The influence of the brainstorming process on the creativity of vocational industrial education students in Taiwan the ROC

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The influence of the brainstorming process on the creativity of vocational industrial education students in Taiwan the R.O.C.

Wu, Ming-hsiung, Ph.D.

Iowa State University, 1993
The influence of the brainstorming process on the creativity of vocational industrial education students in Taiwan the R.O.C.

by

Ming-hsiung Wu

A Dissertation Submitted to the Graduate Faculty in Partial Fulfillment of the Requirements for the Degree of DOCTOR OF PHILOSOPHY

Department: Industrial Education and Technology
Major: Industrial Education and Technology

Approved:
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Signature was redacted for privacy.

For the Graduate College

Iowa State University
Ames, Iowa
1993
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ACKNOWLEDGEMENTS

I am deeply grateful to the individuals who have helped me complete my study program and dissertation for the doctoral degree at Iowa State University.

First, I appreciate the dedicated assistance from Dr. William D. Wolansky. As my major professor, he chaired my program committee and directed my research. Especially, his concern for my progress of the dissertation even though he was going through great difficulties in his health.

I also express my thanks to my committee members, Dr. John N. Riley, Dr. Donald J. Mckay, Dr. Robert F. Stranhan, and Dr. Ted J. Solomon for their assistance and support during my doctoral studies.

Also, I want to thank Dr. John C. Dugger and other faculty members in the Department of Industrial Education and Technology, Iowa State University, for their instructions, and extend my thanks to the professors and colleagues at the National Taiwan Normal University for their past years of assistance and moral support for my study abroad.

Dr. Thomas Andre and Dr. Michael W. O’Boyle offered much valuable information and many documents related to cognitive perspective about creativity. I would like to express my appreciation to both of them.

A special appreciation is extended to the Principal Yang and his staff in Ta-an Se-
ior Vocational Industrial School. Without their help, I could not have accomplished the experimental research for my dissertation. A special thanks is also extended to Dr. Lung-an Chen, Director of Creativity Center in Taipei Municipal Teachers College, and his students for the grading of the pre- and post-tests.

Without the financial support from the National Science Council in the R.O.C., I could not have pursued advanced degree in the United States. I greatly appreciate this valuable support.

Finally, I want to express my gratitude to my parents and younger uncle for their encouragement, and to my wife Mei-lien for her assistance in these three years.
CHAPTER 1. INTRODUCTION

Background of the Study

Creativity is a human driving force which can be applied to improve many human activities and thought patterns. The civilization of mankind is the product of creativity. Everyone possesses the power to be creative (Wiles, 1985). The creative problem-solving skill is man's most important fundamental adaptive ability (Torrance, 1972a), especially now, as the changes in business, technology, politics, and personal lives are more rapid, more bewildering, more unpredictable than before (Land, 1992). Today, leadership and organizational management must accompany creativity in most endeavors (Johnson, 1992; Vaill, 1992). Workers are required to hold a wider set of skills, including creative thinking and problem-solving (Luna, 1992). Most people who are considered as creative derive their creativity from motivation (De Bono, 1992). Accordingly, motivation plays an important role in creative work. Combining the strengths of futurism and creative education is essential to prepare today's students for tomorrow's world (Torrance, 1980).

Enhancing students' creativity has recently become an important goal in education. In fact, it has been suggested that teaching creativity is far more necessary than dispensing knowledge (Wollace, 1986). After the speech delivered by Guilford on creativity in 1950 at the Annual Conference of Psychology in America, research
on "Creative Psychology" has gained recognition in the fields of psychology and education (Gilchrist, 1972). From 1950 to 1964, there were as many as 4,176 papers written on "creativity" or "creative skill" (Chien, 1982). From 1984 to 1987, Dissertation Abstracts International covered a total of 120 doctoral theses on "creativity" or "creative skill" (Wu, 1989).

It is a widely recognized fact that the development of creative skill can be brought about through appropriate education and training procedures (David, 1982). Torrance (1973) conducted a survey and analysis on 142 research projects of creative-skill training, and found that 72% of the training projects proved to be effective in enhancing creativity.

In Taiwan, since 1970 when Chia advocated creative thinking teaching (Chia, 1970), eighteen papers of experimental research in this field have been written. These studies can be classified into two categories. The first includes the use of a creative thinking strategy to teach students creativity; the other is to embed some creative thinking strategies in a special course to teach students creativity. Of these studies, 38% were highly effective, 54% were partly effective, and only 8% were in vain (Chen, 1990). The subjects all were students of general education or non-technological education, except in the cases where Lin (1983) used the students from an industrial institution as the subjects of his research and this researcher (Wu, 1989) used the students of an industrial vocational school as research subjects. Enhancement of creativity of students who major in industrial technology is one of the most important topics to develop and create industrial technology in Taiwan today and in the future.

President Hao of Executive Yuan in the R.O.C Central News on July 16, 1991 challenged specific departments, "to enhance development and research, and not
depend on Japan.” These words are a key phrase of authority. But objectively, there are good reasons for Japanese industrial prevalence around the world. In 1885 Japan started to imitate America in adopting the patent policy, actively promoting and encouraging inventions. In the forty-one Japanese prefectures, a total of ninety-one “Young Men & Young Women Invention Classrooms” were established. By 1984, Japan’s patent applications accounted for 44% of the whole world’s 1,110 thousand applications (Japan Patent Office, 1987).

The industrial development of Japan which has caught the attention of the world, is, in fact, the result of the efforts of inventors. As Koizumil stated in 1982, “Japan now has a sizable advantage in overall technology over the United States” (Lewis, 1986). Japanese industry stands on the leading edge in many industrial sectors (Schwarz, 1992). This demonstrates that “the Japanese are energetically striving for renewed creativity and originality” (Torrance, 1992, p. 235). To promote industry in Taiwan, developing the resources of the brain is of utmost importance. In addition, basic industrial technological education must emphasize creative thinking in order to enhance the training and research abilities and their productivity of high-level technicians. Furthermore, these students can apply what they learn to design new industrial products. The development of creative problem-solving skills has been considered a major objective for industrial education programs (Lolla & Miller, 1980).

In the last ten years, the Educational Department of the Taipei City Government has advocated creative thinking teaching at every level in local education, and it has been found to be particularly effective in elementary education. Huang (1987), an evaluator, suggested that the teaching of creative thinking and the research on its effectiveness should be continued. Because vocational industrial education students are
not all required to take the stressful university or college entrance examinations, an emphasis in creative thinking teaching has been promoted. However, many teachers are uncertain about how to include the subject in industrial technology instruction. Therefore, the establishment of a creative thinking teaching model is worth further research.

The Republic of China has established a vocational industrial educational goal “to improve the students’ abilities to develop their potentials, to create, and to adapt” (The Education Ministry, 1986). The Educational Department of the Taiwan Provincial Government responded to this goal by developing a program “to cultivate the creative and special abilities of vocational students in the province”. The performance project of this program has the purpose of strengthening creative thinking teaching in Taiwan Provincial Vocational Education. This project has been in operation since the 1990 school year. In the project, the purpose, principles, methodology, procedures, finances, supervision, and evaluation have all been regulated explicitly. Several strategies of creative thinking teaching were listed, such as demonstration and enhancement of creation, brainstorming, attribute listing, the morphological synthesis method, ecological analogy, six-w method, word association techniques, and forced relationships. Brainstorming is a basic part in the creative process (Barran 1969) and can be used in the whole training procedure of creative cognitive problem solving. It also may involve the application of other creative thinking methods.

This researcher (Wu, 1989) undertook an experimental study of incorporating creative and inventive concepts into high school vocational curricula and found that an experimental curriculum of creativity and invention could improve the creativity of students. Among nine units of the experimental curriculum, the unit on brain-
storming was reckoned by the students to be the favorite and most helpful strategy.

The effectiveness of brainstorming for increasing creativity has been documented in many research articles, but most of these were in the field of writing or composition, or involved brainstorming in multiple strategies of creative thinking. Very few have used brainstorming as the main strategy in creative thinking teaching research in vocational industrial education. Due to these reasons, this researcher used brainstorming as the main strategy in a study of creative thinking teaching in Vocational Industrial Education in Taiwan with the intention of exploring the feasibility of providing a simple creative thinking teaching model of brainstorming.

The enhancement of creativity seems related to the content of what students learn. Lin (1984) studied creative thinking teaching in writing and drawing courses of fourth grade students. His results demonstrated that verbal creative thinking abilities of students in two courses had increased. On figural creative thinking abilities, students in the writing course increased in flexibility and originality, the students in the drawing course increased in elaboration. Li (1987) found similar results. In his study, the students of watercolor, photography, and design courses in vocational schools increased in verbal creative thinking abilities, but not in figural ones; and the students of a Chinese course increased in figural creative thinking abilities, but not in verbal ones. In previous research, this researcher (Wu, 1989) found that the students who majored in electronics were significantly superior to the students who majored in machinery in scores of fluency in figural creative thinking abilities. A probable reason was that the machinery students were in their fourth semester of the “Engineering Graphics” course, but the electronics students had completed just one semester’s work in that course one and a half years previously. Although the effects of
different courses on the enhancement of creative thinking abilities was not the main purpose of these studies, the effect appears to exist. If such differences are real, creative thinking teaching methods should be included in a special professional curricula to improve students creativity. This phenomenon merits further exploration.

Statement of the Problem

Although brainstorming has been used in creative thinking teaching and research, it has not been used as a main strategy to increase the effectiveness of creative thinking teaching in vocational industrial education in Taiwan. It has also not been proven that students creative thinking abilities are enhanced differently due to their chosen field of study. Therefore, this study addresses the problem of whether teaching brainstorming could enhance the creativities of vocational industrial education students in Taiwan, and whether the students' major area of study influenced the enhancement of their creative thinking abilities.

Purpose of the Study

The central purpose of this study was to:

1. Determine the effectiveness of brainstorming to enhance creativity of vocational industrial education students.

2. Determine the enhancement effects of creative thinking training on different technical subjects.
Questions of the Study

1. Does brainstorming improve the verbal creative thinking abilities of vocational industrial education students?

2. Does brainstorming improve the figural creative thinking abilities of vocational industrial education students?

3. Are there any differences in the enhancement of the verbal creative thinking abilities between machinery and electronics students?

4. Are there any differences in the enhancement of the figural creative thinking abilities between machinery and electronics students?

Hypotheses of the Study

To answer the above questions, the following hypotheses were formulated.

1. The experimental group of students participating in brainstorming sessions will have significantly higher scores in verbal creative thinking abilities, as measured by the Torrance Test of Creative Thinking Verbal Form, than the control group of students.

1.1. The experimental group will have significantly higher verbal-fluency scores than the control group.

1.2. The experimental group will have significantly higher verbal-flexibility scores than the control group.

1.3. The experimental group will have significantly higher verbal-originality scores than the control group.
1.4. The experimental group will have significantly higher verbal-total scores than the control group.

2. The experimental group of students participating in brainstorming sessions will have significantly higher scores in figural creative thinking abilities, as measured by the Torrance Test of Creative Thinking Figural Form, than the control group of students.

2.1. The experimental group will have significantly higher figural-fluency scores than the control group.

2.2. The experimental group will have significantly higher figural-flexibility scores than the control group.

2.3. The experimental group will have significantly higher figural-originality scores than the control group.

2.4. The experimental group will have significantly higher figural-elaboration scores than the control group.

2.5. The experimental group will have significantly higher figural-total scores than the control group.

3. There will be no significant differences in the enhancement of verbal creative thinking abilities, as measured by the Torrance Test of Creative Thinking Verbal Form, after brainstorming sessions between the machinery and the electronic students.

3.1. There will be no significant differences in the enhancement of verbal-fluency scores between the machinery and the electronic students.
3.2. There will be no significant differences in the enhancement of verbal-flexibility scores between the machinery and the electronic students.

3.3. There will be no significant differences in the enhancement of verbal-originality scores between the machinery and the electronic students.

3.4. There will be no significant differences in the enhancement of verbal-total scores between the machinery and the electronic students.

4. The electronic students will make greater gains than the machinery students in figural creative thinking abilities, as measured by the Torrance Test of Creative Thinking Figural Form.

4.1. The electronic students will make greater enhancement in figural-fluency scores than machinery students.

4.2. The electronic students will make greater enhancement in figural-flexibility scores than machinery students.

4.3. The electronic students will make greater enhancement in figural-originality scores than machinery students.

4.4. The electronic students will make greater enhancement in figural-elaboration scores than machinery students.

4.5. The electronic students will make greater enhancement in figural-total scores than machinery students.
Statement of Assumptions

This study assumed that:

1. Contamination of irrelevant variables in this experimental research was controlled to the extent possible.

2. The Torrance Test of Creative Thinking can measure the students' real creative thinking abilities.

3. The conditions of supervising of the pre- and post-tests is the same in the four classes, and all student work seriously on their tests.

4. Differential gains in scores from the pre-test to the post-test between experimental and control groups could be attributed to the effect of the experimental group participating in the brainstorming session.

Delimitations of the Study

This research is limited to the assessment of the influence of the brainstorming process on the creativity of vocational industrial education students. As the sample of this research was selected from the machinery and the electronic departments of Ta-an Senior Vocational Industrial School in Taipei, any generalization made beyond this population can not be assumed to be justified.
Definition of Terms

**Brainstorming** is a creative thinking strategy based on two principles: (1) to delay criticism, and (2) to ask for quality from quantity, and four regulations: (a) criticism is ruled out, (b) "free-wheeling" is welcomed, (c) quantity is wanted, and (d) combination and improvement are sought. It was created by Osborn (1963) in 1938. There are two phases: (1) the ideation phase, and (2) the judgment phase.

**Vocational industrial education students** are the students of vocational industrial schools in Taiwan. These schools produce basic industrial skilled workers. They major in mechanical, electrical, chemical, or construction subjects. The samples in this study were two classes each from the machinery and the electronic departments in the Ta-an Senior Vocational Industrial School in Taipei.

**Creativity** is creative thinking ability. In this study, it is defined as the scores of students on the Torrance Test of Creative Thinking. In this study, creativity is divided into verbal creative thinking abilities, and figural creative thinking abilities.

1. **Verbal creative thinking abilities** are abilities that are performed with words. In this study, they are defined as the scores in the Torrance Test of Creative Thinking, Verbal Forms. Separate scores are reported for fluency, flexibility, originality and total.

2. **Figural creative thinking abilities** are abilities that are performed with drawing. In this study, they are defined as the scores in the Torrance
Test of Creative Thinking, Figural Forms. The scores include fluency, flexibility, originality, elaboration, and total.

3. Fluency is having many ideas. It is defined as the total number of responses on the Torrance Test of Creative Thinking.

4. Flexibility is the variety of kinds of ideas. It is defined as the total number of categories of responses on the Torrance Test of Creative Thinking.

5. Originality is to think in novel or unique ways. It is defined as the total number of statistically rare responses on the Torrance Test of Creative Thinking and its weighted scores.

6. Elaboration is to embellish upon an idea. It is defined as the total scores of student elaborating on ideas on the Torrance Test of Creative thinking.
CHAPTER 2. REVIEW OF LITERATURE

Introduction

This study was designed to determine the degree of influence of the brainstorming process on the creativity of vocational industrial education students in R.O.C. The literature and previous studies related to the present study are reviewed in this chapter. The chapter begins with creativity and its psychological foundation. The content of brainstorming and supportive evidence are described immediately afterward. The related research on the effect of brainstorming is then discussed. A review of the research about creative thinking teaching, and the implementation of creative thinking teaching in R.O.C follows. A summary of the literature review concludes this chapter.

