EURASIA Journal of Mathematics, Science and Technology Education
ISSN: 1305-8223 (online) 1305-8215 (print)
OPEN ACCESS
2017 13(11):7147-7160
DOI: 10.12973/ejmste/77169

Applying TRIZ Instructional Strategies to Vocational Students' Imaginative Learning and Practice

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Received 31 May 2017 ▪ Revised 20 September 2017 ▪ Accepted 24 September 2017

ABSTRACT

The purpose of this study was to explore the effect of TRIZ (Teoriya Resheniya Izobretatelskikh Zadatch) instructional strategies on students' imaginative learning. The subjects of this study were students from a vocational school in Taiwan. The quasi-experimental method was used to incorporate TRIZ instructional strategies into imaginative learning and practice and to analyze the effect of these strategies on students' imaginative learning in their learning portfolios. In addition, a documentary analysis was used to supplement an analysis of the key factors involved with imaginative learning and practice. TRIZ instructional strategies significantly positively affected students' imaginative learning abilities and can aid in their imaginative learning and practice. Based on the results, this paper summarizes 5-stage key factors, constructs the IDEAL-P imagination teaching model, and offers suggestions for providing students with diversified imaginative learning portfolios, all of which can effectively improve students' imaginative learning and practice.

Keywords: imagination, TRIZ, TRIZ instructional strategy, vocational students, learning and practice

RESEARCH MOTIVES AND PURPOSES

Peter Drucker said that the best way to predict the future is to create it (Drucker, 2007). In keeping with this notion, Taiwan's 2011 Education Report listed the cultivation of innovative personnel and innovative industries as major educational policies (Ministry of Education, 2015). A prerequisite for creativity and the foundation of creative thinking is the capability of imagination (Thomas, 2010; Gawain, 2016). Furthermore, education is the source of national competitiveness. Thus, developing "imagination" is a priority for current academic administrations.

Gardner's multiple intelligences theory notes that intelligence has diverse avenues of development, and imagination and dreams can be enhanced through customized instruction (Gardner, 2000; Madani, Moroz, Baines & Makled, 2016). In light of this theory, with accessible information, diversity and rapid societal changes, teachers can use instructional strategies to stimulate student learning, to realize students' creativity, and to develop their motivation to learn so that they can achieve optimal learning (Cagiltay, 2008; Ringwood, Monaghan & Maloco, 2005). Thus, imaginative learning instruction needs to be adjusted in response to the times. The practice of imagination is also important. Among various instructional strategies, TRIZ (Teoriya Resheniya Izobretatelskikh Zadatch) was proposed by Altshuller et al. as a way to shorten the time required for inventions, prevent the waste of human and material resources, and stimulate innovative thinking (Altshuller, 1999; Burnay, Horkoff, & Maiden, 2016). Thus, the authors of the current study were eager to examine the effects of applying TRIZ to imaginative learning.

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Contribution of this paper to the literature

- The quasi-experimental method was used to incorporate TRIZ instructional strategies into imaginative learning and practice and to analyze the effect of these strategies on students' imaginative learning in their learning portfolios.
- TRIZ instructional strategies significantly positively affected students' imaginative learning abilities and can aid in their imaginative learning and practice.
- This paper summarizes 5-stage key factors, constructs the IDEAL-P imagination teaching model, and offers suggestions for providing students with diversified imaginative learning portfolios, all of which can effectively improve students' imaginative learning and practice.

This study uses TRIZ as an instructional strategy, borrowing from other factors related to the performance of imagination, to design the instruction of imagination. Students applied TRIZ methods to compare topics and to solve problems as they were guided to realize their imaginative abilities in concrete works. This exercise provided students with practical experiences from imagination to concrete practice, and it achieved the educational objective of inspiring students' potential for imagination (Rutherford & Rowe, 1987; Lou, Chou, Shih & Chung, 2017). This study aimed to achieve the following:

(1) to explore the influence of TRIZ instructional strategies on students' imaginative learning effects,
(2) to summarize the important factors that can develop imaginative learning and practice,
(3) and to construct the instructional model for TRIZ imaginative learning and practice.

LITERATURE REVIEW

This study summarizes the literature on TRIZ and imagination as follows.

Introduction to TRIZ

TRIZ is an abbreviation of the Russian phrase "Teoriya Resheniya Izobretatelskikh Zadatch," which means "Theory of Inventive Problem Solving." This theory was initially developed by the Soviet scholar Genrich Altshuller (1929-1998) in 1946. After reading technical information disclosed in 200,000 patents from all over the world, he selected 40,000 patents that he considered to be innovative and used inductive methods to explore their solutions. The patents' inventions or levels of creativity did not all come from trial and error methods. Rather, there was a systematic logic in the commonality, repetition, and innovative inventions across the patents he examined (Rantanen & Domb, 2007; Lu & Xue, 2017). There are many TRIZ theories and methods; a contradiction matrix and 40 inventive principles are the most frequently used among them.

