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Design and Verification of an Instructional Model for Blended TRIZ Creative Learning*

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The main purpose of this study was to develop a feasible instructional model for blended TRIZ (Theory of Inventive Problem Solving) creative learning and a verification mechanism. This study summarized the teaching design contents of blended creative learning based on a literature review, and integrated them with TRIZ to develop the teaching model for blended TRIZ creative learning. This model comprises three parts: traditional teaching, online teaching, and learning evaluation. The results of experimental teaching and questionnaire surveys showed that, students are positive and affirmative about the four aspects of the teaching model, namely learning effectiveness, learning attitude, application of the learning platform, and TRIZ creative learning. Moreover, in order to improve the teaching model, this study proposed a verification mechanism, and summarized the items to be improved. Furthermore, this study proposed specific suggestions and revised the model based on the connection between the teaching model and teaching design focuses, in order to achieve the goal of teaching design, improving teachers' creative teaching quality, cultivating a positive attitude towards innovation in the students, and further enhancing their creative ability.

Keywords: blended learning; TRIZ; creative learning; Design and Verification of Teaching Model

1. Introduction

With the development of Internet technology, teaching strategies and tools also have changed rapidly. In terms of educational environment, the diversified information provided by a web-based learning system, the flexibility of a knowledge system, the full application of knowledge, long-distance and independent learning environments, and a highly interactive communication environment can provide an individualized, instantaneous, and ideal learning environment that offers both synchronous and non-synchronous information. In education, an increasing emphasis on blended learning has facilitated its application and global development. Osguthorpe and Graham suggested that blended learning combines online learning with traditional face-to-face learning, and can break through the constraints of time and space and provide the most effective learning [1]. As stated by Mortera-Gutierrez, in the context of blended learning, the combination of traditional teaching with information technology can create numerous educational possibilities, and reflect the richness of education [2]. Therefore, students can obtain the best learning effect from different teaching strategies and tools according to the design of the teaching activities and course contents.

The Ministry of Education announced the "White Paper on Creative Education" in 2007, and clearly indicated that in the era of knowledge-based economies, the Ministry of Education's objective is to activate national creativity potential, develop multiple skills, and enrich high and diversified self-value, with the aim of turning Taiwan into a nation of creativity based on individual knowledge and under the premise of life concern [3]. Moreover, the teaching of creative thinking can also use different educational technologies, especially information networks, to create diversified teaching environments. Therefore, if the teaching of creative thinking can be applied to engineering education, it will substantially benefit the creation of engineering

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skills, the development of techniques, and the progressive innovation of products. Moreover, its effect on teaching strategies, process, and effectiveness are worth in-depth investigation.

Clark and Mayer investigated media research, and found that if teaching materials are simply turned into multimedia or e-files, they are not significantly superior to the traditional media, based on research evidence. The keys to the success of e-learning are still the use of the characteristics of the media and the new abilities provided by technology, consideration of how learning takes place, and effective improvement of teaching methods [4]. Therefore, the critical point of teaching design is that teachers and technology play an indirect role in learning. They can stimulate and support learning activities, and urge their students in order to trigger their motivation to learn. However, learners do not directly learn from technology; instead, they learn from what they have achieved through thinking [5].

Therefore, this study aims to integrate blended learning into TRIZ (Theory of Inventive Problem Solving) to construct a teaching model of creative learning that puts emphasis on three aspects: the design of traditional teaching, the design of online teaching, and the design of teaching evaluation. The main purposes of this study are to develop the teaching model of TRIZ creative learning, to analyze experimental teaching and learning effectiveness, and to design a mechanism for verifying and improving the teaching model. The construction of a complete teaching model for blended TRIZ creative learning is expected to achieve the goal of effectively using information technology to assist in teaching and improving the effectiveness of students' creative learning.

The purposes of the research are as follows:

1. To investigate the contents of the teaching design for blended TRIZ creative learning.
2. To develop the teaching model for blended TRIZ creative learning.
3. To understand the effect of the teaching model for blended TRIZ creative learning on the students' learning.
4. To verify and improve the teaching model for blended TRIZ creative learning.

2. Literature review

This study reviewed previous research concerning teaching strategies for blended learning, TRIZ, blended TRIZ creative learning, and e-learning.

