinking abilities of the experimental group students improved in all aspects: fluency ($F(2, 81) = 3.35$, $p < .05$), flexibility ($F(2, 81) = 17.03$, $p < .05$), originality ($F(2, 81) = 4.16$, $p < .05$), elaboration ($F(2, 81) = 3.54$, $p < .05$), and overall creativity ($F(2, 81) = 3.66$, $p < .05$).

Table 2

ANCOVA Results

Creativity	Group	*Adjusted M*	*SS*	*Df*	*MS*	*F*	η^2
Fluency	Exp	51.00	318.66	2	159.33	3.35*	0.08
	Control	49.83	3849.67	81	47.53		
Flexibility	Exp	50.82	2926.20	2	1463.10	17.03*	0.30
	Control	49.59	6960.47	81	85.93		
Originality	Exp	51.25	442.25	2	221.13	4.16*	0.09
	Control	49.57	4307.83	81	53.18		
Elaboration	Exp	50.57	424.90	2	212.45	3.54*	0.08
	Control	50.42	4857.99	81	59.98		
Overall creativity	Exp	203.86	5453.33	2	2726.67	3.66*	0.08
	Control	199.02	60314.61	81	744.63		

*$p < .05$.

Group Process Analysis

After a close look at the qualitative data, we found several themes worth reporting in the experimental group (i.e., the group that conducted the creativity project curriculum). Therefore, we focused on analyzing the following themes: (1) curriculum characteristics, (2) group dynamics, and

(3) constraining conditions.

Curriculum Characteristics [Fun/Systematic/Autonomy-inducing/Presence of Challenges]

Curriculum characteristics represent how students perceive the creative thinking curriculum, including their feelings and/or thoughts about the class climate and the creative strategies taught.

Fun. It was indicated in our interviews that "fun" is crucial for generating creative thinking. When students felt that the project was fun and interesting, it helped them let their imagination run wild and they could create freely. For example, one student noted that "*everybody was playing while doing the project, and we felt better that way*" (S9). Another student reported, similarly:

> *Actually, I treated the project as a game, so I was thinking, ok, just play it! I thought that was great. I think the purpose of this course is to let us play, to play and create new things, and to enjoy the fun. I think playing is an important process. (S6)*

Systematic. When asked about the creative thinking methods, many found them systematic. They thought that either brainstorming or the 6W method offered them systematic strategies that guided them to collect everyone's opinions according to clear steps, and helped them categorize, evaluate, and determine the project themes. One student described that, "*The 6W method helped each of us collect everyone's ideas and opinions. It helped enrich our contents and our plan was more systematic*" (S8). Another student explained that,

> *Brainstorming helped us see more clearly where our project was headed. We were able to concentrate on one direction and make a plan. So even if we made a mistake, it wouldn't have been that destructive. (S9)*

Autonomy-inducing. Students were given room to try for themselves and to learn while trying. For instance, one student reported that,

> *Brainstorming helped us come up with many ideas, and then they gradually became a plan. We also kept modifying our plan and adding new ideas. It encouraged me to keep wanting to try. (S7)*

Students experienced autonomy and they had to make decisions independently. One student described that, "*Now I can decide what I want to make and I must find resources on my own. It's not*

like the old way when we had to do whatever we were told to" (S6).

Presence of Challenges. Although students encountered challenges, they were willing to face the difficulties and find solutions. From our observation, they gained a sense of accomplishment by conquering challenges by means of creative thinking strategies. The following quote is one example.

> *We decided to push our limits and try to make a special piece of clothing. We came up with this idea by brainstorming. However, we soon found it was very challenging. At first we wanted to use Christmas lights, but then we realized the wires were too long. So we decided to use our own circuit boards to figure something out. (S3)*

Group Dynamics [Leadership/Member Composition]

Group dynamics represents the interaction process among group members. The themes include the interactive mode between leaders and followers, and how the member composition affects the functioning of the group.

Leadership. It was found that the group leaders were often those with higher academic ability and they played an important role. Their leadership determined their team's efficiency and whether they could successfully apply the creative thinking strategies. Some students expressed that they believed the leaders had an obligatory responsibility to be the decision maker who should lead their group in the right direction and assign work to members.

> *You have to be demanding. When told to do so, they would immediately brainstorm to conceive new ideas. As long as the given direction is correct, they would try their best to generate ideas. Thus, the group leader should pinpoint a specific topic for their members to figure out ways to achieve it. (S9)*

Meanwhile, we noticed that when leaders were absent, other members were often unable to make any progress. Compared to other members, group leaders were relatively more active.