Contradiction matrix

Altshuller found that every innovation arises from the discovery of problematic contradictions. TRIZ suggests that traditional brainstorming solutions only choose between contradictions in the problems; they do not actually solve the problems. The main condition for solving creativity problems is to improve one or more features while not deteriorating the other features. If there are contradictions, the factors that cause conflicts must be removed (Altshuller, 1999). There are 39 system features that often encounter technical contradictions, and the corresponding 40 inventive principles of solutions are organized into a 39x39 matrix (i.e., a contradiction matrix). The vertical columns of the contradiction matrix are the worsened engineering characteristics, while the horizontal rows are the engineering characteristics for which improvements are sought. Assuming that when a designer seeks to improve the engineering characteristic A, engineering characteristic B worsens, the intersections can be used to find the inventive principle needed to solve the problem (Yan & Zhang, 2014; Lou, Dzan, Lee & Chung, 2014).

40 inventive principles

Forty inventive principles (innovative laws) are the tools used to resolve technical contradictions. They are also the basic methods used to operate technological systems or their internal mechanisms (Altsuller, Shulyak & Rodman, 1997). From the patent databases examined, the innovative and significant inventions were summarized to find 40 generalizable principles. These principles have sub-principles to explain them.

Based on inspiration from TRIZ, this study referred to the TRIZ instruction model proposed by Lou, Chung, Chao, Tseng and Shih, including the purpose of system development, system design, system mechanisms, TRIZ applications, and platform functions (Lou, Chung, Chao, Tseng & Shih, 2012). Teachers guided students to learn the contradiction matrix and the 40 inventive principles regarding imaginative learning and practice in hopes of improving the strategy of imaginative instruction and of inspiring student creativity through diverse methods.

Table 1. IDEAL Imagination model

Stage	Explanation
Stage 1 Initiation	Starts with an existing experience, and new ideas and possibilities are added to that experience. From the beginning, instructors guide students to use existing experiences and perceptions to initiate an idea; this starting point could be an idea, an image, a concept, or a plan.
Stage 2 Development	Instructors guide students to expand their imagination from their original ideas to new ideas. From the initial idea, they use techniques of segmentation, development, reorganization, expansion, and conversion to develop more possibilities that exceed their original imaginative range.
Stage 3 Alternative	If students stay at the development stage and only think from one perspective or angle, it would be difficult to achieve the objective. Thus, based on the principle of possibility, in the alternative stage, students are guided to start with a different perspective, angle, and direction to actively devote and engage new points of initiation. This stage is the "initiation, development, alternative" cycle, and these stages and methods are repeated over and over to produce more ideas.
Stage 4 Links	Based on "connections," the different solutions are compared to find the optimal solution. Students are encouraged to propose diverse story scenarios and to draw on their ideas. At this stage, students need to choose and link all of the possible ideas together to develop a detailed scenario that will achieve the objectives. Meanwhile, they can develop another competitive model to develop more new ideas.

Imagination

According to Guilford, "People are great because of their dreams," and dreams come from imagination. Furthermore, "Imagination is the innate ability and driving force of advancement unique to humans" (Guilford, 1967). Imagination is the process by which mental images evolve and it is closely connected to imagery and emotions, which are based on existing image memory emotions and new images; senses are used to rearrange and reconstruct brand new images (Vygotsky, 2004; Gawain, 2016). Imagination is the ability to imagine, and it is a prerequisite for creativity and is the foundation for creative thinking (Heath, 2008; Jung, Flores & Hunter, 2016). Thus, through a focus on learner needs and by combining the applications of imagination and developing systematic learning strategies, learners could be assisted in extending the usage of existing foundational abilities to promote learning effects. One such approach, the IDEAL (Initiation, Development, Alternative, Links) imagination model, provides a clear direction for instructors designing imaginative learning activities (Wang, Chu, Hung & Kang, 2011). This model divides imagination into the four stages initiation, development, alternative, and links (**Table 1**).

In summary, this study blends TRIZ instructional strategies into the IDEAL model created by Wang, Chu, Huang and Kang, and it emphasizes students' imaginative learning and practice. This model is used to expand imaginative instructional designs into five stages, to convert them to test questions, to conduct statistical analyses of pre- and post-tests on imaginative learning, and to survey the effects of incorporating TRIZ into imaginative learning instruction strategies on students' imaginative learning and practice.

RESEARCH DESIGN AND METHOD

A literature review was conducted on TRIZ and imaginative learning in accordance with this study's purpose. This review was used to establish the five-stage instructional model for learning and practice of imagination, to establish TRIZ and imaginative learning instructions and to design over an eight-week period an "amphibious vehicle," which involved imaginative learning and design. The research design and procedures are described as follows.