2.1 Contents of blended learning

The definitions of blended learning are comprehensive in domestic and foreign studies. Graham *et al.* summarized three most common definitions: (1) the mixing of different teaching media; (2) the mixing of different teaching strategies and methods; (3) the mixing of different teaching environments [6]. Although their definitions are different, Osguthorpe and Graham suggested that teachers construct environments of blended learning for six accessible reasons, including (1) that these environments can enrich education; (2) that knowledge can be accessed in them; (3) that social interactions can take place in them; (4) that they can act as individuals' representatives; (5) that they can help cut costs; and (6) that it is easy to revise them [1]. This study combined traditional class teaching with e-learning, and chose the most adequate learning environment and tool, in order provide teaching that responded to students' individual differences, teaching purposes, teachers' experiences, and online resources. Moreover, the approach can enable learners to efficiently engage in online learning, face-to-face learning, and autonomous learning by using diversified teaching technologies and relevant teaching strategies [7, 8].

2.2 TRIZ (Theory of Inventive Problem Solving)

TRIZ was created by a Soviet inventor, Genrich Altshuller, in 1940. TRIZ is the abbreviation of the Russian "Teoriya Resheniya Izobretatelskikh Zadatch" and is translated into English as "Theory of Inventive Problem Solving." After analyzing more than 400 000 patents, Altshuller summarized the commonality and repeatability of patent invention, as well as the logics of innovative invention, as the theoretical foundation of TRIZ [9]. Innovative invention represents a new thinking. Inspired by TRIZ, this study used diversified creative teaching to trigger students' active learning motivation and interest, and integrate the procedures of inventive problem solving into the operating procedures of creative teaching, as shown in Fig. 1. A creative practical theme is designed to apply TRIZ theory to teaching students how to analyze a technology system and to obtain an in-depth understanding of it to find the contradictions. Through the application of TRIZ tools, such as the contradiction matrix and 40 inventive principles, a comparative effect can be achieved to promote creativity and resolve technical contradictions [10, 11]. Thus, it is hoped that the strategies of creative instruction can prove to inspire students' creativity and problem-solving abilities.

2.3 Blended TRIZ creative learning

In order to design a suitable and feasible online course and learning environment, it is necessary to consider the design of education, teaching theories and methods, learning theories and methods, and

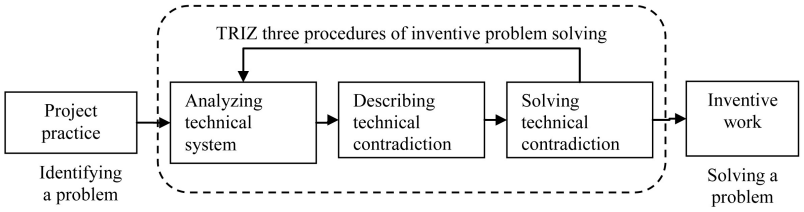


Fig. 1. Flow chart of operation of creative teaching [9].

the development of information technology [12]. Therefore, to develop a blended TRIZ creative learning platform, it is necessary to take into account the purpose of the system development, system design, system mechanism, TRIZ application, and platform functions [13, 14], as shown in Fig. 2. Based on the abovementioned theoretical foundation, this study designed a teaching strategy to encourage students to engage in meaningful learning and to increase the efficacy of their creative learning.

2.4 Teaching strategies of e-learning

Although e-learning is mainly conveyed via computers, different course designs reflect different learning hypotheses. According to Clark and Mayer, the first kind of learning hypothesis is absorptive learning where learners absorb information like a sponge and teachers take on the role of experts to convey this professional information. The focus of course design is on how to efficiently and rapidly convey information at a low cost. The second kind of learning hypothesis is the enhancement of learning response. In teaching, teachers provide short articles and essays for students to read, and then use a test and propose standard answers to evaluate students. The third kind of learning hypothesis is Guided Discovery. This is usually used in a problem-solving context where teachers provide some clues or information resources for problem-solving