> *The group leader must force their members to work or delegate work to them. The members wouldn't always follow their leaders' commands since some of them may think grades are unimportant. If the members loafed around, their leaders would have to complete the task by themselves. (S1)*

Member Composition. Students were assigned to groups randomly according to their GPA at the

beginning of the class. Unfortunately, this grouping method seemed to be an impediment to building consensus, either due to the students' different abilities to perform or the preexisting stereotypes and stigmas caused by low grades. Some students expressed that how they were grouped was one of the factors that influenced the quality of their work. Some expressed that their group could not communicate efficiently because of the gap between members' abilities. Most of the discussion took place among students with higher academic competence, while other students found it difficult to join in the discussion. These perspectives are demonstrated in the following quotes.

> *When we were having discussions, I felt their opinions were useless and that my ideas were certainly better. I think it's just like some big companies make sure they only hire elites. So, I think those members should be responsible, and yet we can't just abandon them! (S4)*

> *I think the results may have been very different had we been grouped according to our abilities. This way, maybe the ones without good abilities would work hard, collaborate more with teammates, and try every possible way to accomplish the project had their grades been at stake. ... Stress may push them to work hard to brainstorm since there would be no one to bail them out. (Teacher interview)*

It is worth noting that although the students were grouped heterogeneously according to their GPA, there was still a certain degree of homogeneity when it came to their ideas and skills. Our participants had studied together for 3 years and had received the same professional training. Therefore, they sometimes found each other's ideas similar, and it was hard to make breakthroughs, which is reflected as follows.

> *We are all information engineering majors and we've had the same learning experience. That was why even though we had so many people working together, we still found it hard to come up with any innovative ideas because we all think alike. (S9)*

Constraining Conditions [Time and Evaluation/Feasibility]

Constraining conditions indicate the limits students encountered during the project curriculum, including the due dates of their project, the teacher's evaluation, and the discrepancies between their plans and reality.

Time and Evaluation. Many students felt trapped because of the time pressure, especially because it was their first time to practice creative thinking methods. Due to insufficient time, some

had to give up on quality. For instance, one student mentioned: "*I dare say if I could draw six drafts for the product now, at least four of them would look different. Why? Because there wasn't enough time to think*" (S2). Nevertheless, some deemed the time pressure to have given impetus to their creativity. For instance, one student said, "*The impending deadline of handing in work would definitely give us pressure. However, it forced us to think of more ideas and work more quickly at the same time*" (S4).

It has been found that the pressure of handing in homework works differently for two types of students. Those who worried that they would not be able to produce a quality product in time had relatively high self-expectations and showed more creativity and willingness to challenge themselves. On the other hand, those who worried about whether their products would be good enough to meet the teacher's standard did the project simply for the teacher's sake and showed relatively lower levels of creativity. The different effects of time pressure could be seen in the following quotes.

> *Yes, if we had started it all over again, we would have to rush, because the deadline was certain. We would have greater pressure. On the other hand, if we had started again, we could have made the project more complete by discussing what we had missed. The effect would have been better. (S7)*

> *Some of them were saying, "If you would just give me more time, I'm willing to show you creativity!" However, I think they were just saying it. If they really wanted, they could have shown me creativity. It can be as easy as simply adding a small wheel to their model. So I had to keep encouraging them and give them a little pressure. Because they may be saying they had tried hard while they actually hadn't. So I encouraged them by grading them to push them into refining their products. (Teacher interview)*

Feasibility. In the project practice, the students first focused on using creative thinking strategies to come up with ideas, and they had to test their ideas and make adjustments when needed in order to create an actual product. Once they moved on to the implementation stage, their original ideas were restrained by practicality, whereas some different thoughts might be inspired at the same time, as demonstrated in the following quote.

> *You can't add cotton under the cushion otherwise it'd be too heavy for the ship to sail. You really have to give it wind to make it move ... After we actually made it, we became more sensitive to practicality. And that inspired different ideas. (S9)*

Discussion

Overall, it is implied from the quantitative results that the creative thinking project curriculum effectively enhanced the students' creative thinking ability. The curriculum worked effectively in several ways. First of all, the creative thinking strategies played a crucial role in cultivating several aspects of creativity proposed by Sternberg and Lubart (1995). For example, students employed brainstorming to develop novel ideas as well as utilizing the attribute listing method to enumerate possible characteristics of their products (the analytic ability of enumeration). Another example is that the students agreed that the creative thinking strategies were helpful for turning abstract ideas into feasible work plans (the practical ability of operating and utilizing). In addition, we observed some significant phenomena relevant to the development of the students' creativity, which are presented as follows.