Research Design and Procedures

With global warming and sea level rise as the spatio-temporal background of the "imagination design project", this study aimed to help students understand environmental changes, leading to the design of an amphibious vehicle. In addition, with the sightseeing promotion of Love River Music Festival in Kaohsiung in southern Taiwan as the topic, the students were asked to complete the design of imaginative amphibious vehicles. It was hoped that this project would stimulate the students' imagination potentials. The research subjects were second-year students in the mechanics program at a vocational high school in Taiwan. There were 15 teams, each with four members, for a total of 60 students. The project activity involved face-to-face lectures along with a digital learning platform for imaginative learning and TRIZ blended instruction. By constructing the environment for imaginative learning and by designing imaginative activities, students were guided to conduct collaborative learning so that they could produce imaginative and unique works. The process was implemented as follows:

(1) TRIZ and imaginative learning instruction (weeks 1 and 2): The teacher implemented TRIZ and imaginative learning guidance instruction using a digital imaginative learning platform to assist students in post-class learning. Collaborative team learning was conducted, and a discussion area and chat room were provided for students to discuss topics with their teams. The teacher used the student discussion content to understand student learning conditions and to provide suitable consultation and assistance for the most efficient student learning.

(2) Imaginative learning process guidance (weeks 3-6): The teacher announced the activity topic, i.e., the multipurpose amphibious vehicle, and implemented the learning guidance for the imagination process. During the process, students were asked to imagine the situational topic and to think about possible problems. Students referred to creativity in the TRIZ 40 inventive principles and to limitations in existing materials, such as charging batteries, motors, and vehicle body modules, to complete the design blueprints for a multipurpose amphibious vehicle and to resolve the problems arising from the situational topic. In addition, the IDEAL imagination model was used to design the work of the four stages of initiation (development, alternative, and links), and students were asked to complete them on time and to upload them to the platform to understand the progress of imaginative learning for each team of students and as a reference for adjusting imaginative instruction strategies.

(3) Imaginative practice and learning (weeks 7-8): This stage focused on the practice of imagination so that students could experience realizing their ideas. Students were guided to produce amphibious vehicles by following the imaginative learning design blueprints and by applying the TRIZ contradiction matrix and the 40 inventive principles so that difficulties would be resolved before they appeared. Finally, students were asked to record in detail the steps they used to analyze the TRIZ problems and their process for choosing their solutions. They were then asked to upload their reports to the platform.

Research Method

This study used the quasi-experiment research method, where the students were administered imaginative learning questionnaire surveys before and after instruction. A paired sample t-test analysis was performed to explore the effect of applying TRIZ instructional strategies on the vocational students' imaginative learning. In addition, a documentary analysis and an emphasis on conceptual development were combined with locating, identifying, and retrieving. In addition, the methods and techniques of the documentary analysis (Denzin & Lincoln, 2005) were used to discover the importance of students' application of TRIZ on their imaginative learning during the experiment. The textual data source for this study was the study unit completed by the student teams and found in their learning portfolios. Concrete descriptions (e.g., texts or images) created by the students were used to analyze how the student teams used their imaginative abilities and TRIZ in the design of their product. The students from the top three teams were used as interview subjects to understand the effect of TRIZ instructional strategies on their imaginative learning. These interviews were used to summarize strategies that were effective in cultivating the students' imaginative abilities and to supplement inadequacies in quantitative research.

RESULTS AND DISCUSSION

Based on the design implementation of this study, questionnaire surveys were administered before and after the course to understand the effect on learning of students' imaginative skills after the implementation of the TRIZ instructional strategies. Textual data were collected from learning portfolios, and interviews were conducted after the course was concluded. These data were used to analyze and summarize the main points of the students' application of TRIZ in their imaginative learning and acted as the main referential basis for subsequent curricular imaginative learning and instructional design. The following describes imaginative learning effects and imaginative learning case studies.

Analysis of Imaginative Learning Effects

This study used the "imaginative learning effects scale" as a pre-test and post-test of students' imaginative skills. The values of the imaginative learning effect from the paired two-sample t-test were significant; there were significant differences in student scores before and after undergoing the TRIZ instructional strategies (**Table 2**). Students' imaginative learning scores were significantly higher after they were instructed with TRIZ instructional strategies than beforehand. This finding shows that TRIZ instructional strategies can help increase students' imaginative learning.

Table 2. Paired sample t-test of imaginative learning effects

Question	Before /Past	Mean	N	SD	t
1. I can apply ideas from the knowledge learned to other fields	Before	3.64	55	.825	-4.311^{***}
	Past	4.27	55	.706	
2. I can form effective ideas about the problem	Before	3.56	55	.660	-4.122^{***}
	Past	4.13	55	.795	
3. I can use concrete images (ideas or objects) to express abstract concepts	Before	3.56	55	.834	-3.034^{**}
	Past	4.05	55	.891	
4. I would rethink the learning content to seek improvement	Before	3.80	55	.826	-2.909^{**}
	Past	4.22	55	.738	
5. I can form rich and diverse ideas about the learning content	Before	3.69	55	.879	-2.909^{**}
	Past	4.11	55	.762	
6. I can form unprecedented ideas about the learning content	Before	3.60	55	.873	-2.591^{*}
	Past	4.02	55	.871	
7. I can intuitively respond to the learning content with new ideas	Before	3.60	55	.830	-3.719^{***}
	Past	4.09	55	.823	
8. I can use sensitive feelings to form ideas about the learning content	Before	3.49	55	.791	-2.700^{**}
	Past	3.89	55	.916	
9. I can be continuously focused on the learning content and form ideas	Before	3.64	55	.868	-2.390^{*}
	Past	4.04	55	.816	
10. I maintain an exploratory attitude toward new or unknown matters	Before	3.79	55	.762	-2.909^{**}
	Past	4.25	55	.844	