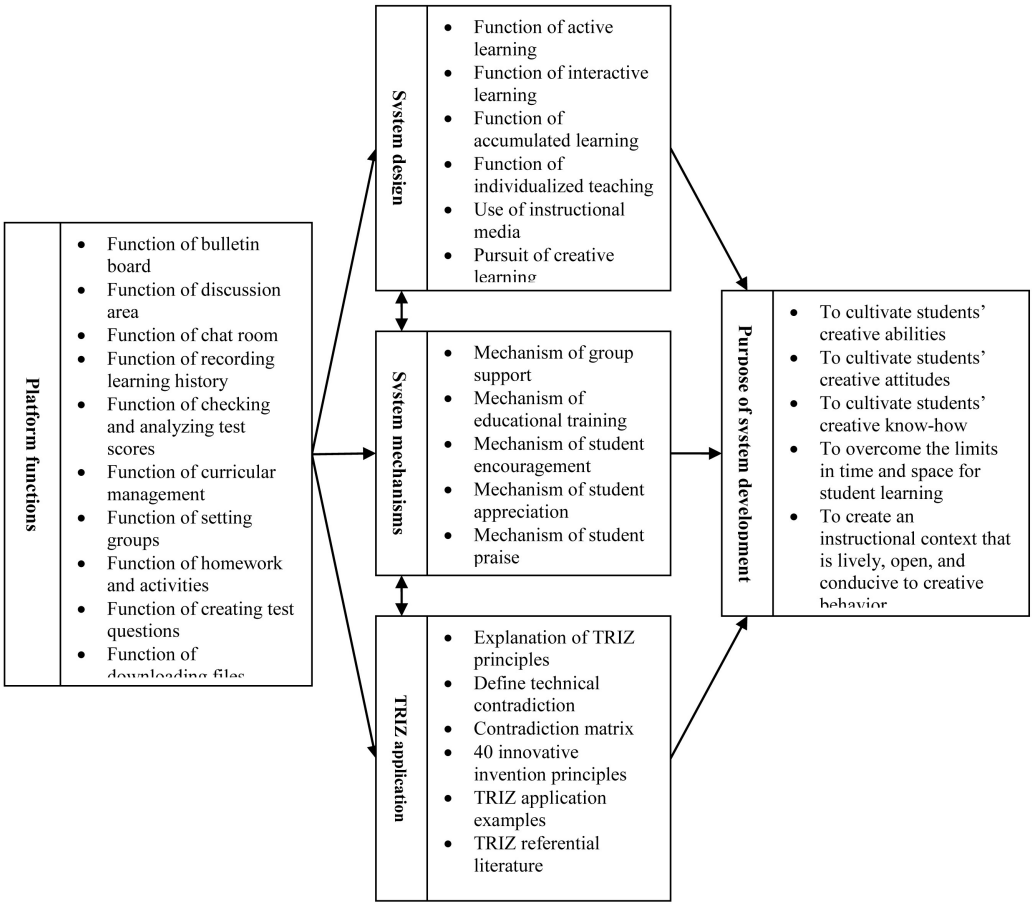


Fig. 2. Contents of Blended TRIZ Creative Learning Framework [13, 14].

to guide the students in active and spontaneous guided discovery. The process attaches importance to knowledge construction. The focuses of each of these three kinds of e-learning design are different [4, 15]. This study used the third kind, guided discovery, and attached importance to the active participation of teachers and students, as well as to their mutual interactions. Therefore, teachers became helpers, assisting students in interaction and cooperation, and were responsible for supporting learning, providing learning opportunities, and encouraging students to cooperate with one another to establish a common knowledge system.

3. Research design and method

This study was designed according to research goals. Detailed explanations are given below.

3.1 Research procedures

This study employed experimental design to conduct a case study, and observed and recorded the students' learning processes. In addition, this study conducted a questionnaire survey on learning effectiveness to be completed after the end of the experiment in order to understand the students' learning condition, as well as to verify the effectiveness of the implementation of the teaching model. The results served as the basis for revising and improving the teaching model, and improving the students' learning effectiveness, as shown in Fig. 3.

3.2 Research subjects and implementation method

The subjects of this study were the students who were enrolled in the "Technological Education" course at a girls' senior high school in Taiwan. The 56 students were divided into 14 groups. At stage 1, the teacher used traditional teaching to explain learning objectives, instruct students in researching topic-related knowledge, and give examples of TRIZ. At stage 2, the teacher assigned students to learning tasks through the implementation of blended teaching activities. Each group could look up data, discuss online, and present relevant contents, feedback, and results on the network platform. During the implementation of the teaching activities, the teacher could control the course progress according to the discussion contents of each group, and provide advice and feedback. At stage 3, the results were published at the end of the activities. Each group delivered a presentation, and a learning effectiveness competition was held. The best group would be selected and rewarded. Moreover, the groups would exchange their experiences and share feedback.