Creativity and its Psychological Foundation

Historical Antecedents

Guilford's (1950) presidential address to the American Psychological Association is commonly viewed as the foundation work of much contemporary creativity research (Brown, 1989). Therefore, the year 1950 is usually cited as the birth of systematic creativity research (Puccio, 1989). In that address, Guilford noted that there were
merely 186 studies related to creativity among 121,000 studies listed in the index of the Psychological Abstracts for the preceding 23 years. Since 1950, the study of creativity blossomed. Puccio (1989) pointed out that Isaksen (1988) found 5,628 literature citations with regard to creativity from 1967 to 1984. This researcher (Wu, 1989) has found that there were 120 doctoral theses in the United States related to creativity between the years 1984 and 1987. Increasing attention is paid to sparking creative thinking and to research on creativity.

The Definition of Creativity

The word “creativity” does not have a uniform definition. Guilford (1950) defined creativity as follows:

In its narrow sense, creativity refers to the abilities that are most characteristics of creative people. Creative abilities determine whether the individual has the power to exhibit creative behavior to a noteworthy degree. Whether or not the individual who has the requisite abilities will actually produce results of a creative nature will depend upon his motivational and temperamental traits. To the psychologist, the problem is as broad as the qualities that contribute significantly to create productivity. In other words, the psychologist’s problem is that of creative personality. (p. 444)

Torrance (1971) defined creativity as:

...the process of becoming sensitive to problems, deficiencies, gaps in knowledge, missing elements, disharmonies, and so forth; identifying the difficulty; searching for solutions; making guesses or formulating hypotheses about the deficiencies; testing and retesting these hypotheses; and finally, communicating the results. (p. 553)
Rogers (1954) defined creativity as "the emergence in action of a novel relational product, growing out of the uniqueness of the individual on the one hand, and the materials, events, people or circumstances of one's life on the other" (p. 139). Tanner (1992) defined creativity as the generation of novel and useful ideas, and the ability to bring these ideas to reality by innovation. Amabile (1983) defines creativity as the production of novel and appropriate ideas generated by one individual or a small group. Although there are numerous definitions for creativity, a consensus is reached in Vernon's (1989) definition "creativity means a person's capacity to produce new or original ideas, insights, restructuring, inventions, or artistic objects, which are accepted by experts as being of scientific, aesthetic, social, or technological value" (p. 94).

From the above, the content of these definitions include four strands (four "P"s): the creative process, the creative product, the creative personality, and the creative environment (press) (Isaksen, 1992). Obviously these strands would be enhanced or improved by education or training; and creativity training involves teaching people how to yield new ideas for a given situation (Mayer, 1992).

**Psychological Perspectives**

Creativity could be viewed and researched through two psychological perspectives: intellectual structure (SI) and cognitive psychology. No matter from which perspective, creativity could be sparked or amended by training with related strategies.

Guilford (1967) divided intelligence into three dimensions: operations, contents, and products, which consisted of 150 independent factors. One factor in the oper-
ations dimension is divergent production. Guilford viewed divergent thought as a
general process based on creative production (Brown, 1989). Some research even
offered the creativity-equals-divergent-thinking assumption (Tannenbaum, 1985).

The belief that divergent thinking ability could be increased is supported by
much research. Cliatt et al. (1980) investigated “the effects of a training procedure
on the divergent-thinking abilities of kindergarten children”. Results indicated that
“not only can elementary school-aged children improve their scores when trained in
divergent thinking, but also very young children can realize dramatic increases when
repeatedly exposed to divergent-thinking situations” (p. 1063). McGinn et al. (1980)
announced that the productive-thinking program significantly advanced scores on
creativity measures. Self-esteem was related to the performance of divergent thinking
in middle-aged and elderly persons (Jaquish & Ripple, 1981). Carr and Borkowski
(1987) found that metamemory was related to divergent thinking. Therefore, these
studies suggest that students can be trained in divergent thinking.

Cognitive psychologists divide human information processing into five separate
aspects of cognition: attention, perception, encoding, storage, and retrieval. Problem
solving is viewed as playing a very important role in information processing. Andre
(1986) claimed “problem solving consists of the behavioral and mental activities and
performance that are involved in dealing with problems. It may involve thinking
(cognitive) components, emotional or motivational components, and behavioral com­
ponents” (p. 171). The problem-solving process is the way to deal with that which
is problematic (Shea et al., 1985). Problem solving stands at the summit of the
hierarchy of all human thinking skills (Christensen & Martin, 1992). Cognitive psy­
chologists stress how to use declarative and procedural knowledge in problem solving,
but not creativity. However what is emphasized in problem solving by the cognitive psychologist is similar to what is emphasized in creative psychology. Therefore, some psychologists combine these two concepts as "creative problem solving".

Much research also supports the theory that problem solving ability can be increased. Firestien and McCowan (1988) pointed out that "groups trained in creative problem solving participated more, criticized ideas less, supported ideas more, exhibited more verbal and nonverbal indications of humor, and produced significantly more ideas than untrained groups" (p. 106). Atwater and Alick (1990) studied the strategies used by successful and unsuccessful Afro-American students to solve specific types of stoichiometric problems. They found that a systematic strategy was applied by successful students when they were asked to balance chemical equations and solve a mole-volume problem. So, to instruct students in skills to enhance their problem solving ability is necessary.

Andre (1980) pointed out that many programs designed to increase problem-solving ability by increasing divergent thinking have been conducted, and have shown positive effects of increasing divergent thinking ability. No matter from which psychological perspective creativity is viewed, it is agreed that creative thinking skills can be enhanced through education. Activities designed to increase fluency, flexibility, and originality can be included in any curriculum (Hicks, 1980).

The Content of Brainstorming and its Supportive Evidence

Principles and Regulations

Brainstorming was originated by A. F. Osborn in 1938. Osborn (1963) described brainstorming as "... a conference technique by which a group attempts to find a
solution for a specific problem by amassing all the ideas spontaneously contributed by its members” (p. 151). Its main purpose is to generate new or innovative ideas to solve particular problems. Brainstorming theory is based on the assumption that creative production will be increased when problem solvers successively produce possible solutions (Buyer, 1988).

Group brainstorming generally has two main phases: the first is the ideation phase, and the second is the adjudgment phase. Osborn (1963) believed that brainstorming should be guided by four regulations: 1) criticism is ruled out, 2) “free-wheeling” is welcomed, 3) quantity is wanted, and 4) combination and improvement are sought. In fact, brainstorming is based on two principles: the delay of judgement and the yield of quality from quantity (Stein, 1974). Stein (1992) emphasized, Brainstorming is that “judgement” and “evaluation” are “deferred” during the ideation process. By controlling oneself, by using one’s mind’s power to dominate the “judicial” mind, it is possible to allow the “creative” mind to do its best work. . . . They are suspended until it is appropriate to use them. (p. 86)

There has been some research to support these two principles.

Christensen et al. (1957) instructed one group of subjects to write clever and relevant responses when composing titles for short stories. A second group was simply instructed to write appropriate responses. A significantly greater number of clever responses were generated under the “appropriate” instructions. The result supported the effect of deferment of judgment.

Parners and Meadow (1959) found that there existed a positive correlation between quantity and quality of ideas. This correlation showed the effect of yielding
quality from quantity, and the authors concluded that brainstorming probably produced an increase in good ideas.

Barriers to Creativity

There are some barriers to effective problem solving or creative thinking. Jones (1984) used the Danzig-Nevis questionnaire to measure and found four different categories of barriers: inhibiting problem-solving strategies, rigid values, lack of perception, and self-image. This researcher also thinks some mental phenomena may as barriers to problem-solving and creative thinking.

Several studies support the contention of some mental phenomena that may act as a barrier to creative thinking. Kosslyn, Ball, and Reiser (1978) conducted an experiment of scanning visual images to determine whether an image is a spatial representation analogous to the experience of seeing an object during visual perception. A map of seven objects was shown for a moment. Then subjects were asked to form a mental image of the whole map with the named objects. After giving two object names, the subject imaged a black speck moving in a straight line from the first object to the second. The mental scanning time was recorded. Among seven objects in the map, there were twenty-one distances. The results showing the time of mental scanning increased with the increment of distance. It was concluded that there was a similar mechanism at work in scanning mental images as in perceiving actual pictures. But some argued that this result was influenced by the Hawthorne Effect (Borg & Gall, 1989), that is, the subject might respond to please the experimenter by speculating what the experimenter expected (Pylyshyn, 1981; Intons-Peterson, 1983; Reed, 1992). This researcher prefers the former conclusion, because the scanning
visual image may be seriously influenced by the prior visual experiences.

In the field of semantic organization, Collins and Loftus (1975) synthesized the hierarchical network model (Collin & Quillian, 1969, 1970) and the feature comparison model (Smith, Shoben & Rips, 1974) to construct the spreading activation model. The assumption of the spreading activation model was that “when a concept is processed, activation spreads out along the paths of a network, but its effectiveness is decreased as it travels outward” (Reed, 1992, p. 221). In this model, links were used to show relationships between concepts, and the length of links indicated the closeness between concepts. There is a strong association in short links, making retrieval from long term memory easier. This researcher thinks the strong association results in strong impressions in one’s mind.

This researcher creates the psychological term “mental inertia” to generalize the phenomena of scanning visual images and the spreading activation model described above. “Inertia” is a physical term, and means that “in the absence of external forces, objects at rest remain at rest, and objects in motion remain in uniform linear motion” (Komar, 1992, p. 136), and refers to the reluctance of a body to a change in its motion. Objects usually remain in the original state. The mental activity could be compared to the physical phenomenon. The “mental inertia” of one’s thinking path will be strongly influenced by previous impression, as illustrated by a Chinese saying “fire tends to dry material; water flows to wet place.” “Mental inertia” is similar to “cognitive unconscious” (Jacoby, Lindsay, & Toth, 1992) and “operation of a supervisory attentional system” (Norman, & Shallice, 1980). Jacoby, Lindsay, and Toth pointed out, “memory for prior experience automatically influences the processing and interpretation of later events,” and “one ubiquitous effect of past
experience is to make current processing more efficient, rapid, or fluent” (p. 803). Norman & Shallice argued that “the supervisory attentional system can provide a boost to a schema’s level of activation, thereby enabling it to ‘get ahead’ in the competition for dominance despite starting from a handicapped position” (McCarthy & Warrington, 1990, p. 363). “Mental inertia” has positive effects in problem solving, especially if there is a similarity between the past experience with a certain function of an object and the new situation with the required function (Mayer, 1992).

Even though “mental inertia” has advantages, it also has disadvantages. Weisberg (1986) pointed out “human perception is strongly influenced by what the perceiver expects to see, and these perceptual expectations can interfere with creative problem solving in various ways” (p. 57). “Mental inertia” usually has a negative effect on creative thinking and problem solving. This phenomenon is called functional fixedness, which means that people make up strong or fixed notions about an object’s functions because of antecedent experience (Crider et al., 1986). The terms similar to functional fixedness are Einstellung effect or mechanization of thought (Anderson, 1985), and negative transfer (Bartlett, 1958). Anderson described functional fixedness as when given a series of problems, “subjects were remembering a particular sequence of operations, and it is memory for this sequence that is blinding them to possibilities” (p. 227). These phenomena are demonstrated in several research studies.

Andre, Schumer and Whitaker (1979) found that subjects performed more creatively on a subsequent divergent thinking test following a discussion experience, but the overall group divergent production was reduced even though subjects who responded after group discussion produced more responses. The later result might
be due to the effect of "mental inertia". Because it was the same item in discussion and writing response, subjects, after discussion by the group, tend to inertly repeat what had been discussed when they were asked to write their responses separately.

The two-string problem and the candle problem are two famous demonstrations illustrating "functional fixedness". Lucnins's 1939 water-jar problems provide verification of the Einstellung effect. These demonstrated how an individual's ability to develop a solution rule of sufficient width and generality could be limited by prior experience (Mayer, 1992). Ransopher (1987) found that when the number of set-induction problems gradually increased, undergraduate subjects were significantly deferred from solving the water jar problems, and this phenomenon was no different between age groups. Smelcer (1989) found functional fixedness as one of four factors that caused error in the omission of the "joint statement", which indicated how to combine multiple database tables. The ability to overcome "functional fixedness" and remote strongly association that interfere with creative thinking were involved in finding relatedness among domains of information and thereby afforded novel ideas to solve problems (Isen, Daubman, & Nowicki, 1987; Kirson, 1990).

From the view of cognitive processing, people experiencing "functional fixedness" would fail to change or find difficulty in changing a schema, even when apparently contradictory evidence was presented (Urban, 1987). Urban concluded that schema instantiating behavior in reading comprehension was related to certain cognitive styles. "Functionally fixed" subjects did not want to change schema, whereas divergent thinkers more easily recalled inconsistent information. "Functional fixedness" will decrease students' academical achievement. Haylock (1987) suggested that there should be emphasis on cultivating the ability to overcome fixations in math-
ematical problem-solving and the ability for divergent production in mathematical situations. Elimination of "mental inertia" or "functional fixation" to conquer barriers to creativity in the instructional field is an important issue.

From the viewpoint of "mental inertia" and "functional fixedness", the progress of creativity seems related to the content of what students have previously learned. This phenomenon has been shown in some research (e.g. Li, 1987; Wu, 1989). Students in the electronic department only took one semester of the Engineering Graphics course when they were in tenth grade. Students of the machinery department had had four semesters of the course, because the Engineering Graphics courses was one of the major courses in the machinery department. Therefore, the students of the machinery department probably progressed less in the scores of the figural test in the Torrance Test of Creative thinking than those of the electronic department. This issue is also be explored in this research.

The Function of Brainstorming

Brainstorming is a means to generate fluent ideas under the guidelines of four regulations. The four regulations are intended to remove a participant’s mental defenses, and cite silly and brilliant ideas as an excellent catalyst of laughter.

Williams and Sterberg (1988) found that "people working in newly formed small groups on written problems stressing divergent, creative solutions generally produce higher quality products than people working alone" (p. 374). In a group working for creative thinking, a group’s creative climate is important. There are three factors that affect a group’s creative climate: 1) the external environment, 2) the internal creative climate of individuals within the group, and 3) the quality of in-
terpersonal relationships among the group members (Vangundy, 1984). Verbal reinforcement for creative responding is effective in increasing creative responses (Griffith & Clark, 1981). Brainstorming facilitates manipulation of external environment and the internal creative climate of individuals, and give verbal reinforcement. Some research indicated brainstorming could increase individual creativity (Andre, Schumer & Whitaker, 1979).

Brainstorming is important in the process of creative problem solving (CPS) which is useful in creative thinking. There are six stages in the process: 1) mess-finding, 2) data-finding, 3) problem-finding, 4) idea-finding, 5) solution-finding, and 6) acceptance-finding (Treffinger & Firestien, 1989). Every stage has two phases; a divergent phase and a convergent phase. Brainstorming is used as the tool of the divergent phase.

The function of brainstorming is obvious. Kim (1990) states that some researchers do not consider the generation of ideas is the real value of brainstorming. But, in a brainstorming session, a teacher can hint at various thought paths. The ideas of the participants lead each other to schema-recall, and a "chain-reaction" of ideas. Because learning through observation of someone else will be relatively efficient (Bandura, 1986), students learn reciprocally. After the practice of brainstorming the mental inertia and functional fixation of students may disappear gradually. Mobility, flexibility, and combinatorial playfulness are some of the feature of brainstorming.

Brainstorming techniques have been widely applied in industrial and educational settings. Brainstorming was quite popular in Japan in the 1960s (Torrance, Goff, & Okabayashi, 1992). In 1990, when the SANNO Institute of Business Administration surveyed 394 Japanese corporations in the topic of creative development, brainstorm-
ing had the highest percentage (87.1%) among creative strategies to be used as training technique (Nakazono, 1992). Kumiega (1992) concluded that creative output is the sum of creativity, environment, and support process. Studies showed that when the environment is consistent with their preferences, children and adults are more effective and productive in their work (Firestien, 1992). Governed by four regulations, it is easier to yield silly ideas in brainstorming sessions, and a positive environment and climate develops. Brainstorming is a common and good way to enhance the abilities of creative thinking and problem solving. Wragg and Allen (1982) suggested the brainstorming technique could be used in ecology, geography, energy and economics for it is adaptable to various fields.