* $p<.05$, ** $p<.01$, *** $p<.001$

In summary, TRIZ instructional strategies can guide students in applying ideas from their previous knowledge and in conducting extensive learning. Thus, students can formulate effective ideas about problems and use concrete images to express abstract concepts. Through the application of TRIZ instructional strategies, students were taught to deeply explore their knowledge relating to a project, which helped them to develop consequent knowledge. Therefore, students can formulate rich, diverse, and unprecedented ideas about the learning content, and after repeated consideration, they can produce new ideas that can be actively improved. Furthermore, guided learning in the imaginative learning process can help students use sensitive feelings to produce ideas about the learning content, to continue their focus and to cultivate an attitude toward exploring unusual or unknown objects and subjects.

Explanation of Imaginative Learning Case Studies

The work design for the imaginative learning process and for the application of TRIZ guided students in completing the imaginative learning blueprints and, in turn, producing works using diverse thinking. The following will explain the work of students during the five stages of the imaginative learning process. It will also explain the team interview data to explore the key factors related to the development and practice of students' imaginative abilities.

Initiation stage – cultivate active learning and flexible application abilities

At this stage, students began with an existing experience and were led to new ideas and possibilities. First, the teacher instructed students on the TRIZ 40 inventive principles and explained practical cases so that they could gain more knowledge related to innovative applications. Diverse learning channels with blended instructions develop students' curiosity and their motivation to learn. Next, the teacher explained the "Kaohsiung Love River versus an amphibious vehicle" theme. The students were divided into groups to discuss the topic. By blending new and old knowledge, the students could gain an in-depth understanding of the appeal of the theme. The students were guided to cooperate and discuss the theme and to form diverse ideas, presenting them as images. Interviews showed that the students thought of rock music, cars with high horsepower, and jumping musical notes as themes to express the passion of southern Taiwan and Kaohsiung (**Figure 8**). Thus, students had an active learning attitude and the ability to apply the knowledge they possessed to other fields.

> *Student interview:*
>
> *The theme of the project was to create an amphibious vehicle with the cultural background of the Kaohsiung Love River, so we used the Passionate Kaohsiung as the starting point to express the human emotions local to Kaohsiung and to thus promote tourism at the Kaohsiung Love River. (S-01)*

Figure 1. Streamlined form of guitar

We used the passionate-sounding themes of rock music, cars with high horsepower, and jumping musical notes to express our passionate spirits. (S-03)

Teachers' observation:

The cross-application of the invention principle of TRIZ 40 can improve the students' innovative application ability. In addition, with the divergent thinking mode, the students can think without restriction and generate unlimited ideas to increase the learning motivation and interest. As a result, the students' unlimited imagination potential can be stimulated.

Development stage – cultivate diverse imaginative and pre-planning abilities

At this stage, the teacher guided the students to expand their imagination and to come up with new ideas. The students widely applied the 40 inventive principles, such as segmentation, combination, preliminary action, and conversion techniques, so that they could develop more-diverse ideas. An imaginative learning instructional design guided students in developing and considering amphibious vehicles from different angles. The interviews showed that based on the topic of rock music, students imagined curves and a vehicle body shaped like a guitar with a bright vehicle casing and speakers. To ensure a vehicle with strong horsepower, the students focused on stability, adding propellers, shock absorbers, and paddles. They effectively applied their knowledge of cranks, water mills, and flotation devices in the concrete presentations of their ideas (**Figure 8**). The application of TRIZ instructional strategies and the group discussion inspired diverse ideas. The discussion results were expressed in both text and images, forming design blueprints for the teams. Thus, this stage effectively cultivated the students' diverse imaginative and pre-planning abilities.

Student interview:

(1) Rock music theme

The theme of rock music was centered on rock musicians on stage, all of whom have electric guitars. Thus, we used the guitar as the external form of the amphibious vehicle. To reduce wind resistance and prevent capsizing, we designed a streamlined external form, as shown in ***Figure 1****. (S-02)*

Additionally, the outer form was designed to sparkle, with speakers added to conform to the theme of rock music and to appeal to the judges. (S-03)

(2) Vehicle with strong horsepower

To us, passionate means being fully motivated, which can be represented by increased horsepower, so we designed a powerful motor with propellers for added horsepower, as shown in ***Figure 2****. The crank mechanism was used for the paddles so that the design would be similar to how a frog swims in the water. (S-01)*