3.3 Design contents of teaching model for blended creative learning

The teaching strategies adopted in this study were the guiding principles for teaching activities. Teachers could choose applicable teaching strategies according to their teaching ideas to facilitate the implementation of teaching activities, and achieve the pre-established teaching objectives. Based on the literature review, this study used the characteristics of blended learning to integrate the teaching of creative thinking as the main basis of the teaching design, in order to further confirm the design contents of the teaching of blended creative learning, as shown in Table 1.

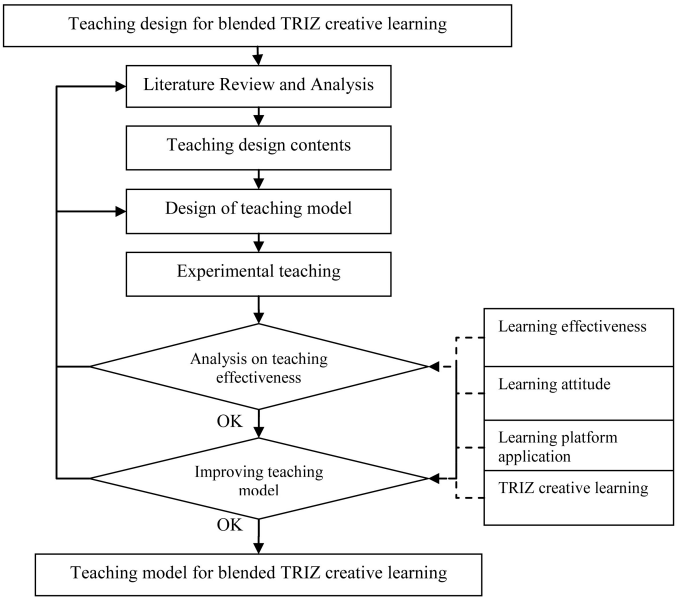


Fig. 3. Design flow chart of teaching model for blended TRIZ creative learning.

Table 1. Summary of the design contents for the teaching of blended creative learning

Focus of teaching design		Explanations of contents
1	Triggering students' learning motivation	To enhance teaching through diversified forms and perspectives to enable students to easily accept teaching and to arouse learners' interest.
2	Confirming students' learning objectives	To enable students to clearly understand learning objectives during the teaching process, to help them concentrate on the focuses to be strengthened by the teacher, and to enable them to engage in the learning of Guided Discovery to develop learning effectiveness with added value.
3	Awakening students' prior knowledge	Cognitive psychologists suggest that when learners are learning new information, the objective of the learning effectiveness of the long-term memory can be achieved if they can connect the information with their own experiences. When facing new knowledge, they will choose to connect it with their former relevant experiences.
4	Requesting students to participate in activities	Learning participation enables students to actively obtain knowledge. Moreover, those who actively participate in learning can arrange knowledge better than those who passively participate in it.
5	Providing students with guidance and feedback	Guidance and feedback can help students choose and tell the differences from website information contents. Guiding individual students in actively connecting themselves with other relevant or more in-depth learning is an important process, assisting students in learning online teaching materials or reviewing their learning results in the future.
6	Evaluating students' learning effectiveness	To discover whether students have obtained knowledge through online or off-line evaluations, there are objective and subjective examinations, and a learning portfolio assessment.
7	Providing teaching with individual differences	When students encounter problems and difficulties in learning, remedial teaching can be implemented. When the students' learning conditions are acceptable, enriched teaching can be provided to deepen and broaden the learning concepts or contents. Moreover, students can be directly provided with additional teaching materials or guided in how to connect with other courses in their learning.

3.4 Design of teaching model for blended TRIZ creative learning

After confirming the design contents for the teaching design of blended creative learning, this study integrated TRIZ into the teaching model, and then initiated the design of the teaching model for blended TRIZ creative learning. A three-step TRIZ inventive problem-solving procedure was adopted to implement teaching activities. Each step included three major parts: traditional teaching, online teaching, and learning evaluation [16], as shown in Fig. 4. Detailed explanations on teaching focuses and implementation methods are given below.

3.4.1 TRIZ Step 1—Teaching focuses and implementation methods

Step 1 is to analyze the technological system by identifying each individual component of the system, to identify the most fundamental problems and system characteristic parameters to be improved, and to describe explicitly the physical status and performance variables of the system.