Studies Related to the Effect of Brainstorming

Brainstorming has been used widely in creative thinking teaching and research, especially in the teaching of writing. Fortner (1986) investigated whether creativity training of intermediate grade disabled students would generalize to better performance on a spontaneous writing exam. Non-judgemental brainstorming led to improved writing in the experimental group as measured by thought units, subordinate clauses, and thematic maturity. Liatsos (1986) studied the effects of imagery and brainstorming on the creativity of children’s poems, applied to 4th grade students. Significantly greater gains were indicated for the group instructed in brainstorming in comparison with the non-instruction group in the areas of total creativity on the criteria of imagery, strangeness of imagery-fantasy, total affect, personal involvement and taking risk in revealing self. Bradbard (1990) studied improved problem-solving through writing based on children’s literature, and used verbal brainstorming with
fourth and sixth grade students for finding different problem-solving strategies. A significant experimental difference was demonstrated confirming the beneficial effect of brainstorming.

Brainstorming also has been used to teach mathematics. Farrar (1984) applied creativity-originality training, divergent thinking, and the brainstorming methods to the teaching of mathematics to fourth graders. The performance of the treatment group did not improve more than that of the traditional group which utilized a convergent thinking approach. Brainstorming may not be appropriate for the math field. The effectiveness of different creative thinking teaching strategies is worthwhile to explore.

Murray (1987) undertook a study of “The Effectiveness of Technology Forecasting as a Method for Improving Learning of Technological Information by Junior High School Industrial Arts/Technology Education Students.” Results of this study indicated teaching methods of brainstorming, trend extrapolation, and use of a relevance tree did not significantly affect experimental groups compared with controls in learning technological information.

Most research on brainstorming has been conducted with other creative strategy methods. Not much research has been conducted where brainstorming is the sole or main focus. For example, Horton (1986) studied the effectiveness of three creative activities of mindstorming, sketchstorming, and modelstorming in the design of appropriate technology prototypes. The subjects were sixth grade students. The study’s result indicated enhanced creativity in the design of three-dimensional appropriate technology prototypes, but no significant differences was found as measured by the Torrance Test of Creative Thinking Figural Form B.
In Taiwan, Shyu (1975) conducted the only research in which brainstorming was the main strategy. The purpose was to explore the effect of internal-external locus of control and brainstorming on enhancement of creative thinking abilities. Brainstorming training was given to eleventh grade students for thirty minutes. The study indicated that the experimental group students performed better than the control group students in scores of verbal creative thinking abilities.

This researcher (Wu, 1989) has also undertaken “An Experimental Study of Incorporating Creative and Inventive Concepts into Vocational High School Curricula” and found that an experimental curriculum of creativity and invention could improve the creativity of students. The units of the experimental curriculum are: (1) the introduction and examples of invention, (2) invention method I, (3) brainstorming, (4) invention method II, (5) creative essay contest in small groups, (6) procedure-designing and analysis of worth, (7) patent rights, (8) observation and imagination, and (9) literal thinking. Among nine units of the experimental curriculum, the unit of brainstorming was considered as the favorite and most helpful strategy employed by the students.

Even though brainstorming does not have an obvious effect in technology courses (e.g. Murray, 1987), it would be worthwhile, from this researcher's research, to explore whether or not brainstorming enhances the creativity of students in Vocational Industrial Education programs in Taiwan.
The Research and Implementation about Creative Thinking Teaching in the Republic of China

The Publications and Research about Creative Thinking Teaching in the R.O.C.

At the initiation of the Republic of China (1917-1919), some articles on creativity in Chinese were published in the educational journals. Chen (1991) has collected and categorized the literature about creativity. There were 29 doctoral dissertations or master theses, 371 articles published in journals or periodicals, 19 books, and 6 kinds of tests and handbooks in last 32 years.

Since Chia's (1970) own report advocating empirical research in creative thinking teaching, there has been a total of eighteen such reports which can be classified into two categories. The first is to use a creative thinking strategy to teach students; the other is to embed some creative strategies in one special course to teach students. Among these studies, 38% were highly effective, 54% were partly effective, and only 8% were in vain (Chen, 1991). From analyzing this body of research, the samples included students from kindergarten to university level, but the pupils of the elementary school are the most frequently studied subjects. Creative thinking teaching strategies were used in mathematics, science, society and composition and drawing in the elementary and senior secondary education level, but not in special training on the university level.

From the above information, it can be concluded that the topic of creative thinking has been applied in the academical field in the R.O.C.
The Conditions to Advocate Creative Thinking Teaching in the R.O.C.

Performance in creative thinking teaching. Cultivation of the abilities of creative thinking and problem solving is listed in the educational goals of various institutions. To reach this goal, the teachers need to apply valid teaching methods. To enhance the student's creativity and promote innovation in teaching methods, the Education Department in Taipei City Government (E.D.T.C.G.) has utilized creative thinking teaching since 1983 (Chen, 1989). By means of correcting teaching concepts, establishing positive teaching environments, innovating teaching methods, building proper teaching measurements, and verifying teaching atmospheres, the creative thinking teaching was undertaken in every subject of each level of education based on the contemporary curriculum.

To assure effectiveness of the program, the E.D.T.C.G. has held many supporting activities. The first one is the Conference of Creative Thinking Teaching in the city of Taipei in 1983, presided by the Director of E.D.T.C.G. The participants included all schoolmasters, principals, supervisors, and supervisory teams for every subject in all city schools. Many professors of creative thinking were also invited. The topics were to explore (1) what model should be used to promote the creative thinking teaching in Taiwan; (2) what method and style could be used in the teaching; (3) how to establish a good environment for creative thinking teaching (4) how to change the atmosphere in the classroom (5) how to arrange teaching affairs for creative thinking teaching between the teachers and the schoolmaster or principal. After enthusiastic discussion, some conclusions were generated: (1) creative thinking teaching should include the innovation of teacher's teaching methods and the cultivation of the student's creative abilities. (2) creative thinking teaching and traditional teaching could complement
each other. (3) creative thinking teaching should be embedded in the current curriculum, not taught as a separate curriculum on its own. (4) establishing the teaching environment, innovating teaching methods, fitting with instructional measurements, changing teachers' attitudes, and vivifying teaching atmosphere are the premises to promote creative thinking teaching; and (5) the differences among teachers should be considered. The processes were also decided: (1) founding of supervisory teams; (2) appointment of one school to experiment with each subject; (3) planning a seminar; (4) creation of an editorial team; (5) constitution of a curriculum design team; (6) holding a conference for professors in the teacher college (Chen, 1989). After the conference, Taipei seriously promoted creative thinking teaching in various activities. This conference firmly established the direction to promote creative thinking teaching in Taipei. This became the milestone for teaching in the educational history of the R.O.C.

Following Taipei City, the Education Department of Kaohsiung City government held a Creative Thinking Teaching Seminar at the junior middle school level in 1985. Since 1985, the Education Department of the Taiwan Provincial Government has also annually held a creative thinking teaching seminar for vocational education to strengthen the teachers' knowledge to guide students who possess special abilities. A students' guidance project for creative and special ability was organized and executed entirely in 1988 (Chen, 1989).

According to the vocational educational goal, "to establish the students' abilities of creation, adaption, and self-development" and the performance project "to cultivate the creative and special abilities of the vocational educational students in Taiwan province", the Educational Department under the Taiwan Provincial Gov-
ernment has further set up "the performance project to strengthen creative thinking teaching in Taiwan Provincial Vocational Education". This project has been in operation since the 1990 school year. In the project, the purpose, principle, methodology, procedure, finances, supervision, and evaluation have all been explicitly regulated, and some strategies of creative thinking teaching were listed. According to the performance project, every vocational school was to construct a more detailed performance project and hold teaching demonstration sessions within the school (Education Department of Taiwan Province, 1991a). Furthermore, Ro-ton Senior Vocational Industrial School has held Teaching Demonstration of Taiwan Provincial and Private Vocational School for this project under the support of the Educational Department of Taiwan Province on March, 1991. In the demonstration sessions there was a lecture about creative thinking teaching, ten teaching display sections for ten subjects, and two symposiums to communicate about project outcomes. A handbook collecting many articles about creative thinking teaching was also given to every participant. Afterward, the handbook was amplified with more articles to send to every vocational school as the reference for creative thinking teaching (Education Department of Taiwan Province, 1991b).

Activities related to creative thinking teaching. In addition to the performance of creative thinking teaching, there has been an Exposition of Vocational Educational Students' Creation and Research annually since 1986. Every vocational school needs to select student's work(s) to participate. The entries were initially categorized as industrial and agricultural. More recently there are five categories: 1) mechanical, 2) electrical, 3) food and chemical, 4) agriculture and cultivation, and 5)
arts, construction and home economics. The excellent works of every group received an award.

In addition to the school education system to encourage creative, Taiwan National Science Education Center has also undertaken some activities, such as the Science Exposition of Elementary and Middle Schools yearly since 1960, and recently invention and creation expositions for students, teachers, and general society. The works from every exposition have been compiled and sent to every school. Circulating lectures to advocate creativity and invention have been conducted all over Taiwan (National Taiwan Science Education Center, 1986). It is apparent that these projects and activities were held to enhance and incite students' creativity.

The Review of Performance to Enhance Students’ Creativity

To realize the effectiveness of creative thinking teaching, the Evaluating Committee of Development and Research in Taipei City had Biang-huang Huang(1987) evaluate the creative thinking teaching in elementary schools. The evaluating problem included teaching materials, teaching methods, opinions of teachers and executive authorities (Chen, 1989). The conclusions were described as follows.

Evaluation of teaching material and measurement.

1. The teaching plans designed under the advice of experts correspond with the principle of creative thinking teaching. The key point of its effectiveness was how teachers use them.

2. The evaluation sheets of students' home work were not enough to reflect the spirit of creative thinking teaching. The evaluation sheets reflecting the spirit
of the teaching were not easily made and graded.

**Evaluation of teachers' opinions.**

1. Most of the teachers agreed the teaching material provided by the Education Department was useful, but not easily taught in the usual allotted time.

2. Most of the teachers agreed that the students liked creative thinking teaching, and progressed in the abilities of expression, question skills, imagination, and problem solving, and interest in learning. However, 50% of teachers thought students didn’t progress in academic achievement.

3. Most of the teachers thought the opportunity for on-job training was not sufficient for creative thinking teaching.

4. Most of teachers thought creative thinking teaching was an especially difficult teaching method. It easily disordered discipline of the classroom, and had students daydream impractically.

**Evaluation of teaching method.** Teachers usually used a dialogue method in teaching. The common phenomenon was that there was too much explanation, questions in cognitive and memory items, and repetition to students’ answer. These showed that indeed teachers do need on-the-job training. The topics for at-the-job training should be how to question, how to move from cognitive and memory items to creative and critical ones, and how to employ the students' answers to conduct gainful learning activities.
Evaluation of students' creativities, achievement, and learning interest. The measures used in the evaluation were not sufficient to evaluate the students' ability in creative thinking. This misled people to think the creative thinking teaching was invalid.

The Way to Strengthen the Effect of Creative Thinking Teaching in Vocational Industrial Education

Although creative thinking teaching had been increased since EDTCG's education promotion of two former directors since 1983, it has been attenuating in the last couple of years. Vocational industrial education in Taipei has also utilized creative thinking teaching, but many teachers have been confused on how to include performance as a part of creative thinking in industrial technological teaching.

Although the vocational industrial education in Taiwan Province has advocated cultivating students' creative thinking ability, the number of entries in the Exposition of Vocational Educational Students' Creation and Research has not increased in the last five years.

Therefore, it can be clearly seen that the effectiveness of creative thinking teaching has never occurred in vocational industrial education. Development of methods for planting the function of creative thinking teaching in vocational industrial education is an important topic. Vocational industrial education occupies a large proportion in secondary education in R.O.C. The work force generated from vocational industrial education is important in the national development. It is necessary to enhance students' creativity in this field. In fact, it is not easy to strengthen the effect of creative thinking teaching unless a simple and effective strategy of creative
thinking teaching is applied extensively.

This researcher (Wu, 1989) conducted research about creative thinking teaching with nine teaching units. The unit of brainstorming was most favored by students and considered the most effective one. Brainstorming is very simple to understand. So it is worthwhile to examine its real effect on creative thinking. If its effect is supported, brainstorming could be advocated in vocational industrial education.

Summary of the Literature Review

The emphasis on creativity within the educational field is a world-wide trend. Enhancing creative thinking and problem solving should be promoted by instruction. To guide students to overcome barriers to creativity is important. How to enhance the creativity of students in Taiwan vocational industrial education is stressed gradually. To explore and set up a simple strategy of creative thinking teaching is important. The effect of brainstorming has been presented through several research studies, and wherein the process of brainstorming has been mutually accepted by the participants. Therefore, the researcher desired to undertake the proposed research study to investigate the effect of brainstorming on vocational industrial education students in Taiwan. The main purpose is to find a simple, effective and creative strategy for vocational industrial education students in Taiwan.
CHAPTER 3. METHODOLOGY

The purpose of this study was to determine the effectiveness of brainstorming to enhance creativity of vocational industrial education students, and the enhancement effects of creative thinking abilities on different technical subjects. The method is described below.

Research Subjects

Samples were chosen from the Ta-an Senior Vocational Industrial School in Taipei City. Four eleventh grade classes were randomly assigned. Because it is difficult to break these classes to assign subjects completely randomly because of school administrative policy, the original classes served as the units of teaching and measure. Two electronic classes, randomly selected from three classes, of approximately 49 students each were assigned by the flip of a coin. One served as the experimental class and the other as the control class. The two machinery classes were randomly assigned to experimental and control groups in a similar manner. The reason for selecting these students as subjects is that the electronic and the machinery departments are separately the most representative of the mechanical cluster and the electrical cluster in vocational industrial education, and these two clusters are the biggest among five clusters in vocational industrial education schools in Taiwan.
Table 3.1: The actual sample of this research

<table>
<thead>
<tr>
<th>Group</th>
<th>Electronic Dep.</th>
<th>Machinery Dep.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental</td>
<td>40</td>
<td>44</td>
</tr>
<tr>
<td>Control</td>
<td>45</td>
<td>44</td>
</tr>
</tbody>
</table>

After eliminating students who did not want to take this experimental teaching, who were absent more than two hours of five hours of teaching, or who did not take the pre-test or the post-test, the actual sample is shown in Table 3.1.

Experimental Design

This quasi-experimental study was composed of a non-equivalent control-group design (Borg & Gall, 1989, p-690). Table 3.2 shows the experiment design.

Table 3.2: Experimental design

<table>
<thead>
<tr>
<th>Group</th>
<th>Pretest</th>
<th>Treatment</th>
<th>Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental</td>
<td>T1</td>
<td>X1</td>
<td>T2</td>
</tr>
<tr>
<td>Control</td>
<td>T3</td>
<td>X2</td>
<td>T4</td>
</tr>
</tbody>
</table>

1. Pretest (T1,T3): Two groups were tested by participating in the Torrance Test of Creative Thinking, Figural Form A and Verbal Form B.

2. Treatment: The experimental group was taught with brainstorming sessions (X1) (see Appendix A); and the control group, with the material unrelated to creativity (X2) (introduction of American culture, customs, and national parks). The teaching time in the experimentation is five hours with each group, two hours a week. All treatment groups were taught by this researcher.
3. Post-test (T2, T4): Two groups were tested with the Torrance Test of Creative Thinking, Figural form B and Verbal Form A. All tests were supervised by the counseling teachers of experimental schools according to the directions manual of the Torrance Test of Creative Thinking.

Variables

Independent Variables

There were two independent variables in these study: teaching material and department of study. Experimental groups were taught by brainstorming session; control groups, by the introduction of American culture and national parks. The two types of departments included were machinery majors and electronic majors.