Figure 2. External propellers and motor

Figure 3. Water mill device

Figure 4. Counter water mill device

In addition, we used the principle of a reverse water mill. The water mill is a device that uses natural water flow to gain motion, as shown in ***Figure 3****. A reverse water mill uses motion to move the water so that the boat can move forward. We installed a water mill-like mechanism next to the wheels, as shown in* ***Figure 4****. It is very important to accurately compute flotation, and the water line must be maintained at the center of the wheels, as shown by the red line in* ***Figure 4****, to enable the boat to propel forward. If the water line moves past the center position, the forward motion will be disrupted, greatly reducing the function of this device. (S-04)*

(Flotation = the mass of displaced object × fluid density = the mass of the object under fluid surface × fluid density)

(3) Moving musical notes

To differentiate our projects from others with stationary external appearances, we combined the motor and crank mechanisms and then added musical notes as decoration, as shown in ***Figures 5*** *and* ***6****. The motor triggers the cranking motion so that the musical notes jump up and down, completing a moving outer decoration. We are proudest of this feature of our design, shown in* ***Figure 7****. (S-03)*

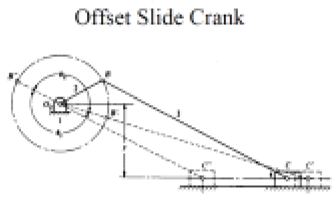

Figure 5. Principle of crank mechanism

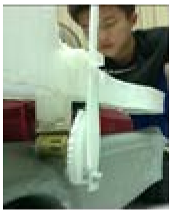

Figure 6. Half-completed crank mechanism

Figure 7. Musical notes crank mechanism

Teachers' observation

The application of the knowledge of the TRIZ 40 invention principle can stimulate the students' imaginational potential and unlimited thinking. In combination with daily life knowledge and the connotation of professional courses, it is helpful to extend the students' creative thinking ability and integrate the diversified ideas so as to improve their ability to plan and design in advance.

Alternative stage – cultivate imaginative sensitivity and collaborative learning abilities

In this stage, the teacher guided students to start with different perspectives, angles, and directions and to actively engage in new points of initiation. For instance, the teacher guided the students to consider the Love River as a new point of initiation and to repeat the cycle of "initiation, development, alternative" to produce more ideas. The interviews show that students developed the various features of the Kaohsiung Love River and its local characteristics (e.g., street performers expressing its cultural background; the atmosphere of art and dance, as expressed by its dancing waters; and its literary and musical atmosphere as expressed by the music played on its shores) (**Figure 8**). The student teams continuously manipulated the imaginative steps to maintain a focus on the learning content. They used different angles and tried various methods, and they communicated with each other to find the optimal combination. This method can train students' imaginations to be sensitive and teach them the importance of team cooperation.

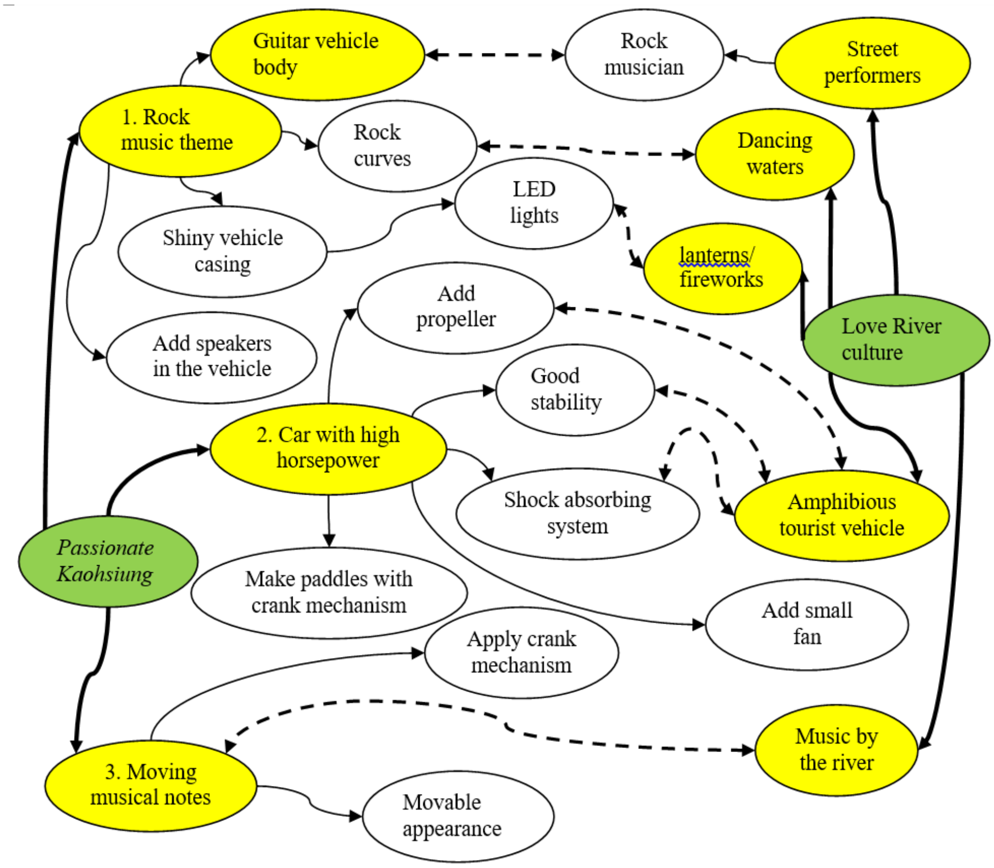

Figure 8. Imaginative design blueprint created by students

Student interview:

The teacher guided us to begin from the heart with the Love River at the center of our project, developing the various characteristics of the Love River as well as its cultural qualities, such as the street performers, expressing its cultural background. (S-02)

The atmosphere of art and dance is expressed by its dancing waters; its literary and musical atmosphere is expressed by the music played on its shores; and the Love River festivals are expressed by lanterns, fireworks, and a bustling atmosphere. (S-03)

Teacher's observation:

After repeated operation and the thinking cycle of "brainstorming, imagination and transformative thinking", the students jumped out of their inertial thinking, reopened their way of thinking and integrated such elements as science, technology and culture so as to present imaginative creativity. In combination with the brainstorming of the team members, the students thought and carried out cooperative learning from different aspects to improve the learning efficiency.

Links stage – cultivate systematic thinking and integrated planning abilities

This stage focuses on "links," in which different solutions are compared to find the optimal solution. To avoid stifling imagination and creativity, feasibility was not considered. Therefore, the teachers encouraged the students to use diverse storylines to connect all possible ideas. The interviews showed that the students imagined that tourists could ride the "Passionate Kaohsiung" amphibious tourist vehicle to enjoy the passionate performances of rock singers. The Love River was surrounded by stages, lanterns, fireworks, and dancing fountains, and there were special effects on the stage. Tourists were surrounded by beautiful music as they enjoyed the passion and beauty of the Kaohsiung Love River, which effectively promoted tourism there (**Figure 8**). Meanwhile, students were guided to develop a competing model for comparison and to develop additional ideas. At this point, teams of students shared their ideas and stories for each project to achieve the effect of diverse and collaborative learning, which produced unprecedented ideas. Finally, the diverse ideas of the students on each team were concretely expressed as they planned their blueprints for the optimal design; these actions cultivated the students' abilities in systematic thinking and integrated planning.

> *Student interview:*
>
> *We attempted to combine the idea of the Passionate Kaohsiung with the culture of the Love River to promote tourism at the Kaohsiung Love River. The Passionate Kaohsiung's guitar shape recalls the rock musicians of the Love River culture who would play to tourists. The curved, streamlined body of the vehicle recalls the dancing waters of the river. The sparkling lights of the vehicle recall lanterns and fireworks, and their bright colors bring to mind the colored LED lights used for special effects on stage. The music played by the river is invoked by the moving musical notes on the vehicle.*
>
> *Teacher's observation:*
>
> *The students connected the results of divergent thinking in series, integrated the passionate performance of rock and roll in the amphibious vehicle and in the waterside pavilion stages, festival lanterns and special fireworks show surrounding the Love River, developing the amphibious vehicle with beating notes in the water and presenting a unique intention. The students' unlimited imagination potential was stimulated.*

Practice stage – cultivate repeated thinking and problem-solving abilities

The purpose of this stage of the project was for the students to concretely create blueprints from their ideas. However, there were always differences between their ideas and reality. During this period of production, the students encountered many problems. They used TRIZ to find optimal solutions and to resolve the problems that appeared. The following case is an example (**Table 3**). The "Passionate Kaohsiung" amphibious tourist vehicle conformed to the theme and was very imaginative. However, upon completion of the work, the guitar-shaped body was found to be too long, which severely affected the performance of the amphibious vehicle when it moved up and down slopes. The physical appearance decreased the vehicle's functionality and was thus a severe problem. Therefore, the student team held an emergency meeting to discuss and analyze the issue. The problem was summarized as follows: if the original vehicle body-length ratio is maintained, the function of the amphibious vehicle in moving up and down slopes will be affected; if the body-length ratio is shortened, the overall creative expression will be severely affected (**Figure 9**). Thus, it was necessary to sacrifice one function for the sake of the other. At this point, TRIZ helped the students discover a contradiction. Through using these strategies, the students found corresponding technical contradictions (function parameter #03, Length of Moving Object and function parameter #12, Shape). Using the contradiction matrix, students found several corresponding inventive principles from among the 40 inventive principles. After the team had a discussion, the students decided to combine the application of Principle 1 (Segmentation) and Principle 10 (Preliminary Action). The part of the body that would touch the ground was segmented, and a hinge was installed to connect the body and the segmented portion (**Figure 10**). In this way, the excessively long part would lift automatically upon coming into contact with the slope (**Figure 11**). Thus, without affecting the functions, the problem resulting from the vehicle's length versus its appearance was resolved. In addition, preliminary actions were taken to add wheels and Styrofoam to the longer parts of the vehicle to cope with its amphibious characteristics (**Figure 12**). At the presentation, the vehicle successfully traversed the obstacles set by the contest and completely fulfilled the functions of an amphibious vehicle (**Figure 13**). The practical creativity and implementation in this stage cultivated students' abilities in repeated thinking and problem solving.