Teaching focuses: Building a vivid and open teaching context and triggering students' sensitivity to problems. The implementation steps from Weeks 1 to 6 are:

1. through traditional instruction, the teacher explains the learning objectives to create a lively and open instructional context, and awaken the students' relevant pre-existing knowledge;
2. explain the TRIZ case and guide the students in learning how to analyze technology systems and obtain TRIZ knowledge;
3. ask the students to use the learning platform to conduct online diverse learning and download cases to increase their learning motivation;
4. encourage the students to use the platform functions to conduct online group discussions and knowledge exchanges;
5. provide the students with online feedback and consulting functions, where they can seek assistance from teachers and teaching assistants to work together to complete Homework 1;
6. use learning evaluation to understand students' learning and individual differences;
7. adopt a creative and diverse method of instruction to enhance students' sensitivity to problems and issues.

3.4.2 TRIZ Step 2—Teaching focuses and implementation methods

Step 2 is to describe contradiction and identify the characteristics needed to be improved in Step 1. This study has to point out the technical contradictions that need to be solved. Because once a part of technological system is improved, another part of it may deteriorate, it is necessary to identify technical contradictions.

Teaching focuses: Guiding students in comprehensive consideration of problems and attaching importance to their learning and application of TRIZ knowledge. The implementation steps from Weeks 7 to 9 are:

1. use novel and effective instructional strategies

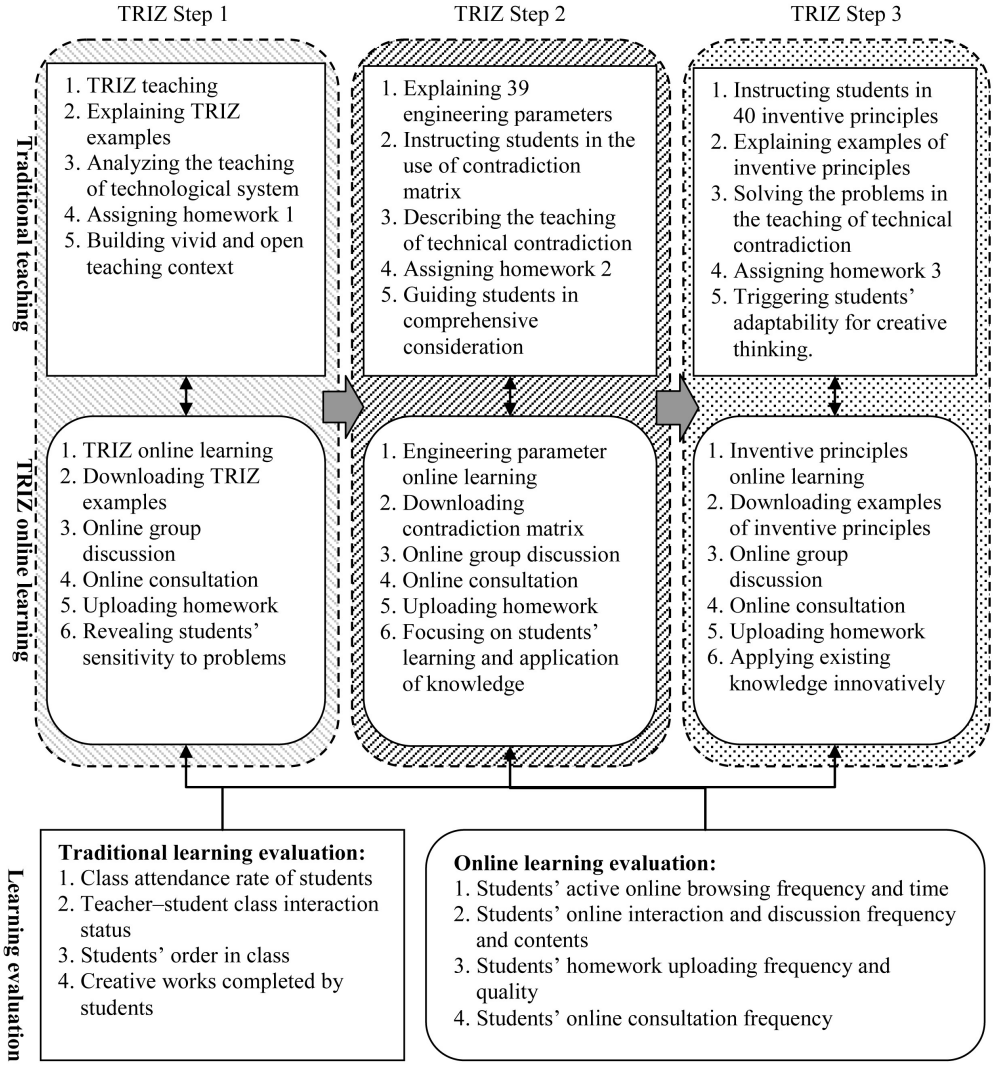


Fig. 4. Teaching model of blended TRIZ creative learning [16].