Dependent Variables

There were nine dependent variables in this study. The variables were a) scores of verbal-fluency, verbal-flexibility, verbal-originality, and verbal-total of post-test in the verbal form of Torrance Test of Creative Thinking; b) scores of figural-fluency, figural-flexibility, figural-originality, figural-elaboration, and figural-total of post-test in figural form of Torrance Test of Creative Thinking.

Covariates

The covariates in this study were the scores mentioned at “Dependent Variables” of pre-test in the verbal and figural forms of Torrance Test of Creative Thinking.
In this study, Torrance Tests of Creative Thinking was used to determine the experimental effect. This test includes two figural forms and two verbal forms (see Appendix B).

**Verbal Test of the Torrance Test of Creative Thinking**

The verbal test in the Torrance Test of Creative Thinking has two forms, Form A and Form B (Torrance, 1974a; 1974b). There are seven activities in each form. Form A has Activity 1: asking activity, Activity 2: guessing causes, Activity 3: guessing consequences, Activity 4: product improvement, Activity 5: unusual uses of cardboard boxes, Activity 6: unusual questions, and Activity 7: just suppose. There are similar activities in Form B, except for Activity 5: unusual uses of tin cans. These were revised independently by Ing-mao Liu (1979) and Jing-jyi Wu (1981a) in Taiwan. This study adopted the fifth activities, unusual uses; Form B in pre-test, Form A in post-test, and the test time was ten minutes devoted to each activity. This activity was the most representative and yielded scores of fluency, flexibility, originality and total. This activity could collect the scores of fluency, flexibility, originality, and total.

**Reliability.** Torrance (1974a,b) determined the interjudge reliability of this test. The mean Pearson product-moment coefficients for verbal tests between the scoring of trained and untrained graders were: fluency, .99; flexibility, .95; and originality, .91. Jing-jyi Wu (1981a) announced that there was a satisfactory result in interjudge reliability of the verbal test. Lin (1983) determined the coefficient of the
test-retest reliability in Form A with an interval of four months. The results were: fluency, .67; flexibility, .68; and originality, .52. Jing-jyi Wu (1979) investigated students of primary, middle and high school. With an interval of two years, the test-retest reliability in Form B was from 0.256 to 0.77. Among eighteen correlation coefficients, sixteen reached a significant level. These results show that this test has good coefficient of reliability. Interval test has been found significant at the .01 level between tin can subtest and Torrance's other figural and verbal subtests (Forther, 1986 Mackeler & Shontz, 1967; Mahan & Mahan, 1981).

Validity. Concurrent validity is satisfactory with the criteria of peer nominations, teacher nominations, sales productivity and educational achievement, and the content validity, predictive validity, and construct are satisfactory as well (Wu, 1981a). The predictive validity was significant compared to creative behaviors on short-range and long-range (Torrance, 1972c).

Figural Test of the Torrance Test of Creative Thinking

The figural test of the Torrance Test of Creative Thinking has two forms, Form A, and Form B (Torrance, 1972b). There are three activities in each form. Form A has Activity 1: picture construction, Activity 2: picture completion, and Activity 3: lines. There are similar activities in Form B except that Activity 3 contains circles, rather than the lines activity of form A. They were revised separately by Jing-jyi Wu (1981b) and Lung-ann Chen (1986). This study adopted the third activity, lines and circles. Form A, lines, is used in the pre-test; Form B, circles in the post-test. Each activity was completed in ten minutes. The activity was the most representative. It
yielded the scores of fluency, flexibility, originality, elaboration and total.

Reliability. Torrance (1972b, 1974c) has determined the interjudge reliability of this test. The mean Pearson product-moment coefficients for figural tests between the scoring of trained and untrained grades were: fluency, .96; flexibility, .94; originality, .86; and elaboration, .91. Jing-jyi Wu (1981b) obtained a coefficient of the interjudge reliability from .81 to .99 between seven graders; Lung-an Chen (1986) obtained the coefficients of the interjudge reliability from .66 to .99. Sulan Guo (1984) reported the coefficient: fluency, .78; flexibility, .96; originality, 1.00; and elaboration, .97. Jing-jyi Wu (1979) investigated performance of 198 students in the fourth, seventh and tenth grades to determine the test-retest reliability. With an interval of two years, the coefficients were: fluency, .27-.57; flexibility, .12-.55; originality, .19-.50; and elaboration, .19-.75. Lung-ann Chen (1986) also reported the coefficients of test-retest reliability were from .28 to .64 after testing 176 students of third and fifth grades with an interval of four months. These show this test has a high coefficient of stability.

Validity. Lung-ann Chen (1986) tested construct validity with 410 students among 32 primary schools in Taipei, and found construct validity reached significant level with the criterion of teacher nominations. Other types of validity evidence, such as content validity, predictive validity, and concurrent validity also were satisfactory (Wu, 1981b). The predictive validity was significant compared to creative behaviors on short-range and long-range (Torrance, 1972c).
Procedures

Permission for this experimental research was granted by Ta-an Senior Vocational Industrial School in Taipei City (see Appendix C). The Iowa State University Committee on the use of Human Subjects in Research reviewed this study and concluded that the rights and welfare of the subjects were protected properly (see Appendix D). Two letters were sent to each subject to explain the teaching and test. One was by the name of this researcher; the other, the director of counseling office in Ta-ann Senior Vocational Industrial School (see Appendix C).

Coordination Meeting

A coordination meeting was held before experimental teaching to avoid the biasing of the experiment. The meeting was presided over by the Principal of the Ta-an Senior Vocational Industrial School. The participants included deans of studies, dean of students, directors of the counseling office, mechanical and electronic departments, and academic advisors of four classes. At this meeting, this researcher explained the content of the experimental research and how they would be asked to help, then discussed the project generally.

Experimental Teaching

Experimental teaching was conducted for five hours with each class, taught by this researcher. The teaching was performed during students' independent study times, two separate hours in each class. Experimental groups performed the brain-storming session (see Appendix A). The topics of brainstorming discussed in the session were the improvement of the electronic driver, the bicycle, and the table lamp,
and the application of the photo-resistance (CDS) for the electronic experimental group; the improvement of pencil, bicycle, door, and chair for the mechanical experimental group. All topics intentionally avoided the content of pre- and post-test. Control groups were performed with the introduction of American culture, customs, and national parks. Five hours per class was spent with each control group. The program for control groups was based on the purpose of the global education to develop students' global perspective. There were five units: 1. Iowa State University, introduced by lantern slides; 2. American culture and customs, by lecture; 3. American national parks(I), by lantern slides; 4. Americans with a spirit of risk taking, by tape of stunts; and 5. American national parks(II), by lantern slides. After teaching, the students of four classes were asked to take a questionnaire on their learning reaction (see Appendix E).

The Avoidance of the Hawthorne and John Henry Effects

In experimental teaching, the Hawthorne and Henry effects might be caused easily if the treatment process was careless. Because the content of brainstorming for experimental groups was relevant to the creative thinking test, this researcher hoped that students did not know they were part of an experimental or control group, and so possibly, let students feel that there was no relationship between the teaching and test. Under this premise, in addition to the coordination meeting, this researcher told the students that the researcher just wanted to examine whether the results of brainstorming sessions and global education suited the needs of students in vocational industrial schools, and the students were asked to take the tests under the auspices of the counseling office. When performing the tests, the teachers at the office told
students that the counseling office offered students the chance to understand their creative thinking abilities and enhancement in those abilities within the interval of three weeks. The program for control groups was to make the effect of placebos (Borg & Gall, 1989, p. 196-199).

Treatment of Data

Grading

The Torrance Test of Creative Thinking is regarded as a psychological standardized test, and was graded according to the scoring guide. The graders were the students of a creativity course in Taipei Municipal Teachers College. Due to high coefficients of interjudge reliability, Torrance (1972, 1974a, 1974b, 1974c) suggested that it is not necessary to train specially in scoring tests for reliable results. Nevertheless, to improve the scoring, Lung-Ann Chen, the director of Creativity Center in Taipei Municipal Teachers College, taught two seminars for these students to interpret, demonstrate, practice, and discuss the scoring. After the seminars, five students graded the verbal tests, and seven students graded the figural tests. The figural elaboration score was graded by one student to unify the standard.

Analysis of Data

A 2x2 analysis of covariance (ANCOVA) was used to test the effects of the experimental teaching, in which group and department variables served as the independent variables. The scores of the post-test were dependent variables, and the scores of the pre-test served as covariates. Before the analysis of covariance, a test for homogeneity of regression was conducted to check if it violated the assumption of homogeneity in
ANCOVA. Keppel (1991) suggested rejection rate was $\alpha = .10$ used in the test of violating statistical assumption to unequal sample size when the nominal rejection rate was $\alpha = .05$, so the level of significance was $\alpha = .10$ in the test for homogeneity of regression. In this research there were two scores, verbal-flexibility and figural-elaboration, reached the significant level on the test for homogeneity. This meant that the conventional ANCOVA model did not fit the data of these two scores (Huitema, 1980; Tabachnick & Fidell, 1983). Some statistical scholars (Huitema, 1980; Kepple, 1991) suggested that Johnson-Neyman technique (Johnson & Neyman, 1936) could be used for further analysis. The technique is to categorize the covariate as high and low levels to analyze the data separately. This seemed not to have significance in the research, and there is no any appropriate statistics program package available for the two-way experimental study so far, so the researcher analyzed these two scores with the two-way analysis of variance (ANOVA) for difference between t scores of the pre-test and the post-test. In this study, the reason to consider ANCOVA as the first priority for statistical analysis was that the ANCOVA is the most powerful statistical method for pretest-posttest data (Jennings, 1988).

If there was interaction between the groups and the department in ANCOVA, then an adjusted means would be used to test the simple effect. When the interaction effect was statistically significant, the method of LSMEANS (Least Squares Means) was used to test the simple effect. The level of significance in ANCOVA and ANOVA was $\alpha = .05$. All processing was done with SAS package.
Summary

Chapter 3 presented the methodology used in this study. The experimental design was a quasi-experimental, non-equivalent control group design. Experimental and control groups received different teaching materials. The instrument used for pre- and post-testing was the Torrance Test of Creative Thinking, a standardized test. Experimental design and procedures attempted to control for Hawthorne and Henry effects.

Data were analyzed by ANCOVA and ANOVA. The results of the analyses is shown in Chapter 4.
CHAPTER 4. RESULTS AND DISCUSSION

This chapter presents and discusses the results of the statistical analysis of the data collected by the researcher in administering the Torrance Test of Creative Thinking. These tests were given to each subject in the electronic experiment group \( n=40 \), the electronic control group \( n=45 \), the machinery experiment group \( n=44 \), and machinery control group \( n=44 \).

Results

The results are presented in three sections: 1) the effect of brainstorming on verbal creative thinking abilities, 2) the effect of brainstorming on figural creative thinking abilities, and 3) summaries.

The Effects of Brainstorming on Verbal Creative Thinking Abilities

This section presents the effects of brainstorming on verbal creative thinking abilities. The main purpose is to examine Hypothesis 1: The experimental group students participating in brainstorming sessions will have significantly higher scores in verbal creative thinking abilities than the control group students, and Hypothesis 3: There will be no significant differences in the enhancement of verbal creative thinking abilities after brainstorming sessions between machinery and electronic students. For
ease of understanding the results, the means and standard deviations of pre-test and post-test, and adjusted means in verbal test of the Torrance Test of Creative Thinking are first presented in Table 4.1.

The effects of brainstorming on verbal fluency scores. The result of the test for homogeneity of regression on verbal-fluency scores was $F(3,165)=1.61$, $p>.10$. It was not statistically significant at $\alpha = .10$. Therefore, the assumption of homogeneity of regression was tenable on the analysis of covariance (ANCOVA) of this score. The analysis of covariance for verbal-fluency scores is presented in Table 4.2. On both group and department main effects, group was statistically significant, $F(1,168)=39.61$, $p<.01$, and department was not statistically significant. The interaction effect between group and department was not statistically significant. The adjusted means, reported by groups, were 26.98 for the experimental group and 19.28 for the control groups. Reported by department, adjusted means for the electronic department and machinery department were 23.88 and 20.38, respectively. This indicated that there was no significant difference between the machinery and the electronic departments, and the experimental group was significantly higher than the control group on verbal-fluency scores. From the analysis, the results supported Hypothesis 1.1 and Hypothesis 3.1. Hypothesis 1.1 is: The experimental group will have significantly higher verbal-fluency scores than the control group; and Hypothesis 3.1 is: There will be no significant differences on the enhancement of verbal-fluency scores between the machinery and the electronic students.

The effects of brainstorming on verbal-flexibility scores. The result of the test for homogeneity of regression on verbal-flexibility was $F(3,165)=2.97$, $p<.10$. 
Table 4.1: Means and standard deviation of pre-test and post-test in verbal test of the Torrance Test of Creative Thinking

<table>
<thead>
<tr>
<th>Group</th>
<th>Number</th>
<th>Fluency Scores</th>
<th>Flexibility Scores</th>
<th>Originality Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean(S.D)</td>
<td>Mean (S.D)</td>
<td>Mean(S.D)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pre-test</td>
<td>Post-test</td>
<td></td>
</tr>
<tr>
<td>Electronic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dept.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experiment</td>
<td>40</td>
<td>21.18(8.98)</td>
<td>30.78(11.13)</td>
<td>28.15</td>
</tr>
<tr>
<td>Group</td>
<td>45</td>
<td>15.80(8.38)</td>
<td>18.04(9.54)</td>
<td>19.58</td>
</tr>
<tr>
<td>Machinery</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dept.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experiment</td>
<td>44</td>
<td>16.09(6.22)</td>
<td>24.52(9.83)</td>
<td>25.83</td>
</tr>
<tr>
<td>Group</td>
<td>44</td>
<td>18.41(8.16)</td>
<td>19.48(9.93)</td>
<td>18.99</td>
</tr>
<tr>
<td>Electronic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dept.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experiment</td>
<td>40</td>
<td>15.48(8.89)</td>
<td>25.20(11.73)</td>
<td>22.43</td>
</tr>
<tr>
<td>Group</td>
<td>45</td>
<td>8.47(6.46)</td>
<td>13.93(8.67)</td>
<td>14.68</td>
</tr>
<tr>
<td>Machinery</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dept.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experiment</td>
<td>44</td>
<td>6.84(5.13)</td>
<td>14.36(6.44)</td>
<td>15.93</td>
</tr>
<tr>
<td>Group</td>
<td>44</td>
<td>9.57(5.47)</td>
<td>11.34(6.15)</td>
<td>11.53</td>
</tr>
</tbody>
</table>
Table 4.1 (Continued)

<table>
<thead>
<tr>
<th>Group</th>
<th>Number</th>
<th>Mean(S.D) Pre-test</th>
<th>Mean(S.D) Post-test</th>
<th>Adjusted Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electronic Dept.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experiment Group</td>
<td>40</td>
<td>50.30(21.31)</td>
<td>68.75(24.21)</td>
<td>61.67</td>
</tr>
<tr>
<td>Control Group</td>
<td>45</td>
<td>34.71(16.73)</td>
<td>41.62(23.61)</td>
<td>44.64</td>
</tr>
<tr>
<td><strong>Machinery Dept.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experiment Group</td>
<td>44</td>
<td>33.66(13.60)</td>
<td>50.41(18.85)</td>
<td>54.35</td>
</tr>
<tr>
<td>Control Group</td>
<td>44</td>
<td>39.91(16.78)</td>
<td>41.09(18.86)</td>
<td>40.74</td>
</tr>
</tbody>
</table>

The result was statistically significant at $\alpha = .10$. Therefore, the assumption of homogeneity of regression was violated. This meant that the conventional ANCOVA model did not fit the data of this score (Huitema, 1980). The analysis of variance for difference between t scores of the pre-test and the post-test was used for further statistical analysis of the verbal-flexibility scores. The result is presented in Table 4.3. Of the two main effects, group was statistically significant, $F(1,68)=3.90, p<.05$, and department was not statistically significant. The interaction effect between group and department was not statistically significant. The mean of the difference between t scores of the pre-test and post-test verbal-flexibility scores, was 0.87 for the experimental groups and -1.52 for the control groups. These results indicated that there is no significant difference on this score between the machinery and the electronic departments, and the experimental group was significantly higher than the control group on figural-originality scores. From the analysis, the data supported Hypothesis 1.2 and Hypothesis 3.2. Hypothesis 1.2 is: The experimental group will have signifi-
**Table 4.2: Analysis of covariance for verbal-fluency scores**

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>Prob</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate</td>
<td>1</td>
<td>6460.03</td>
<td>6460.03</td>
<td>100.84**</td>
<td>0.000</td>
</tr>
<tr>
<td>Group</td>
<td>1</td>
<td>2537.91</td>
<td>2537.91</td>
<td>39.61**</td>
<td>0.000</td>
</tr>
<tr>
<td>Dept.</td>
<td>1</td>
<td>90.33</td>
<td>90.33</td>
<td>1.41*</td>
<td>0.237</td>
</tr>
<tr>
<td>Group * Dept.</td>
<td>1</td>
<td>30.33</td>
<td>30.33</td>
<td>0.47</td>
<td>0.492</td>
</tr>
<tr>
<td>Residual</td>
<td>168</td>
<td>10762.81</td>
<td>64.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>172</td>
<td>21394.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**P < .01. *P < .05.