Curriculum Characteristics

In the present study, it is indicated that the students viewed the hands-on project as a process of playing games, where relaxation and interest generated ideas. Benjelloun (2009) noted that an enjoyable approach in the classroom can create a climate for cultivating creativity. Students in this study also experienced a supportive and autonomy-inducing environment where creativity may grow. Li et al. (2018) suggest that job autonomy may induce one's intrinsic motivation, render one more cognitively flexible, and further promote one's creativity. However, random setbacks or obstacles are inevitable in an environment that develops creativity (Sternberg & Lubart, 1995). For instance, Caniëls and Rietzschel (2015) empirically demonstrated that the constraining organizational factors do enhance how one perceives one's creative skills. Therefore, the presence of some challenges may indeed generate creativity, as was found in the present study.

Group Dynamics

In the group process, we observed the follower-leader dynamic, whereby most members were relatively more passive compared to the group leaders; they were often unable to make any progress without their leader. The passivity of some students in this study resembles the "passive followers" in Kelley's (1992) typology of followership. These "passive followers" were rather reluctant to voice their opinions or take the initiative, and they remained uncritically dependent on their leaders. Unfortunately, we found that the passive students in this study seemed to lack independency in their thinking, which is relevant to creativity.

Another phenomenon worth further discussion is the composition of the group members. Heterogeneity in composition could be classified into several forms, one of which is ability. In this study, the members within the same group were heterogeneous in their abilities since they were grouped randomly according to their GPAs. The students found it difficult to exchange opinions when members in a group varied broadly in terms of their skills and abilities, in which case, those with better abilities would be put in charge, which very likely resulted in a lack of mutual understanding. According to social categorization theories (Tajfel & Turner, 1986; Turner et al., 1987), groups of diverse members are likely to suffer from intergroup biases, where members of similar backgrounds may distinguish themselves as an in-group and those dissimilar to them as an out-group. Categorization within groups could cause dysfunctionality when group members are extremely heterogeneous (van Knippenberg & Schippers, 2007). In the study by Jensen and Lawson (2011), the benefit of grouping by similar abilities was tentatively explained. It demonstrated that in an inquiry-based learning context (i.e., encouraging high cognitive development such as reasoning), when grouped with peers of similar reasoning ability, students with low-reasoning ability benefit more than when grouped with peers of high-reasoning ability. The rationale is that being grouped homogeneously offers these low-reasoning students the opportunity to experience cognitive conflicts ad self-regulation without being guided or impeded by a more capable peer.

Heterogeneity in composition could have been in the form of skill background. Some students suggested that introducing members from different disciplines may stimulate novel ideas. A diverse group could utilize various abilities and perspectives of its members to have a more comprehensive understanding of problems (van Knippenberg & Schippers, 2007; van Knippenberg et al., 2004). Somech and Drach-Zahavy (2013) empirically demonstrated that teams composed of different disciplines and functions showed higher creativity.

Constraining Conditions

Creativity could emerge from a supportive environment, even though sometimes it may also come from a constrained task environment (Hoegl et al., 2008). We found that the constraints worked differently for two types of students. Those attributing their pressure to deadlines were more willing to accept challenges, and showed higher creativity. On the contrary, those attributing their pressure to meeting the teacher's standard of evaluation held lower self-expectations and showed lower creativity. The differences are often reflected in students' motivational states. Roskes (2015) proposed the interactional effect of motivations and constraints on creative performance, indicating that moderate levels of constraints that limit cognitive resources, such as time pressure, can increase

creativity, especially under approach motivation rather than avoidance motivation. This is because, when people are avoidance motivated (e.g., sensitive to potential failure), their creative performance depends to a greater extent on cognitive resources than when they are approach motivated (e.g., earning for gains or success). Therefore, approach-motivated students could employ their cognitive resources to a greater extent than avoidance motivated students, under conditions constraining their cognitive resources.

Another constraining condition found in this study is practicality, which is one of the three component abilities of creativity (Sternberg & Lubart, 1995). Pavlović et al. (2013) found that the practical aspect of creativity could be described as using available resources and applying ideas to attain the best results. Furthermore, they suggested that the practical aspect of creativity implies the increased efficiency of bringing ideas into reality, which bears some meaning for a competitive business environment.

As a whole, the creative thinking project curriculum at the vocational high school effectively elevated the students' creative thinking ability via guidance of the instructional curriculum. The creative thinking curriculum offered a facilitative environment for creativity to happen. However, the method of grouping, communication among group members, and environmental constraints need further consideration for future studies.