and methods to explain 39 engineering parameters and a contradiction matrix in instruction to students;

2. along with students' prerequisite knowledge, to guide the students to take in and think through problems thoroughly in order to train their ability to summarize technical contradictions;
3. ask the students to engage in online learning, download the contradiction matrix, and do some practice;
4. encourage the students to engage in online discussions and share learning experiences with others;
5. use online consulting functions to enhance student–teacher interactions and bidirectional exchanges to cooperatively complete Homework 2.

The teacher will be able to understand the students' learning conditions and abilities in applying TRIZ tools and the application of TRIZ knowledge from the learning evaluation.

3.4.3 TRIZ Step 3—Teaching focuses and implementation methods

Step 3 is to solve technical contradictions. Technical contradictions are identified in Step 2, and a contradiction matrix is used to find out the most effective theory in 40 inventive principles. Moreover, complicated problems are solved by using analogies.

Teaching focuses: Triggering the students' adaptability in creative thinking to enable students to use existing knowledge creatively. The implementation steps from Weeks 10 to 15 areas follows.

1. Instead of using an authoritarian instruction, the teacher strongly encouraged students in learning the 40 inventive principles, and

inspired the students' flexibility in creative thinking.
2. Ask the students to learn the 40 inventive principles, download cases, and practice on the online platform.
3. Encourage the students to engage in online group discussions and brainstorming, and share ideas to inspire new creativity.
4. Actively use the online consulting functions and give more praise and appreciation to students' performances.
5. Encourage the students to pursue creative learning as the objective, to jointly complete Homework 3.
6. From the learning evaluations, the teacher can understand the students' learning conditions and application ability for the 40 inventive principles, so students can creatively apply their learnt knowledge.

3.4.4 Teaching focuses and implementation methods of the learning evaluation

The evaluation focuses on how students applied the knowledge that they had learnt to specific results and the application process. It also attaches importance to the development of high-level abilities, such as thinking, analysis, assembly, judgment, and the ability for inspiration of expression. Moreover, it takes into account the thinking processes and logical inference procedures.

Teaching focuses: Recording students' knowledge learning process and analyzing their learning effectiveness. The implementation steps (Weeks 3~16: analysis of learning process; Weeks 17~18: presentation of accomplishments and 15 minutes for every presentation) are as follows.

1. The teacher can collect students' learning process data from the instructional platform records, including online post-class learning, data downloads, group discussions, experience sharing, online consultation, and homework submissions.
2. The teacher can focus on the students' learning processes and participation as evaluation indicators to be in accordance with the characteristics of technological instruction, and further evaluate the true learning accomplishments of the students to serve as a reference for proceeding with individual students' differences.
3. At the final presentations, the teacher evaluates the innovative works and theme reports of each group in order to understand the students' innovative design ideas, as well as their abilities in organization, summarization, and expression.

To summarize the above, this study used project practice to provide the Technological Education course, and used the characteristics of blended learning and TRIZ to provide traditional teaching, online teaching, and the mixed course of traditional and online teaching to overcome the restrictions on time and space for student learning. The platform could encourage students in creative thinking and cooperative learning. Moreover, three homework assignments were given according to TRIZ to enable the teacher to understand the students' learning conditions, and provide them with assistance and consultation in a timely manner. As a result, students could become familiar with TRIZ's inventive principles and complete the actual works of creative design within the deadline in order to further improve their creative skills and pursue creative learning.

3.5 Research tools

This study recorded the process of students' participation in project-related activities, and collected and investigated the data concerning their learning condition according to the research aims. The research tools used in this study were a web-based learning platform and questionnaire on learning effectiveness. These are explained below.