...significantly higher verbal-flexibility scores than the control group; and Hypothesis 3.2 is: There will be no significant differences on the enhancement of verbal-flexibility scores between the machinery and the electronic students.

The effect of brainstorming on verbal-originality scores. The result of the test for homogeneity of regression on verbal-originality scores was $F(3,165)=1.27$, $p>.10$. The result was not statistically significant at $\alpha = .10$. Therefore, the assumption of homogeneity of regression was tenable on the ANCOVA of this score.

The analysis of covariance for verbal-originality scores is presented in Table 4.4. Both group and department main effects were statistically significant. For group, $F(1,168)=25.43$, $p<.01$, and for department, $F(1,168)= 15.22$, $p<.01$. The interaction effect between group and department was not statistically significant. The adjusted means, reported by group, were 19.17 for the experimental groups and 13.10 for the control groups. Reported by department, the adjusted means were 18.55 for the electronic department and 13.73 for the machinery department. These results...
Table 4.3: Analysis of variance for difference between t scores of the pre-test and post-test on verbal-flexibility scores

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>Prob</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>1</td>
<td>234.68</td>
<td>234.68</td>
<td>3.90*</td>
<td>0.0498</td>
</tr>
<tr>
<td>Dept.</td>
<td>1</td>
<td>21.06</td>
<td>21.067</td>
<td>0.35</td>
<td>0.5548</td>
</tr>
<tr>
<td>Group* Dept.</td>
<td>1</td>
<td>205.29</td>
<td>205.29</td>
<td>3.41</td>
<td>0.0664</td>
</tr>
<tr>
<td>Residual</td>
<td>169</td>
<td>10163.35</td>
<td>60.14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>172</td>
<td>10633.22</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*P < .05.

indicated that the electronic department was significantly higher than machinery department, and the experimental group was significant higher than the control group on verbal-originality scores. From the analysis, the results supported Hypothesis 1.3 and Hypothesis 3.3. Hypothesis 1.3 is: The experimental group will have significantly higher verbal-fluency scores than the control group. Hypothesis 3.3 is: There will be no significant differences on the enhancement of verbal-originality scores between the machinery and the electronic students.

The effects of brainstorming on verbal-total scores. The result of the test for homogeneity of regression on verbal-total scores was $F(3,165)=1.58$, $p>.10$. The result was not statistically significant at $\alpha = .10$. Therefore, the assumption of homogeneity of regression was tenable on the ANCOVA of this score. The analysis of covariance for verbal-total scores is presented in Table 4.5. Both group and department main effects were statistically significant. For group, $F(1,168)=32.84$, $p<.01$, and for department, $F(1,168)=4.63$, $p<.05$. The interaction effect between group and
Table 4.4: Analysis of covariance for verbal-originality scores

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>Prob</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate</td>
<td>1</td>
<td>1848.18</td>
<td>1848.18</td>
<td>30.34*</td>
<td>0.000</td>
</tr>
<tr>
<td>Group</td>
<td>1</td>
<td>1548.74</td>
<td>1548.74</td>
<td>25.43**</td>
<td>0.000</td>
</tr>
<tr>
<td>Dept.</td>
<td>1</td>
<td>927.13</td>
<td>927.13</td>
<td>15.22**</td>
<td>0.000</td>
</tr>
<tr>
<td>Group * Dept.</td>
<td>1</td>
<td>106.79</td>
<td>106.79</td>
<td>1.75</td>
<td>0.187</td>
</tr>
<tr>
<td>Residual</td>
<td>168</td>
<td>10233.08</td>
<td>60.91</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>172</td>
<td>16731.98</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**P < .01.

department was not statistically significant. The adjusted means, reported by group, were 57.89 for the experimental groups and 42.69 for the control groups. Reported by department, the adjusted means were 53.16 for the electronic department and 47.42 for the machinery department. These results indicated that the electronic department was significantly higher than the machinery department and experimental group was significant higher than control group on the verbal-total scores. From the analysis, the results supported Hypothesis 1.4 and Hypothesis 3.4. Hypothesis 1.4 is: The experimental group will have significantly higher verbal-total scores than the control group; and hypothesis 3.4 is: There will be no significant differences on the enhancement of verbal-total scores between the machinery and the electronic students.

The Effects of Brainstorming on Figural Creative Thinking Abilities

This section presents the effects of brainstorming on figural creative thinking abilities. The main purpose is to examine Hypothesis 2: The experimental group
Table 4.5: Analysis of covariance for verbal-total scores

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>Prob</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate</td>
<td>1</td>
<td>21003.36</td>
<td>21003.36</td>
<td>70.47**</td>
<td>0.000</td>
</tr>
<tr>
<td>Group</td>
<td>1</td>
<td>9786.71</td>
<td>9786.71</td>
<td>32.84**</td>
<td>0.000</td>
</tr>
<tr>
<td>Dept.</td>
<td>1</td>
<td>1378.64</td>
<td>1378.64</td>
<td>4.63*</td>
<td>0.033</td>
</tr>
<tr>
<td>Group * Dept.</td>
<td>1</td>
<td>131.55</td>
<td>131.55</td>
<td>0.44</td>
<td>0.507</td>
</tr>
<tr>
<td>Residual</td>
<td>168</td>
<td>50070.99</td>
<td>298.04</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>172</td>
<td>91794.99</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**P < .01. *P < .05.

students participating in brainstorming sessions will have significantly higher scores in figural creative thinking abilities than the control group students, and Hypothesis 4: The electronic students will make greater enhancement gains in figural creative thinking abilities than the machinery students. For ease of understanding the results, the means and standard deviations of pre-test and post-test and adjusted means on the verbal test of the Torrance Test of Creative Thinking are first presented in Table 4.6.

The effects of brainstorming on figural-fluency scores. The result of the test for homogeneity of regression on figural-fluency scores was $F(3,165)=0.23, p>.10$. The result was not statistically significant at $\alpha = .10$. Therefore, the assumption of homogeneity of regression was tenable on the ANCOVA of this score. The analysis of covariance for figural-fluency scores is presented in Table 4.7. On both group and department main effects, group was statistically significant, $F(1,168)=8.36, p<.01$, and department was not statistically significant. The interaction effect between group and
Table 4.6: Means and standard deviation of pro-test and pos-test in figural test of the Torrance Test of Creative Thinking

<table>
<thead>
<tr>
<th>Group</th>
<th>Number</th>
<th>Mean(S.D)</th>
<th>Mean(S.D)</th>
<th>Adjusted mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Pre-test</td>
<td>Post-test</td>
<td></td>
</tr>
<tr>
<td><strong>Fluency Scores</strong></td>
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</tr>
<tr>
<td>Electronic Dept.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experiment Group</td>
<td>40</td>
<td>13.25(4.73)</td>
<td>19.75(8.17)</td>
<td>17.54</td>
</tr>
<tr>
<td>Control Group</td>
<td>45</td>
<td>8.22(3.36)</td>
<td>12.40(5.59)</td>
<td>14.39</td>
</tr>
<tr>
<td>Machinery Dept.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experiment Group</td>
<td>44</td>
<td>10.00(4.10)</td>
<td>15.77(6.73)</td>
<td>16.28</td>
</tr>
<tr>
<td>Control Group</td>
<td>44</td>
<td>11.25(3.82)</td>
<td>14.98(5.08)</td>
<td>14.44</td>
</tr>
<tr>
<td><strong>Flexibility Scores</strong></td>
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<td></td>
<td></td>
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<tr>
<td>Electronic Dept.</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Experiment Group</td>
<td>40</td>
<td>10.85(3.71)</td>
<td>13.23(3.97)</td>
<td>12.13</td>
</tr>
<tr>
<td>Control group</td>
<td>45</td>
<td>7.11(3.16)</td>
<td>9.44(3.86)</td>
<td>10.33</td>
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<td>Machinery Dept.</td>
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<td></td>
</tr>
<tr>
<td>Experiment Group</td>
<td>44</td>
<td>8.43(3.61)</td>
<td>11.59(4.93)</td>
<td>11.77</td>
</tr>
<tr>
<td>Control Group</td>
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<td>8.93(3.10)</td>
<td>11.48(3.57)</td>
<td>11.39</td>
</tr>
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<td><strong>Originality Scores</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Experiment group</td>
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<td>23.68(9.89)</td>
<td>40.55(17.24)</td>
<td>37.23</td>
</tr>
<tr>
<td>Control group</td>
<td>45</td>
<td>14.33(8.12)</td>
<td>26.38(11.67)</td>
<td>29.73</td>
</tr>
<tr>
<td>Machinery Dept.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experiment Group</td>
<td>44</td>
<td>19.43(8.22)</td>
<td>33.57(16.20)</td>
<td>33.28</td>
</tr>
<tr>
<td>Control Group</td>
<td>44</td>
<td>19.18(8.47)</td>
<td>27.27(11.53)</td>
<td>27.16</td>
</tr>
</tbody>
</table>
Table 4.6  (Continued)

<table>
<thead>
<tr>
<th>Group</th>
<th>Number</th>
<th>Mean(S.D) Pre-test</th>
<th>Mean(S.D) Post-test</th>
<th>Adjusted mean</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Elaboration Scores</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electronic Dept.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experiment Group</td>
<td>40</td>
<td>22.10(9.81)</td>
<td>23.50(8.83)</td>
<td>22.54</td>
</tr>
<tr>
<td>Control Group</td>
<td>45</td>
<td>15.69(7.53)</td>
<td>20.69(9.41)</td>
<td>22.83</td>
</tr>
<tr>
<td>Machinery Dept.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experiment Group</td>
<td>44</td>
<td>19.75(11.17)</td>
<td>16.84(9.80)</td>
<td>17.02</td>
</tr>
<tr>
<td>Control Group</td>
<td>44</td>
<td>23.21(9.58)</td>
<td>16.11(6.02)</td>
<td>14.62</td>
</tr>
<tr>
<td><strong>Total Scores</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electronic Dept.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experiment Group</td>
<td>40</td>
<td>69.88(18.23)</td>
<td>97.03(31.27)</td>
<td>88.23</td>
</tr>
<tr>
<td>Control Group</td>
<td>45</td>
<td>45.36(18.23)</td>
<td>68.89(27.53)</td>
<td>79.10</td>
</tr>
<tr>
<td>Machinery Dept.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experiment Group</td>
<td>44</td>
<td>57.61(22.11)</td>
<td>77.77(32.80)</td>
<td>78.48</td>
</tr>
<tr>
<td>Control Group</td>
<td>44</td>
<td>62.57(20.56)</td>
<td>69.84(22.67)</td>
<td>66.70</td>
</tr>
</tbody>
</table>
department was not statistically significant. The adjusted means for the experimental and control groups were 16.90 and 14.41, respectively. These results indicated that the electronic department was significantly higher than the machinery department on the figural-fluency scores. From the analysis, the results supported Hypothesis 2.1 and did not supported Hypothesis 4.1. Hypothesis 2.1 is: The experimental group will have significantly higher figural-fluency scores than the control group. Hypothesis 4.1 is: The electronic students will make greater enhancement in figural-fluency scores than machinery students.

Table 4.7: Analysis of covariance for figural-fluency scores

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>Prob</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate</td>
<td>1</td>
<td>1905.48</td>
<td>1905.48</td>
<td>62.70**</td>
<td>0.000</td>
</tr>
<tr>
<td>Group</td>
<td>1</td>
<td>254.10</td>
<td>254.10</td>
<td>8.36**</td>
<td>0.004</td>
</tr>
<tr>
<td>Dept.</td>
<td>1</td>
<td>15.91</td>
<td>15.91</td>
<td>0.52</td>
<td>0.470</td>
</tr>
<tr>
<td>Group * Dept.</td>
<td>1</td>
<td>15.96</td>
<td>15.96</td>
<td>0.53</td>
<td>0.470</td>
</tr>
<tr>
<td>Residual</td>
<td>168</td>
<td>5150.52</td>
<td>30.39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>172</td>
<td>8179.05</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**P < .01.

The effect of brainstorming on figural-flexibility scores. The result of the test for homogeneity of regression on figural-flexibility scores was $F(3,165)=0.17$, $p>.10$. The result was not statistically significant at $\alpha = .10$. Therefore, the assumption of homogeneity of regression was tenable on the ANCOVA of this score. The analysis of covariance for figural-flexibility scores is presented in Table 4.8. Neither group nor department main effects were statistically significant. The interaction effect
between group and department was not statistically significant. These results indi­
cated that the electronic department was not significantly higher than the machinery
department and the experimental group was not significantly higher than the control
group on figural-flexibility scores. From the analysis, the results did not support
Hypothesis 2.2 and Hypothesis 4.2. Hypothesis 2.2 is: The experimental group will
have significantly higher figural-flexibility scores than the control group. Hypothesis
4.2 is: The electronic students will make greater enhancement in figural-flexibility
scores than the machinery students.

Table 4.8: Analysis of covariance for figural-flexibility scores

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>Prob</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate</td>
<td>1</td>
<td>551.24</td>
<td>551.24</td>
<td>40.08*</td>
<td>0.000</td>
</tr>
<tr>
<td>Group</td>
<td>1</td>
<td>48.47</td>
<td>48.47</td>
<td>3.52</td>
<td>0.062</td>
</tr>
<tr>
<td>Dept.</td>
<td>1</td>
<td>5.51</td>
<td>5.51</td>
<td>0.40</td>
<td>0.528</td>
</tr>
<tr>
<td>Group * Dept.</td>
<td>1</td>
<td>19.89</td>
<td>19.89</td>
<td>1.45</td>
<td>0.231</td>
</tr>
<tr>
<td>Residual</td>
<td>168</td>
<td>2310.46</td>
<td>13.75</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total            | 172| 3168.82 |      |      |      |

**P < .01.

The effect of brainstorming on figural-originality scores. The result of
the test for homogeneity of regression on figural-originality scores was $F(3,165)=0.19,
p>.10$. The result was not statistically significant at $\alpha = .10$. Therefore, the assump­
tion of homogeneity of regression was tenable on the ANCOVA of this score. The anal­
ysis of covariance for figural-flexibility scores is presented in Table 4.9. On both group
and department main effects, group was statistically significant, $F(1,168)=11.09,$
p<.01, and department was not statistically significant. The interaction effect between group and department was not statistically significant. Adjusted means for the experimental and control groups were 35.25 and 28.44, respectively. These results indicated that the electronic department was not significantly higher than the machinery department, and the experimental group was significantly higher than the control group on figural-originality scores. From the analysis, the results supported Hypothesis 2.3 and did not supported Hypothesis 4.3. Hypothesis 2.3 is: The experimental group will have significantly higher figural-originality scores than the control group. Hypothesis 4.3 is: The electronic students will make greater enhancement in figural-originality scores than the machinery students.