Table 3. Textual analysis of the practice stage

Problem 1	When the amphibious vehicle moved up and down a slope, it would touch the ground because the body was too long (Figure 9). How can the body be prevented from touching the ground without changing its length?
Results of group's discussion (technical contradictions)	1. Overall physical appearance Pros: good physical appearance and suitable length ratio (shape). Cons: when the body was too long, the vehicle touched the ground when it moved up and down a slope (length of the moving object). Contradiction: restrain the body from touching the ground while maintaining the overall physical appearance. (#03 length of moving object* #12 shape)
40 inventive principles	No. 01 segmentation No. 08 anti-weight No. 10 preliminary action No. 29 pneumatics and hydraulics
Method	After much consideration, we realized that the key to the problem was the design of the vehicle body. We should have selected a method that allowed us to maintain the original appearance and to resolve the problem of the vehicle touching the ground. Principle 1 was combined with Principle 10. Parts of the body that would touch the ground were segmented, and a hinge was installed to connect the body with the segmented portion (Figure 10). When the object touched the ground, the part that was too long would be raised and would therefore not affect the vehicle's length and shape (Figure 11). Next, preliminary action was applied to add wheels and Styrofoam to the parts of the vehicle that were excessively long so that the vehicle could ride on land and float on water without affecting its speed (**Figure 12**).

Figure 9. Vehicle body too long

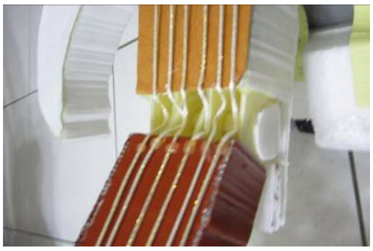

Figure 10. Cutting the main body of the vehicle

Figure 11. The front part lifts when encountering obstacles

Teacher's observation:

When students' imaginative creation is realized, there will be unexpected problems. The students learned to apply the TRIZ tool to think about the root of the problem repeatedly until they obtained a solution, thus effectively linking their knowledge and skills, as well as developing a most imaginative amphibious vehicle.