Limitations and Future Directions

Because of the grouping method, which was to assign members randomly according to their GPAs, group discussions mainly occurred among those with higher academic abilities, while other members found it hard to join them. Students with higher abilities had to hold themselves back because they felt an impulsion to help those with lower abilities. On the other hand, those with lower abilities did not engage actively in the process since there were others assuming responsibility for the project, which may have jeopardized their creativity learning. This study has provided an initial finding of how the composition of group members' ability affects the creative performance of the group, which is an area less probed by prior research. It awaits future research to clarify whether homogeneous grouping by ability can indeed benefit creativity, and whether heterogeneous grouping by ability engenders a social categorization process that would negatively affect group performance. That being said, numerous studies have indicated that the diversity of group members' backgrounds could generate varied perspectives, which is beneficial for creativity. Another limitation of this study is that the participants were all information-engineering majors. Future studies can adopt instructional approaches that merge participants of different disciplines into a group in order to

increase diversity.

Regarding the curriculum design, this study has confirmed that creative thinking instruction could indeed promote students' creativity. However, the students encountered numerous problems in the "learning by doing" process since the project curriculum featured practicality. Students had to bring the learned theories into practice. Therefore, for future studies, we suggest that not only should students be trained in creative thinking strategies, but they should also be further guided with methods of creative problem solving. Through solving problems encountered in real-life contexts, creative thinking strategies may be more grounded in everyday life. In addition, since the 9-week course was implemented at the beginning of a semester, the quality of the end results of the group projects were not included in our data for analysis. In future research, we suggest that researchers examine the quality of the group project to see whether there are differences between the experimental group and the control group that indicate the effectiveness of the creative teaching curriculum. Furthermore, we adopted two divergent thinking tests (TTCT and New Creativity Test for Use) as measurement of creative thinking ability in this study. However, not only divergent thinking but also convergent thinking ability should be included in creativity. For future studies, we suggest that researchers can use other measuring tools which include the creative process of divergent and convergent thinking to represent creative thinking ability, such as revolutionary drawing developed by Hong et al. (2019).

Conclusion

To understand the effectiveness of a creative teaching curriculum for vocational high school students, in the present study, a creative thinking curriculum designed based on Guilford's SOI model was implemented in a "Project Practice" course. After a 9-week long course, it was found that, compared to the control group, students in the experiment group scored higher in all aspects of creative thinking ability, including fluency, flexibility, originality, and elaboration. Our results are consistent with past findings that creative thinking teaching is effective for increasing student creativity when implemented in regular education. To the best of our knowledge, past research was mostly conducted to test the effect of creative teaching strategies at non-vocational schools. Thus, our findings extend the scope of the existing literature by showing that creative teaching strategies can also be successfully implemented at a vocational high school, particularly in an engineering program. In addition, past research mainly focused on the effects of creative thinking instruction on individuals' ability, and the associations of individual creativity and group interactions have rarely

been emphasized in the field of creativity instruction. In the present study, we used learning diaries, in-class observation logs, the instructor's teaching log, focus group interviews, and one-on-one interviews with group leaders to collect qualitative data to understand how group interactions affect individuals' creative thinking abilities. We examined associations of group interactions with creativity through factors such as curriculum characteristics, group dynamics, and constraining conditions. Our findings provide suggestions for educators and policymakers to consider when implementing creative thinking teaching techniques at vocational high schools, especially in engineering programs.

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創造思考教學方案對高職生創造思考能力之效果與團體歷程分析

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摘要

教導學生如何創意思考是國家持續發展與繁榮的重要關鍵。然而，目前普遍缺乏如何有效應用創意思考教學策略之討論。本研究主要目的在設計9週的創造力教學方案，並檢驗對於高職資訊科學生之創造思考能力的影響。採用準實驗研究之不等組設計，共85位高職生參與，實驗組為41人、控制組為44人。以新編創造思考測驗、Torrance圖形創造思考測驗之表現，分別作為創造力教學方案之前、後測，進行共變數分析。同時，蒐集教師個別訪談、課室觀察，以及學生焦點團體訪談與個別訪談等質性資料，來分析創造思考教學對高職生創意氛圍之影響。量化研究結果指出，實驗組於創造思考能力之流暢性、變通性、獨創性及精進性，皆顯著高於控制組。根據質性資料結果發現，實驗組在課程特性、團體動力、限制情境等主題上，皆有較佳的創意發想效果，此意味著本研究採用之創意思考教學策略，可有效提升高職生之創造思考能力，建議未來可整合至資訊科教育中。

關鍵詞：創造思考能力、創造思考教學、擴散性思考、歷程分析、高級職業學校

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