Table 4.9: Analysis of covariance for figural-originality scores

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>Prob</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate</td>
<td>1</td>
<td>6488.01</td>
<td>6488.01</td>
<td>38.80**</td>
<td>0.000</td>
</tr>
<tr>
<td>Group</td>
<td>1</td>
<td>1854.86</td>
<td>1854.86</td>
<td>11.09**</td>
<td>0.001</td>
</tr>
<tr>
<td>Dept.</td>
<td>1</td>
<td>458.47</td>
<td>458.47</td>
<td>2.74</td>
<td>0.100</td>
</tr>
<tr>
<td>Group * Dept.</td>
<td>1</td>
<td>19.20</td>
<td>19.20</td>
<td>0.11</td>
<td>0.735</td>
</tr>
<tr>
<td>Residual</td>
<td>168</td>
<td>28091.99</td>
<td>167.21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>172</td>
<td>40003.55</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**p < .01.

The effects of brainstorming on figural-elaboration scores. The result of the test for homogeneity of regression on figural-elaboration scores was $F(3,165)=2.84$, $p<.10$. The result was statistically significant at $\alpha = .10$. Therefore, the assumption of homogeneity of regression was violated. This meant that the con-
ventional ANCOVA model did not fit the data of the scores (Huitema, 1980). The analysis of variance for difference between t scores of the pre-test and the post-test was used for further statistical analysis in the figural-elaboration scores. The result is presented in Table 4.10. For the two main effects, the group was not statistically significant, and the department was statistically significant, $F(1,168)=39.11$, $p<.01$. Because the interaction effect between group and department was statistically significant, the method of LSMEANS was used to test the simple effect. The results showed that, for the different t scores, there was significant difference between the experimental groups of the electronic and the machinery departments, $p=.015$; there was a significant difference between scores of the control groups of the electronic and the machinery departments, $p=0.00$; there was no significant difference, however, between the experimental and the control groups of the electronic department, $p=0.098$; and there was a significant difference between the experimental and the control groups of the machinery department, $p=.031$. The means of the difference in T-scores on figural-elaboration scores are 2.76 in the experimental group of the electronic department, 6.10 in the control group of the electronic department, -2.23 in the experimental group of the machinery department, and -6.51 in the control group of the machinery department. These results indicated that, on the figural-elaboration scores, there was no statistical difference between the experimental and the control groups in the electronic department, the experimental group performed better than the control group in the machinery department, the experimental group of the electronic department performed better than that of the machinery department, and the control group of the electronic department performed better than that of the machinery department. Considering the effect of the experimental teaching, the
machinery department appears better than the electronic department on the figural-elaboration scores. Hypothesis 2.4: The experimental group will have significantly higher figural-elaboration scores than the control group was supported in the machinery department, but not in the electronic department. Hypothesis 4.4: The electronic students will make greater enhancement in figural-elaboration scores than machinery students was not supported.

Table 4.10: Analysis of variance for difference between t scores of the pre-test and the post-test on figural-elaboration scores

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>Prob</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>1</td>
<td>9.41</td>
<td>9.41</td>
<td>0.11</td>
<td>0.740</td>
</tr>
<tr>
<td>Dept.</td>
<td>1</td>
<td>3339.16</td>
<td>3339.16</td>
<td>39.11**</td>
<td>0.000</td>
</tr>
<tr>
<td>Group * Dept.</td>
<td>1</td>
<td>625.74</td>
<td>625.74</td>
<td>7.33**</td>
<td>0.008</td>
</tr>
<tr>
<td>Residual</td>
<td>168</td>
<td>14429.82</td>
<td>85.38</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>172</td>
<td>18488.33</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**P < .01.

The effects of brainstorming on figural-total scores. The result of the test for homogeneity of regression on figural-total scores was $F(3,165)=0.80$, $p>.10$. The result was not statistically significant at $\alpha = .10$. Therefore, the assumption of homogeneity of regression was tenable on the ANCOVA of this score. The analysis of covariance for figural-total scores is presented in Table 4.11. Both group and department main effects were statistically significant. For group, $F(1,168)=7.97$, $p<.01$, and for department, $F(1,168)=9.39$, $p<.01$. The interaction effect between group and department was not statistically significant. The adjusted means, reported by group,
were 83.35 for the experimental groups and 72.90 for the control groups. Reported by department, the adjusted means were 83.66 for the electronic department and 72.59 for the machinery department. These indicated that the electronic department was significantly higher than the machinery department and the experimental group was significant higher than the control group on figural-total scores. Results from the analysis of the data supported Hypothesis 2.5: The experimental group will have significantly higher figural-total scores than the control group students; and did not support Hypothesis 4.5: The electronic students will make greater enhancement of figural-total scores than the machinery students.

Table 4.11: Analysis of covariance for figural-total scores

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>Prob</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate</td>
<td>1</td>
<td>45575.58</td>
<td>45575.58</td>
<td>81.23**</td>
<td>0.000</td>
</tr>
<tr>
<td>Group</td>
<td>1</td>
<td>4473.78</td>
<td>4473.78</td>
<td>7.97**</td>
<td>0.005</td>
</tr>
<tr>
<td>Dept.</td>
<td>1</td>
<td>5269.14</td>
<td>5269.14</td>
<td>9.39**</td>
<td>0.003</td>
</tr>
<tr>
<td>Group * Dept.</td>
<td>1</td>
<td>66.57</td>
<td>66.57</td>
<td>0.12</td>
<td>0.731</td>
</tr>
<tr>
<td>Residual</td>
<td>168</td>
<td>94261.45</td>
<td>561.08</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total 172 160980.13

**P < .01.

Summary

Summarized from above statistical analysis, Hypothesis 1 and most of subhypotheses of Hypothesis 2 were supported. Hypothesis 3 was supported while Hypothesis 4 was not supported by results of analysis. Specifically, the experimental group students had higher scores than the control group students in verbal-
fluency, verbal-flexibility, verbal-originality, verbal-total, and figural-fluency, figural-originality, figural-total. For figural-elaboration, experimental group students had higher scores than control group students for the machinery students only. There were no significant differences between the machinery and the electronic students on the enhancement of verbal and figural scores on the Torrance Test of Creative Thinking, except on figural-elaboration scores. The effect of the brainstorming training was greater for the machinery students than for the electronic students on figural-elaboration scores.

Discussion

The result of analysis for this study is discussed in this section in three parts: 1. the effect of experimental teaching, 2. the learning reaction of students on brainstorming sessions, 3. the whole procedure of brainstorming, and 4. summary.

The Effect of Experimental Teaching

Excepting figural-flexibility and figural-elaboration scores, the statistical analyses provided evidence that the brainstorming process could enhance the creative thinking abilities. This result is similar to much of the reported research about creative thinking teaching. For convenience of discussion, the result is summarized in Table 4.12. From this table, it is clear that the experimental group progressed in the scores of verbal-fluency, verbal-flexibility, verbal-originality, verbal-total, figural-fluency, figural-originality, and figural-total; and figural-elaboration in the machinery department; but not in figural-flexibility. The figural-flexibility was the only score in which the experimental group did not significantly progress. Even though the
Table 4.12: Summaries of significance for experimental teaching result

<table>
<thead>
<tr>
<th>Scores</th>
<th>Form of TTCT</th>
<th>Fluency</th>
<th>Flexibility</th>
<th>Originality</th>
<th>Elaboration</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal Form</td>
<td>ex. &gt; con.</td>
<td>ex.</td>
<td>Ex. &gt; con.</td>
<td>ex &gt; con.</td>
<td>El &gt; Ma.</td>
<td>El. &gt; Ma</td>
</tr>
<tr>
<td>Figural Form</td>
<td>ex. &gt; con.</td>
<td>ex.</td>
<td>ex. Ma &gt; con.Ma</td>
<td>ex &gt; con.</td>
<td>ex.El &gt; ex.Ma</td>
<td>El. &gt; Ma.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>con.El &gt; con.Ma</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ex.: Experimental group,  
con.: Control group.  
El.: Electronic Department.  
Ma.: Machinery Department.  
>: Higher than.  

Verbal-flexibility scores increased significantly in the experimental group from the original means of verbal creative thinking scores shown in Table 4.1, compared to other verbal-scores, verbal-flexibility had apparently less enhancement in the experimental groups between the pre-test and post-test. Besides conducting the analysis of variance for verbal-flexibility and figural-elaboration, this researcher also conducted the analysis of variance for the other verbal-scores. None of the interaction effects between groups and departments were statistically significant. For the group main effect, the p value was .0001 on verbal-fluency scores, .0498 on verbal-flexibility scores, .0042 on verbal-originality scores, and 0.0001 on verbal-total scores. Regardless of the comparison of original means or for p values, it is obvious that the increase of the experimental group in verbal-flexibility scores was weaker than in other verbal scores.

Before attempting to provide an interpretation of the results on flexibility scores,
the terms of fluency, flexibility, originality, and elaboration should be described. Fluency is the ability to yield many ideas that related to the degree of succession in producing association (Guilford, 1968). Fluency is viewed as flow of thought and generation of a quantity and applied to various types of content to the complexity of associations. Speed is its assumed characteristic. In the research, fluency was defined as the total number of relevant responses in the task. Flexibility is the ability to shift categories in thinking. Flexibility was viewed as variety of kinds of ideas and detour in direction of thought. In the research, the flexibility score was determined by the number of different categories counted into which responses were classified. Originality is the ability to perceive far-off association, to generate clever responses, or produce unusual responses, that is, production away from the obvious. In this research, originality was defined as the number of statistically infrequent responses. Elaboration is the ability to extend a simple design to a more complex, detail, or elegant design. It is viewed as an attempt to embellish or embroider upon ideas (Haensly & Reynolds, 1989; Horton, 1985; Prentky, 1989; Torrance, 1974b; Williams, 1981).

In accordance with the above description, it is easy to understand that the reason students are unable to enhance the ability of flexibility much was attributed to the "mental inertia" mentioned in Chapter 2. The thinking path of students had more difficulty in shifting among various categories than generating fluency or original ideas. The hierarchical network model (Collins & Quillian, 1969, 1970) assumes that category information is stored in memory with association. Classification time is influenced by hierarchical organization. An instance in a basic-level category can be verified faster than that in a superordinate category. The feature comparison model (Smith, Shoben, & Rips, 1974) assumes that comparing the features or attributes
of the two nouns is used to classify instances for representing the category. The spreading activation model (Collins & Loftus, 1975) assumes that activation spreads out more effectively along the paths of a semantic network than outside the paths. These models of semantic organization were supported by some research (Reed, 1992). Generalized from the above models and the phenomenon of “mental inertia”, one’s thinking path will be strongly influenced by previous impression, and the current idea will influence the subsequent idea. Students retrieve the new idea associated to the current idea more easily than that which is remote from the current one, especially in a short test time. When students wrote ideas in the test, they might tend to write the subsequent ideas related to the previous one as possible until the ideas in the same category were exhausted. Therefore, experimental group students got significant enhancement in fluency scores, but no enhancement or weaker scores in flexibility scores. The number of responses increased in the creative thinking test of experimental groups, but the number of categories of response did not. This might be attributed to the short experimental teaching time, only five hours.

Modulation and control of more fundamental or routine cognitive skills are required in the ability of “problem solving”. Changing between skills for problem solving has to be flexible (McCarthy & Warrington, 1990). McCarthy and Warrington defined flexibility as “the ability to shift comparatively rapidly between different concepts and to adopt different perspectives on a concept is a prerequisite for carrying out the operations necessary for much problem solving” (p. 350). Flexibility is a very important component in problem solving and creative thinking. Flexibility in idea production describes a condition necessary for reducing functional fixedness (Haensly & Reynolds, 1989). This study indicated that the enhancement of flexi-
bility is more difficult than the other creative abilities. Inevitably, it is necessary to increase students' flexibility in creative thinking teaching in vocational industrial education. Therefore, for promotion of the validity of creative thinking teaching, it is worthwhile to study ways to help students build a smooth thinking path among different categories for easy shifting in creative thinking.

The results of this study indicated there were no differences between the machinery and the electronic students in the enhancement of verbal and figural scores of the Torrance Test of Creative Thinking except that the scores of figural-elaboration in which the effects of the experimental teaching for the machinery department students achieved more than the electronic department students. This finding differed from some mentioned researchers (e.g. Li, 1987; Lin, 1984; Wu, 1989). This researcher (1989) found the electronic students made greater enhancement gains in figural-fluency than machinery students in previous research. This might be attributed to the different teaching time in the “Engineering Graphic” course. Machinery students had four semesters to learn this course; but electronic students had merely one semester. Li (1987) found the students of watercolor, photography, and design courses in vocational schools increased in verbal creative thinking abilities, but not in figural ones; and the students of a Chinese course made greater gains in figural creative thinking abilities. The above two research studies reported that the students majoring in courses related to painting or graphics had more difficulty in the enhancement of figural scores in the Torrance Test of Creative Thinking. The probable reason that the result of this study differed from that of the previous two studies may be due to different intelligence of subjects among the three studies. The competition of entrance examination is intense in senior middle school level. The
students strongly desire to enter the star or excellent school. This competition arises in big differences of students' intelligence among different schools. Ta-an Senior Vocational Industrial School is usually considered as the first choice of qualified entrants in vocational education level in Taipei district. The school in which students were used as subjects in this researcher's previous research is usually considered as the second or third choice; and the schools in the Li's research as the third or fourth choice. The subjects in this research were more intelligent. If the assumption that enhancement of scores of creative thinking abilities differs with students of different intelligence is true, this will mean that the extent of students' fixedness varies with the students' intelligence. Reducing students' functional fixedness is one pivotal point in creative thinking teaching, therefore, how the factor of intelligence influences the effect of creative thinking teaching could be studied further.

The Learning Reaction of Students on Brainstorming Program

As mentioned in methodology chapter, this researcher distributed the questionnaire of learning reaction. The result are shown as Table E.1 in Appendix E for control groups, and Table 4.13 for experimental groups. From Table 4.13, on brainstorming session, 67.4 % of the students reported enjoying the brainstorming program; 83.1 % of the students thought the program was useful; 91.6 % of the students thought the brainstorming program enhanced their creative ability; 68.6 % of the students hoped to take additional class like the brainstorming program; and 54.2 % of the students thought that brainstorming should be required in vocational industrial schools. Generalizing the result, especially on item 3, the brainstorming was well received by most of the experimental group students, and considered useful in increasing creativity.
Table 4.13: The analysis for questionnaire of learning reaction on the program to teach brainstorming

<table>
<thead>
<tr>
<th>Item</th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S.A</td>
<td>A.</td>
</tr>
<tr>
<td>1. I enjoy this program.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>34.9%</td>
<td>32.5%</td>
</tr>
<tr>
<td>2. I think this program is useful to me.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>34.9%</td>
<td>48.2%</td>
</tr>
<tr>
<td>3. I think this program did enhance my creative ability</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>37</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>44.6%</td>
<td>47.0%</td>
</tr>
<tr>
<td>4. I hope I can take additional classes like this program.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>29</td>
</tr>
<tr>
<td></td>
<td>33.7%</td>
<td>34.9%</td>
</tr>
<tr>
<td>5. This program should be required in industrial vocational schools.</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>29</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>34.9%</td>
<td>19.3%</td>
</tr>
</tbody>
</table>

S.A: Strongly Agree.
A: Agree.
U: Uncertain.
D: Disagree.
S.D: Strongly Disagree.
The Whole Procedure of Brainstorming

The preceding two sections demonstrated that the brainstorming process could increase the students' creativities, and that students liked the brainstorming process as this researcher's (Wu, 1989) previous research also confirmed. The brainstorming process is not complicated, and is easy to understand and teach, so brainstorming could be utilized in vocational industrial education for enhancing creative thinking teaching. The function of brainstorming is mainly based upon four regulations: 1. criticism is ruled out, 2. free wheeling is welcomed, 3. quantity is wanted, and 4. combination and improvement are sought (Osborn, 1963). Brainstorming was originally developed as one tool in the creative problem-solving process, but practitioners and researchers would like to treat it as a whole process rather than a single tool (Beaton, 1990). In fact, there are many forms of brainstorming. This researcher has outlined the procedure of brainstorming as Figure 4.1.