3.5.1 Web-based platforms

This study constructed an interactive "web-based TRIZ learning platform" for students' online discussion to facilitate data collection by the researcher. The main functions of the platform included: problem guidance, bulletin, chat room, discussion board, uploading/downloading of data, and a web-based teaching assistant. Group members could freely share their discussion results, experiment findings and problems on the platform, so the online teaching assistant can provide timely guidance. Also, the online platform can record students' learning histories in the database. The textual data such as learning histories are analyzed to supplement the shortcomings of the questionnaire surveys. Qualitative data collection and analytical principles are used to understand TRIZ in the progression of task activities and reflection and feedback after the activities have been completed.

3.5.2 Questionnaire on learning effectiveness

This study designed a "Questionnaire on Learning Effectiveness" where a 5-point Likert scale was used. A scholar and an expert were invited to establish expert validity. The questionnaire became a formal one (Cronbach $\alpha = 0.96$) after it was amended. The questionnaire mainly included four aspects: effectiveness (Cronbach $\alpha = 0.88$), attitude (Cronbach $\alpha = 0.89$), platform application

Table 2. The production process and TRIZ application comparison table for Case 1

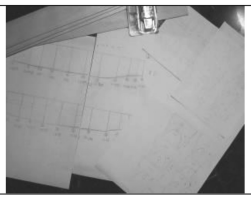
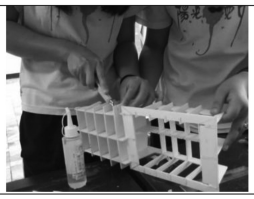
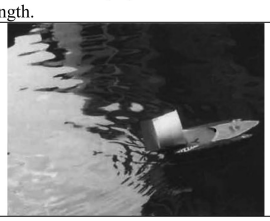
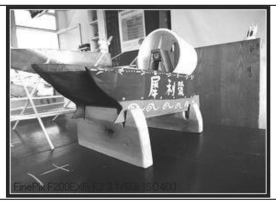
Explanations on thinking direction and application	Students chose the materials and methods to produce the creative work and took into account the ease of producing the hull. However, the strength of the hull would be reduced.	As for the structure, (1) and hull ribs were used to produce the work to increase the strength. (3) and (10) were used. Walnut wood was mainly used in the main structure, while Styrofoam board was mainly used in other parts for ease of production.
TRIZ application	➢ Contradiction matrix: The improvement of (32) made it easy to produce the hull. However, it resulted in the deterioration of (14).	➢ Inventive principles: (1) Segmentation (3) Improving local properties (10) Principle of pre-emptive action
Photographs of the process		

Table 3. The production process and TRIZ application comparison table of Case 2

Explanations on thinking direction and application	The tests showed that the boat sailed slowly. However, if the speed of the ship was improved, the stability and strength of the hull would be reduced.	The design of the boat was a streamlined hull, and thus the stability was reduced. (1), (3), (8) and (26) were used to design the double hull to prevent the deterioration of stability and strength.
TRIZ application	➢ Contradiction matrix: a. Because (9) was used to improve the speed, it led to (13) deterioration of stability of the compositions. b. Because (9) was used to improve the speed, it lead to (14) the deterioration of strength.	➢ Inventive principles: a. (1) Segmentation b. (3) Improving local properties (8) Balancing (26) Reproducing
Photographs of the process		

(Cronbach α = 0.87), and TRIZ creative learning (Cronbach α = 0.89). To conform to the perspective of the scholars Camines and Zeller, the reliability coefficient value of a good education questionnaire should be at least 8.0 [17], otherwise it is not practicable. The self-reported questionnaire survey was conducted after completion of the teaching activities. A total of 56 questionnaires were distributed, and 56 effective questionnaires were returned, with an effective return rate of 100%. The questionnaire survey was implemented to the students, and a one-sample t-test was employed to analyze the students' learning conditions after the instructional experiment as well as the dimensions for improvement in the instructional model, and to serve as a basis for verifying and improving instructional design.

4. Results and discussion

After the design of the teaching model for blended TRIZ creative learning was completed, this study implemented one-semester experimental teaching at the selected school to record students' learning and discussion processes on the platform. Moreover, after the course had finished, this study conducted a questionnaire survey and performed statistical analyses to understand the students' learning condition and learning effectiveness under the implementation of this teaching model. Further analyze was made of the aspects of the teaching model that required to be strengthened as the important reference for improving this teaching model, in order for the teaching model developed in this study to better improve students' learning effectiveness.

4.1 Analysis on learning effectiveness and attitude of blended TRIZ creative learning

This study used a single-sample t-test (with a test value of 3) to analyze the research results, in order to understand the students' learning conditions and effectiveness in various aspects under the implementation of this teaching model.