Figure 12. Adding wheels and Styrofoam to the vehicle

Figure 13. At the contest

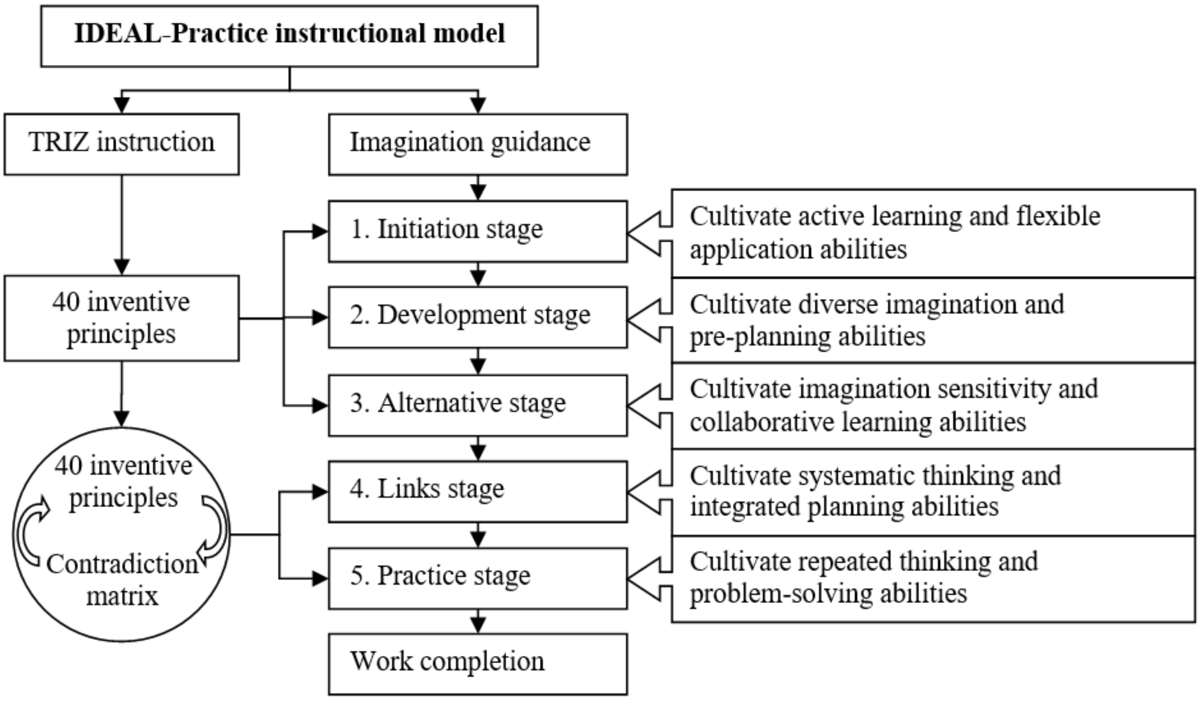

Figure 14. IDEAL-Practice instructional model flowchart

IDEAL-Practice Instructional Model

An analysis of imaginative learning and learning portfolios shows that incorporating TRIZ instructional strategies into imaginative learning can help develop students' capacity for imagination and the concrete presentation of their works. Thus, this study used TRIZ instructional strategies to realize the IDEAL imagination model, practicing and elevating the capacity for imagination, and to achieve the five stages of learning and practice in the IDEAL-Practice instructional model (Initiation, Development, Alternative, Links, and Practice).

Prior to implementation of the IDEAL-Practice instructional model, teachers must provide a topic and then conduct an imaginative learning course with a TRIZ instructional strategy design for this topic. These topics can generally be divided into five stages with five important objectives, and the teacher designs the learning sheets for each stage. First, TRIZ instruction strategies are incorporated into the students' learning, innovative thinking and case experiences from the 40 inventive principles, which are beneficial for cultivating preexisting knowledge. The guidance of imaginative learning instruction effectively inspires students to develop more-diverse imaginative abilities and to strengthen the extension of their development and their alternative stages. Furthermore, the multiple feedback and reflection mechanisms of imaginative learning are combined with the systematic thinking related to the contradiction matrix, allowing students to develop an in-depth understanding of the characteristics of various systems, ascertain correlations among systems, increase the effectiveness of connections among systems, and, in turn, complete the design blueprint with their ideas. Finally, students follow the blueprints in the Practice stage. The best time to apply TRIZ instructional strategies is when problems arise during this process. TRIZ is used to create new ideas and to concretely practice the process of creativity, which leads students to develop diverse and extensive ideas. This fully inspires and allows the students to practice their imaginative skills so that they can create richer and more-diverse creative works.

CONCLUSIONS AND SUGGESTIONS

This study provides the following conclusions and suggestions.

Conclusions

This study applied TRIZ instructional strategies to imaginative learning course instructions for vocational students in Taiwan. Statistical analyses were performed on questionnaire surveys from students' pre-tests and post-tests, which were supported by the qualitative analysis of the textual data from the students' imaginative learning portfolios. Based on the analysis and discussion, we conclude the following.

A significant number of students approved of the effect of applying TRIZ instructional strategies to imaginative learning. This suggests that the instruction of the TRIZ 40 inventive principles can help students apply their ideas from what they have learned in other fields to form new and effective ideas in the imagination stage. In the current case, the students continuously concentrated on the imaginative design topic of the amphibious vehicle, and they generated rich, diversified and unprecedented ideas so as to extend newer ideas and effectively improve their learning interest and exercise their imagination. In the practical stage of imagination, the application of the TRIZ tool improved the specific realization of the students' imaginative design works. By applying the contradiction matrix and the 40 inventive principles, the students were able to effectively solve the conflict between the imaginative design and the specific realization of its working, which helped the students extend their imagination without limits. As stated above, by observing the students' imagination and TRIZ learning course, the 5-stage key factors for TRIZ to improve imaginative learning and practice can be summarized along with the benefits of the 40 inventive principles of TRIZ: (1) in the initiation stage, cultivate the students' ability to actively learn along with flexible application; (2) in the development stage, cultivate the students' ability to diversify their imagination during pre-planning; and (3) in the alternative thinking stage, cultivate the students' acuity of imagination and facilitate cooperative learning. Then, the TRIZ contradiction matrix and 40 inventive principles are used as follows: (4) in the links stage, solve the students' connection problems and cultivate their systematic thinking and integrated planning abilities; (5) then, in the practice stage, guide the students to think repeatedly and improve their problem solving ability. Finally, based on the IDEAL-P teaching model constructed in the above 5-stage key factors, this study provides a learning and practical teaching design integrating TRIZ vertically into imagination. Students can put their ideas into practice, conduct a verification of the solutions to problems, and complete works that are both creative and conform to focused topics, which will help students sharpen their imaginative abilities.

Suggestions

Based on the above research conclusions, the following suggestions are provided as a reference.

This study found that students following TRIZ instructional strategies believe that this learning methodology and practice had a significant positive effect on their imaginative learning, suggesting that these strategies can improve the imaginative learning of students. Therefore, TRIZ instructional strategies should be adopted in instructional design projects in imaginative learning courses. Meanwhile, teachers should increase their academic abilities relating to TRIZ as well as their knowledge of TRIZ instructional strategies to prepare for the future introduction of TRIZ into imaginative learning courses and to guide students in learning how to use their imaginations. Furthermore, teachers can use the IDEAL-Practice instructional model constructed in this study to effectively utilize the innovative thinking of TRIZ in imaginative learning and practice. Teachers can design diversified imaginative situational topics and a five-stage unit of study based on curricular characteristics to integrate students' imaginative learning and practice.

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