Figure 4.1 shows that it may not be a single path between the problem or question to be solved and actions to solve the problem or question. In this study, this researcher led the exercise of ideation phase and adjudgement phase of brainstorming with four topics separately in each experimental group, but the ideation phase was emphasized in brainstorming process, and the adjudgement phase was emphasized and directed less. Each topic was discussed only once in the brainstorming process. Actually, to generate the substantial and useful acts to solve the problem or question usually requires repetition of the brainstorming process several times. After the repetition, the adoptable acts will be clear gradually. Because the whole procedure as Figure 4.1 illustrated is time-consuming, and this study was limited by time, the experimental teaching progressed with simple procedure to examine the influence of the
Figure 4.1: The Figural Circle for the Procedure of Brainstorming
brainstorming process on the creative thinking abilities of vocational industrial education students. Indeed, because one of the vocational industrial education goals is "to establish the students' abilities of creation, adaptation, and self-development", to cultivate the inventive ability and creative technological problem solving of students should be the main purpose of creative thinking teaching in vocational industrial education. The circle of Figure 4.1 could reach the destination to produce the substantial act to solve the technological problem.

Summary

That flexibility scores of experimental students were not enhanced or were only slightly enhanced, while other scores were increased may be due to the phenomenon of "mental inertia". The prediction of differences on the enhancement of creative thinking abilities with the content of what students learn was not supported. This may demonstrate that the difference is influenced by the students' intelligence. This study indicated that brainstorming was appropriate for use in increasing students' creative thinking ability. The procedure of brainstorming as illustrated in Figure 4.1 also may be used to enhance students' ability of creative technological problem solving.
CHAPTER 5. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The purposes of this chapter are to provide an overview of the study, and to make conclusions and recommendations. The contents of this chapter is organized as follows:

1. Summary of the study,
2. Conclusions of the study,
3. Recommendations for creative thinking teaching in vocational industrial education in the R.O.C., and
4. Recommendations for future research.

Summary of the Study

The tendency of education throughout the world is to emphasize increasingly student creativity. In Taiwan, research into creative thinking teaching has been advocated since 1970 and the performance of creative thinking teaching has progressed in the last eight years. Creative technological problem solving is vital to students of vocational industrial education. The appropriate strategy to increase the students' creativity in vocational industrial education should be implemented. This
researchers' previous research (Wu, 1989) reported that students most liked the unit of brainstorming among nine units of creative thinking teaching material. This study explored whether the brainstorming process could be used as a primary strategy in vocational industrial education.

The central purpose of this study was: 1) to determine the effectiveness of brainstorming to enhance creativity of vocational industrial education students, and 2) to determine the enhancement effects of creative thinking abilities on different subjects in different technical areas.

To accomplish the purpose, 173 students in two classes of the electronic and the machinery departments in Ta-an Senior Vocational Industrial School were involved in this study as subjects. The quasi-experimental study composed of a non-equivalent control group design was used. Teaching time was five hours in each of four classes. Experimental groups were taught with the brainstorming process, while the control group was provided instruction in the introduction of American culture, customs, and national parks. The verbal and figural forms of Torrance Test of Creative Thinking were used in pre-test and post-test of all students. The scores of fluency, flexibility, originality, elaboration, and total were collected from the Torrance Test of Creative Thinking. Some special precautions were taken to avoid the Hawthorne and John Henry effects in the experimental research.

After the collection of data, a two-way analysis of covariance (ANCOVA) was used. Before analysis of covariance, a test for homogeneity of regression was conducted to check if it violated the assumption of homogeneity of regression in ANCOVA. If the assumption was violated, the data were analyzed with the analysis of variance for difference between t scores of the pre-test and the post-test.
This research indicated that the brainstorming process could promote the students' creativities, but the enhancement in flexibility was weaker than in the other abilities. No differences on the enhancement of creative thinking ability across students in different technical fields was found excepting the figural-elaboration scores. The analysis for questionnaire of learning reaction on brainstorming program showed that most of experimental group students liked the brainstorming.

The discussion was conducted for the result of this study. The reason that students are unable to enhance the ability of flexibility much was attributed to the "mental inertia". The thinking path of students had more difficulty in shifting among various categories than generating fluency or original ideas. Students retrieve the new idea associated to the current idea more easily than that which is remote from the current one, especially in a short test time. When students wrote ideas in the test, they might tend to write the subsequent ideas related to the previous one as possible until the ideas in the same category were exhausted. Therefore, experimental group students got significant enhancement in fluency scores, but no enhancement or weaker scores in flexibility scores. The number of responses increased in the creative thinking test of experimental groups, but the number of categories of response did not. This might be attributed to the short experimental teaching time, only five hours.

The results of this study indicated there were no differences between the machinery and the electronic students in the enhancement of verbal and figural scores of the Torrance Test of Creative Thinking except that the scores of figural-elaboration in which the effects of the experimental teaching for the machinery department students achieved more than the electronic department students. This finding differed from some mentioned researchers. The probable reason that the result of this study
differed from that of the previous two studies may be due to different intelligence of subjects among the three studies. The competition of entrance examination is intense in senior middle school level. The students strongly desire to enter the star or excellent school. This competition arises in big differences of students' intelligence among different schools. The subjects in this research were more intelligent than in other research.

**Conclusions**

From the results of the statistical analyses, some conclusions for this research can be presented as follows:

1. The experimental group students participating in the brainstorming session made significantly greater gains in fluency, flexibility, originality, and total of verbal creative thinking abilities than the control group students.

2. The experimental group students participating in the brainstorming session made significantly greater gains in fluency, originality, and total of figural creative thinking abilities than the control group students, but not in flexibility. The enhancement of figural-elaboration scores for the experimental group occurred for the machinery department students, but not for the electronic department students.

3. There were no significant differences in the enhancement of the scores of fluency, flexibility, originality, and total in verbal creative thinking abilities after the brainstorming sessions between the machinery and the electronic students.
4. There were no significant differences on the enhancement of the scores of fluency, flexibility, originality and total in figural creative thinking abilities after the brainstorming sessions between the machinery and the electronic students, while the effects of experimental teaching on the machinery department was better than that of the electronic department on the figural-elaboration scores.

Recommendations for Creative Thinking Teaching in Vocational Industrial Education in the R.O.C.

This research revealed that the brainstorming process has a clear function in increasing students' creativity. The brainstorming process is a simple strategy of creative thinking, and could be utilized broadly for creative thinking teaching in vocational industrial education. The following recommendations are for the performance of creative thinking teaching in vocational industrial education.

1. It is recommended that the educational administrative authority hold seminars to introduce the strategy of brainstorming to teachers of vocational industrial education.

2. It is recommended that when teachers choose to lead students to creative thinking, teachers could use the simple process of brainstorming or employ the procedures and the principles of brainstorming to direct and enhance student thinking.

3. It is recommended that if product development is the goal of creative thinking teaching, teachers repeat the brainstorming process until the emergence
of complete ideas. Of course, under this condition, the teacher may have the knowledge of patents with which to advise student product design.

**Recommendations for the Future Research**

Some further problems were found from the result of the analysis of data. The following recommendations for future research are based on the findings of this study.

1. It is recommended that the effective way or strategy to strongly improve students' flexibility should be explored. Flexibility is an important factor for creative technological problem solving. Whether longer teaching of the brainstorming process would produce greater increase in students' flexibility, or there is another better strategy to increase it is a subject for further research.

2. It is recommended that the effect of variation in the intelligence of students on the enhancement of creative thinking abilities after creative thinking teaching be explored in future research. If the differences vary with the student intelligence, the way or strategy of creative thinking teaching should be changed with the students' intelligence levels.
REFERENCES


Andre, T. (October, 1980). The incredible green creative – or – releasing the powers that dwell within us. Paper presented at Mid-Western Educational Research Meeting, Toledo, OH.


Education Department of Taiwan Province (1991a). *The handbook of teaching display session for Taiwan provincial and private Vocational School Teaching Display in 1990 school Year*. Tai-chung, Taiwan: Author.

Education Department of Taiwan Province (1991b). *The collection of references for creative thinking teaching*. Tai-chung, Taiwan: Author.


National Taiwan Science Education Center (1986). *The review and perspective for 30th anniversary of National Taiwan Science Education Center*. Taipei: Author.


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APPENDIX A. TEACHING PLAN FOR EXPERIMENTAL GROUP
A. Topic of the Unit of Instruction: Brainstorming

B. Students: The 11th grade students in vocational industrial education, in Taiwan the R.O.C.

C. Goal: To enhance students creative (divergent thinking) ability.

D. Objectives: Upon completion of this lesson, the student will be able to:

1. Generate ideas under the four regulation of group brainstorming: a) criticism is ruled out, b) "free-wheeling" is welcomed, c) quantity is wanted, and d) combination and improvement are sought.

2. Combine, apply, and evaluate the ideas to generate valuable ideas.

E. Instructional Materials:

1. Teaching aids: projector, slide projector, blackboard.

F. Estimated Time to Complete Lesson: 5 hours

G. Instructional Procedures:

1. Show some inventions and perform the example of functional fixedness to let students understand how simple it is to invent and the reason to participate in brainstorming.

2. Explain the meaning and function of brainstorming. (transparencies)

3. Introduce the four regulations of brainstorming. (transparencies)

4. Take some examples of odd ideas producing valuable inventions. (inventions, transparencies)
5. Practice to generate ideas.  
   (blackboard)

   --1st hour end--

6. Explain two principles of brainstorming.  
   (transparencies)

7. Explain the criteria and principles to assess ideas.  
   (transparencies)

8. Assess ideas generated in the last class.  
   (transparencies)

9. Introduce briefly the creative thinking methods that could be 
   used in brainstorming.  
   (shortage listing, hope listing, attribute listing, and check 
   listing)

   --2nd hour end--

10. Repeat the procedure of ideation and assessment of 
    brainstorming.

    --3rd hour end--

11. Introduce the method of K.J. (Kawakita Jiro).  
    (transparencies)

12. Use K.J. method to cluster ideas for generation of more novel 
    ideas.  
    (transparencies)

    --4th hour end--

13. Perform the small group competition of brainstorming.  

    --5th hour end--
H. Topics to Discuss in Brainstorming.

1. How to improve the bicycle?
2. What is the function of a pencil?
3. How to improve the door?
4. How to improve the chair?
5. How to apply CDS?
6. How to improve the electric drier?
7. How to improve lamp?

I. Evaluation

1. Apply the 2 principles, 4 regulations, and 2 phases.
2. Assess the ideas.

J. Introduction of Brainstorming

Group Brainstorming is a type of conference that is used to produce ideas. It was first used by A. F. Osborn in 1938. Generally, the group includes one leader and two secretaries. The difference between brainstorming and the common conference is that in group brainstorming members avoid criticizing each other. The main purpose is to generate some good ideas to solve problems of administration or technology. It has two principles: delay the judgement and yield quality from quantity.

Group Brainstorming generally has two main phases, the first is
ideation phase, and the second is adjudgement phase. They are described as following:

In the ideation phase, four regulations should be obeyed. These are that criticism is ruled out, "free-wheeling" is welcomed, quantity is wanted, and combination and improvement are sought. In the beginning of this conference, the leader states the topic or the problem. Of course, if somebody in the group does not understand the regulations, the leader has to explain them. Then, the members offer ideas. The secretaries are in turn responsible for writing ideas on a large paper or blackboard that every member can read. The purpose of presenting ideas is to start a chain reaction to produce more ideas. The leader is very important in handling the conference. In addition to reminding everybody to obey the regulations, he should stimulate the responses of the members, especially during lulls in production of ideas. The goal of this phase is to get many ideas. The phase should ended in thirty minutes or less.

In the adjudgement phase, the purpose is to evaluate the ideas produced in the ideation phase to select good ideas. The leader and secretaries work as in the former phase. The adjudgement phase should emphasize how to apply the ideas, but not do how to choose them, so
the ideas may be combined or transferred. In this phase, criticism is not inhibited, but positive, rather than negative criticism, is encouraged. In general, during the adjudgement phase, the person who presented the idea during ideation phase may not participate in the discussion, because a different person will more easily apply or transfer the ideas to produce better ideas.

To gain the best idea, these two phases may be repeated many times. The time of the ideation phase is limited, but that of the second phase is not. In whole group brainstorming, imagination and association of the members have to be encouraged.

The KJ (Kawakita Jiro) method is one of transformations of brainstorming. In the session using the KJ method, every idea generated will be written in a card. All cards are spread on a table, and categorized into "teams" according to similar ideas. The initial categories or "teams" are then grouped into broader categories, based on the similarity of the ideas. The main function of KJ method in a technological field is to generate a better idea or to find new implications from the grouping procedure.
APPENDIX B. TORRANCE TEST OF CREATIVE THINKING

(TTCT)
Activity 3. LINES

In ten minutes see how many objects or pictures you can make from the pairs of straight lines below and on the next two pages. The pairs of straight lines should be the main part of whatever you make. With pencil or crayon add lines to the pairs of lines to complete your picture. You can place marks between the lines, on the lines, and outside the lines—wherever you want to in order to make your picture. Try to think of things that no one else will think of. Make as many different pictures or objects as you can and put as many ideas as you can in each one. Make them tell as complete and as interesting a story as you can. Add names or titles in the spaces provided.

1. ____________________ 2. ____________________ 3. ____________________

4. ____________________ 5. ____________________ 6. ____________________
活動三：線 條

下面一共有三十對的直線，看你十分鐘以內能夠畫出多少東西或圖畫。在你的圖畫裡，每一對直線必須是主要的部份。用鉛筆或粗筆或其他的筆加些線條把圖畫完成。為了畫你的圖畫，你可以在兩線之間、兩線上、兩線之外任何地方作畫。試著想出別人想不到的東西。儘量畫出各種不同的圖畫或東西，同時在每一幅圖畫裡注入許多的觀念，讓每一幅圖畫顯示出完整而且有趣的故事來。在適當的空白處題上它們的名稱。

1. _________  2. _________  3. _________

4. _________  5. _________  6. _________
Activity 3. CIRCLES

In ten minutes see how many objects or pictures you can make from the circles below and on the next page. The circles should be the main part of whatever you make. With pencil or crayon add lines to the circles to complete your picture. You can place marks inside the circles, outside the circles, or both inside and outside the circles—wherever you want to in order to make your picture. Try to think of things that no one else will think of. Make as many different pictures or objects as you can and put as many ideas as you can in each one. Make them tell as complete and as interesting a story as you can. Add names or titles below the objects.
活動三 圓圈

下面有許多圓圈，請你隨意在圈內圈外加上線條，使它成為一幅幅畫，但是無論你怎麼畫，圓圈應該是畫畫的主要部分。請盡量去畫別人不容易想到的東西，並盡量多畫幾幅畫，每幅畫也儘量充實，使它們都能代表一個完整而有趣的故事。請在圈畫下面加上題目或名字。

這個活動的時間是10分鐘

翻到下頁繼續做
Activity 5: UNUSUAL USES (Cardboard Boxes)

Most people throw their empty cardboard boxes away, but they have thousands of interesting and unusual uses. In the spaces below and on the next page, list as many of these interesting and unusual uses as you can think of. Do not limit yourself to any one size of box. You may use as many boxes as you like. Do not limit yourself to the uses you have seen or heard about; think about as many possible new uses as you can.

1. 

2. 

3. 

4. 

5. 

6. 

7. 

8. 

9. 

10. 

11. 

12. 

13. 

14. 

15. 

16. 

17. 

18. 

19. 

20. 

21. 

22. 

23.
作業 5：不平凡的用途

大多數的人們將空紙盒扔掉。其實他們忽略了許多有關紙盒有趣且又不平凡的用途，現在你儘量想一些既有趣又不平凡的用途，並且將它們列在下面及下一頁的空白處。你可以隨心所欲的用你所需的紙盒，不要考慮它們的大小和數目。你自己想一些新奇的用途，最好不要只限於你以前看過的或是聽說過的。

1. ____________________________
2. ____________________________
3. ____________________________
4. ____________________________
5. ____________________________
6. ____________________________
7. ____________________________
8. ____________________________
9. ____________________________
10. ____________________________
11. ____________________________
12. ____________________________
13. ____________________________
14. ____________________________
15. ____________________________
16. ____________________________
17. ____________________________
18. ____________________________
19. ____________________________
20. ____________________________
21. ____________________________
22. ____________________________
23. ____________________________
Activity 5: UNUSUAL USES (Tin Cans)

Most people throw their tin cans away, but they have thousands of interesting and unusual uses. In the spaces below and on the next page, list as many of these interesting and unusual uses as you can think of. Do not limit yourself to any one size of can. You may use as many cans as you like. Do not limit yourself to the uses you have seen or heard about; think about as many possible new uses as you can.

1. ___________________________________________
2. ___________________________________________
3. ___________________________________________
4. ___________________________________________
5. ___________________________________________
6. ___________________________________________
7. ___________________________________________
8. ___________________________________________
9. ___________________________________________
10. ___________________________________________
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12. ___________________________________________
13. ___________________________________________
14. ___________________________________________
15. ___________________________________________
16. ___________________________________________
17. ___________________________________________
18. ___________________________________________
19. ___________________________________________
20. ___________________________________________
21. ___________________________________________
22. ___________________________________________
23. ___________________________________________
TTCT Verbal Form B (Chinese)

活動五：不尋常的用途（空罐子）

大多數人用完了空罐子後就把它丟棄，其實空罐子有許多有趣而且不尋常的用途。在這一頁以及下一頁空白的地方，儘量寫出你所能想到的所有有趣而且不尋常的用途。不要受罐子大小的限制，你喜歡的話，可以使用很多的罐子，你寫的不要僅限於你看過或聽過的用途，儘量想出所有可能的新用途。（十分鐘）

1. 
2. 
3. 
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23. 

10
APPENDIX C. LETTERS RELATED TO THIS STUDY
February 8, 1992

Dr. Patricia Keith, Chairperson
Human Subjects Review Committee
203 Beardshear Hall
Iowa State University
Ames, Iowa 50011-3130

Dear Dr. Keith:

As the Principal of Ta-An Industrial Vocational School in Taipei, R.O.C., I consent to allow Mr. Wu, Ming-hsiung to conduct experimental research at our school. Mr. Wu's research on the influence of the brainstorming process in the creativity of Industrial Vocational Education students in Taiwan is very worthwhile and will add to the body of knowledge on creativity.

If you desire additional information, please contact me through Mr. Wu.

Sincerely,

Yours sincerely,

Yang, Chin-sheng, Principal
Ta-An Industrial Vocational School
Feb. 28, 1992

Dear Student:

For educational purposes, the Counseling Office will be giving the Torrance Test of Creative Thinking (TTCT) in selected classes. The tests will be taken twice. The interval time will be about 4 weeks between the tests. Each test will require a total of 30 minutes including both the verbal form and the figural form. The purpose of these tests is to compare your enhancement of creativity during this four-week period.

Participation in these tests is voluntary, and you may withdraw from the tests at any time. However, it is an opportunity for you to learn and understand more about your creative abilities. I hope you will consent to take these tests. Each student's identify will be kept confidential; only group analyses of the data will be reported.

After the tests are graded, the Counseling Office will inform you of your results. If you want to known your creativity scores, please come to counseling office with in two weeks. The counseling teacher will explain the scores to you according to the norms of the TTCT. After 3 weeks, the graded tests will be destroyed.

If you have any question about this request, please come to see me. Your participation will be highly appreciated.

Sincerely

Yih-jieh Liang
Director, Counseling Office
Ta-an Senior Voc. Ind. School
Feb. 28, 1992

Dear Student:

I am a graduate student pursuing a Ph. D. degree in the Department of Industrial Education and Technology at Iowa State University. To meet the requirements of my degree, I have constructed two teaching programs for industrial education students, and I want to know your reactions to them.

This program will be performed in your class and it will consist of served brainstorming sessions. In this program, I will instruct you how to create ideas for invention. This program will be 5 hours long, for two hours each week. It will be performed during your free class time at your school's audio-visual room. After this program, you will be asked to answer a questionnaire related to your learning reactions. This program is very interesting. I believe that this program will be useful to you and enhance your inventive ability.

Your responses to the questionnaire will be held absolutely confidential, and only group analyses of the data will be reported.

I hope you will take part in this program. Of course, the participation in this program is voluntary, and you may withdraw from the program at any time. Your participation will be highly appreciated.

Sincerely,

Ming-hsiung Wu

William D. Wolansky, Ph.D. (Supervisor)
Professor of Industrial Ed. & Technology
Feb. 28, 1992

Dear Student:

I am a graduate student pursuing a Ph. D. degree in the Department of Industrial Education and Technology at Iowa State University. To meet the requirements of my degree, I have constructed two teaching programs for industrial education students, and I want to know your reactions to them.

This program that will be performed in your class includes the introduction of American culture, customs, and national parks with projector slides and video-tapes. It is based on the goal of global educational curriculum. This program will be 5 hours long, for two hours each week. It will be performed during your free class time at your school's audio-visual room. After this program, you will be asked to complete a questionnaire regarding your reactions to the instruction. This program is very interesting. I believe that this program will be useful to you and will enhance your global perspective.

Your responses to the questionnaire will be held absolutely confidential, and only group analyses of the data will be reported.

I hope you will take part in this program. Of course, the participation in this program is voluntary, and you may withdraw from the program at any time. Your participation will be highly appreciated.

Sincerely,

Ming-hsiung Wu

William D. Wolansky Ph. D. (Supervisor)
Professor of Industrial Ed. & Technology
APPENDIX D.  HUMAN SUBJECTS FORM
Information for Review of Research involving Human Subjects
Iowa State University
(Please type and use the attached instructions for completing this form)
The influence of brainstorming process on the creativity of industrial vocational education students in Taiwan the R.O.C.

1. Title of Project:

2. I agree to provide the proper surveillance of this project to insure that the rights and welfare of the human subjects are protected. I will report any adverse reactions to the committee. Additions to or changes in research procedures after the project has been approved will be submitted to the committee for review. I agree to request renewal of approval for any project continuing more than one year.

Wu, Ming-Hsiung Feb 10, 92 Ming-Hsiung Wu
Typed Name of Principal Investigator Date Signature of Principal Investigator
Industrial Education & Technology 1461 Hawthorn court, Ames, IA 50010 296-8351
Department Campus Address Campus Telephone

3. Signatures of other investigators Date Relationship to Principal Investigator
William D. Wolansky 2-10-92 Major Advisor

4. Principal Investigator(s) (check all that apply)

☐ Faculty ☐ Staff ☑ Graduate Student ☐ Undergraduate Student

5. Project (check all that apply)

☐ Research ☑ Thesis or dissertation ☐ Class project ☐ Independent Study (490, 590, Honors project)

6. Number of subjects (complete all that apply)

☐ # Adults, non-students ☐ # ISU student ☐ # minors under 14 ☐ # minors 14-17 ☐ other (explain)

200 11th grade students in the Ta-An Industrial Vocational School

7. Brief description of proposed research involving human subjects: (See instructions, Item 7. Use an additional page if needed.)

Please see the attached sheets

(Please do not send research, thesis, or dissertation proposals.)

8. Informed Consent: ☑ Signed informed consent will be obtained. (Attach a copy of your form.)
☐ Modified informed consent will be obtained. (See instructions, Item 8.)
☐ Not applicable to this project.
9. Confidentiality of Data: Describe below the methods to be used to ensure the confidentiality of data obtained. (See instructions, item 9.)

1. All students' ID numbers and names used in this research will be erased after recording the scores of the pretest and posttest.
2. Each student's identification will be kept confidential; only group analyses of the data will be reported.
3. All data will be eliminated after my final defense.
4. All personal data will not be reported openly.

10. What risks or discomfort will be part of the study? Will subjects in the research be placed at risk or incur discomfort? Describe any risks to the subjects and precautions that will be taken to minimize them. (The concept of risk goes beyond physical risk and includes risks to subjects' dignity and self-respect as well as psychological or emotional risk. See instructions, item 10.)

Since in the research, we give only positive reinforcements to the subjects, the chance of discomfort is little.

11. CHECK ALL of the following that apply to your research:

- A. Medical clearance necessary before subjects can participate
- B. Samples (Blood, tissue, etc.) from subjects
- C. Administration of substances (foods, drugs, etc.) to subjects
- D. Physical exercise or conditioning for subjects
- E. Deception of subjects
- F. Subjects under 14 years of age and/or [ ] Subjects 14 - 17 years of age
- G. Subjects in institutions (nursing homes, prisons, etc.)
- H. Research must be approved by another institution or agency (Attach letters of approval)

If you checked any of the items in 11, please complete the following in the space below (include any attachments):

- Items A - D Describe the procedures and note the safety precautions being taken.
- Item E Describe how subjects will be deceived; justify the deception; indicate the debriefing procedure, including the timing and information to be presented to subjects.
- Item F For subjects under the age of 14, indicate how informed consent from parents or legally authorized representatives as well as from subjects will be obtained.
- Items G & H Specify the agency or institution that must approve the project. If subjects in any outside agency or institution are involved, approval must be obtained prior to beginning the research, and the letter of approval should be filed.

Please see the attached sheets
Checklist for Attachments and Time Schedule

The following are attached (please check):

12. □ Letter or written statement to subjects indicating clearly:
   a) purpose of the research
   b) the use of any identifier codes (names, #'s), how they will be used, and when they will be removed (see Item 17)
   c) an estimate of time needed for participation in the research and the place
   d) if applicable, location of the research activity
   e) how you will ensure confidentiality
   f) in a longitudinal study, note when and how you will contact subjects later
   g) participation is voluntary; nonparticipation will not affect evaluations of the subject

13. □ Consent form (if applicable)

14. □ Letter of approval for research from cooperating organizations or institutions (if applicable)

15. □ Data-gathering instruments

16. Anticipated dates for contact with subjects:

<table>
<thead>
<tr>
<th>First Contact</th>
<th>Last Contact</th>
</tr>
</thead>
<tbody>
<tr>
<td>March 1, 1992</td>
<td>March 30, 1992</td>
</tr>
</tbody>
</table>

   Month/Day/Year          Month/Day/Year

17. If applicable: anticipated date that identifiers will be removed from completed survey instruments and/or audio or visual tapes will be erased:

   Aug 31, 1992
   Month/Day/Year

18. Signature of Departmental Executive Officer

   □ Project Approved  □ Project Not Approved  □ No Action Required

   Patricia M. Keith
   Name of Committee Chairperson

   8/18/92
   Date

   Signature of Committee Chairperson

   Industrial Education & Technology
APPENDIX E. THE QUESTIONNAIRE OF LEARNING REACTION
Questionnaire of Learning Reaction  
(Brainstorming Section)

Directions:

Please provide the lecturer your reactions to this brainstorming instruction program. Your opinion is very important. All responses will be kept confidential. Please react to each statement by circling the number that most accurately reflects your reaction towards each statement.

5. Strongly Agree (S.A.)
4. Agree (A.)
3. Uncertain (U.)
2. Disagree (A.)
1. Strongly Disagree (S.D.)

1. I enjoyed this program.
2. I think this program is useful to me.
3. I think this program did enhance my creative ability.
4. I hope I can take additional classes like this program.
5. This program should be required in industrial vocational schools.

Please share with the lecturer your additional suggestions or other opinions about this program:

-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
Questionnaire of Learning Reaction
(The Introduction of American Culture and National Parks)

Directions:

Please provide the lecturer your reactions to this instruction program about the introduction of American culture and national parks. Your opinion is very important. All responses will be kept confidential. Please react to each statement by circling the number that most accurately reflects your reaction towards each statement.

5. Strongly Agree (S.A.)
4. Agree (A.)
3. Uncertain (U.)
2. Disagree (A.)
1. Strongly Disagree (S.D.)

1. I enjoyed this program. 5 4 3 2 1
2. I think this program is useful to me. 5 4 3 2 1
3. I think this program did enhance my knowledge about global perspective. 5 4 3 2 1
4. I hope I can take additional classes like this program. 5 4 3 2 1
5. This program should be required in industrial vocational schools. 5 4 3 2 1

Please share with the lecturer your additional suggestions or other opinions about this program:

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Table E.1: The analysis for questionnaire of learning reaction on the program to introduce American culture and national parks

<table>
<thead>
<tr>
<th>Item</th>
<th>S.A</th>
<th>A.</th>
<th>U.</th>
<th>D.</th>
<th>SD</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I enjoy this program.</td>
<td>45</td>
<td>42</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>49.5%</td>
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<td>4.4%</td>
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<td>0%</td>
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<tr>
<td>2. I think this program is useful to me.</td>
<td>28</td>
<td>52</td>
<td>9</td>
<td>2</td>
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<tr>
<td>3. I think this program did enhance my knowledge about global perspective.</td>
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<td>36</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>56.0%</td>
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<td>4. I hope I can take additional classes like this program.</td>
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<td>32</td>
<td>12</td>
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<td>51.6%</td>
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<tr>
<td>5. This program should be required in industrial vocational schools.</td>
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<td>34</td>
<td>22</td>
<td>10</td>
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<td>1.1%</td>
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</tbody>
</table>

S.A: Strongly Agree.
A : Agree.
U : Uncertain.
D : Disagree.
S.D: Strongly Disagree.
JOB 7037  MHE1422  BIN 379  THES  M.H.W.  04/28/93  01:05:06
B8B8B8B8B8  III III III  NN  NN  3333333333  7777777777  9999999999
B8B8B8B8B8  III III III  NN  NN  3333333333  7777777777  9999999999
BB  BB  II  NN  NN  39  39  77  77  99  99
BB  BB  II  NN  NN  33  33  77  77  99  99
BBB8B8B8B8  II  NN  NN  3333  77  9999999999
BBB8B8B8B8  II  NN  NN  3333  77  9999999999
BB  BB  II  NN  NN  33  33  77  77  99  99
BB  BB  II  NN  NN  33  33  77  77  99  99
BBB8B8B8B8  III III III  NN  NN  3333333333  77  9999999999
B8B8B8B8B8  III III III  NN  NN  3333333333  77  9999999999

$  JOBNAME=MHWE1422  JOB#=7037  PTR-END=04/28/93  01:05:06
$  PRINTER CHARGES  BLOCK=W  PRIO=S  RATE=EDUC
$  $ .00  574  LINES PRINTED ON FR1
$  $ 3.30  68  PRINTED SIDES ON FORM THES
$  $ .06  2  PRINTED SIDES ON SEPARATORS
$  $ .75  1  FORM SETUPS
$  $ 4.11  1  PRINTER CHARGE
$  $ 16099  BALANCE= $ 139.15  EXPIRES=12/31/99
$  $ 5.08  CURRENT ACCUMULATED CHARGES THIS JOB

END 7037-2  BIN 379  M.H.W.  28.05  APR 28, 993  HHE1422  M.H.W.  7037-2  END
END 7037-2  BIN 379  M.H.W.  28.05  APR 28, 993  HHE1422  M.H.W.  7037-2  END
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END 7037-2  BIN 379  M.H.W.  28.05  APR 28, 993  HHE1422  M.H.W.  7037-2  END