4.1.1 Analysis on learning effectiveness

The homework assigned to students at three stages in the course and students' learning portfolio on the platform were arranged and summarized in Table 2

according to their groups. Moreover, this study also analyzed the results of the questionnaire survey.

1. Explanations on the analysis on students' production process

The homework completed by the students in various groups at each stage and the learning process discussed by the groups on the platform were summarized in order to understand the students' learning condition. The results showed that students could discover many problems during the process of producing actual works. The contradiction in the system was confirmed through the cooperative learning and systemic discussion by the groups. Moreover, the TRIZ tool contradiction matrix was used to find the corresponding inventive principles to solve problems and complete creative works (as shown in Tables 2 and 3).

The production histories of the two groups of students are explained as follows.

Case 1

- Analyze the technology system.
- When students selected materials for the boat and manufacturing methods, they found that ease of production for a material would result in decreased boat strength and lead to contradictions in manufacturing.
- Describe the technical contradictions.
- Students applied TRIZ contradiction matrix to seek 39 similar engineering parameters. After group discussion, (32) ease of production and (14) strength were separately assured.
- Resolve technical contradictions.
- Students further discovered corresponding discovery principles, which were (1) separation, (3) improvement of partial characteristics, and (10) the principle of advanced action. These three inventive principles were the directions for students' problem-solving and creative thinking. Applications are explained as follows. The structure portion adopted the inventive principle (1) separation, using ribbed slabs in production to enhance boat strength. They also use the inventive principle (3) for improvement of partial characteristics and (10) the principle of advanced action, with walnut in the main structure, while the other structural portions were mainly Styrofoam, achieving the purposes of ease of production and boat strength.

Case 2

- Analyze technology system.
- After the boats entered water, students found that the speed was unsatisfactory. Consideration of sailing speeds would cause boat stability and strength to decrease, causing functional contradictions.
- Describe technical contradiction.
- Students used the TRIZ contradiction matrix, to seek 39 similar engineering parameters. After group discussion, it was ascertained that there are two contradictions, which are due to the improvement of (9) speed, which causes (13) deterioration of object composition stability. The other was due to the improvement of (9) speed, resulting in (14) declined strength.
- Resolve technical contradiction.
- Students further found that the corresponding inventive principles, which were (1) separation, (3) improvement of partial characteristics, (8) balance, and (26) replication. These four inventive principles are used as directions for students to resolve problems and thinking creatively. Applications were explained as follows. The boat design was streamlined, resulting in lower stability. Using (1), (3), (8) and (26), in a dual boat structure method of design, assisted speed while preventing a loss of stability and strength.

2. Analysis of students' learning effectiveness

As shown in Table 4, in terms of students' learning effectiveness, the items all reached statistical significance. The mean of all of them was higher than 4.09 (except for A06), and the standard deviations of all of them was lower than 0.757, indicating that most of the students agreed with the items of the questionnaire (between Agree and Strongly Agree). The further analysis showed that the mean scores of A05, A04 and A02 (M = 4.63, 4.5 and 4.36 respectively) were the highest, indicating that students were satisfied with and approve of the cultivation of learning experiences, doing practical work, problem-solving, data collection, and analysis, as well as gaining knowledge relating to the theme.

To summarize the above, this study found that the use of TRIZ to guide students in applying engineering principles and technological techniques can improve their hands-on implementation and problem-solving abilities. Moreover, students' learning effectiveness could be improved through the competitive activities of blended teaching strategies and the discussion mechanism of the web-based platform. The research finding is consistent with Lou *et al.*, who suggested that students can cultivate a good attitude and the objective of eagerly participating in the project while taking part in the learning of projects. In order to increase the level of work and to enable students to fully and actively apply relevant knowledge, student discussions allow them to exploit their creativity to complete their work [18].

Table 4. Learning effectiveness analysis on a single-sample t-test (test values = 3 and 4)

Items of various aspects	Mean	Std. deviation	t-test value = 3	t-test value = 4
A01) I could gain more knowledge about the research topic by participating in the "project learning course" compared with attending the teacher's class.	4.09	0.745	10.937***	0.896
A02) The process of project practice could improve my problem-solving ability.	4.36	0.699	14.534***	3.825***
A03) The process of project practice could improve my ability in data collection and analysis.	4.16	0.757	11.468***	1.588
A04) The process of project practice could improve my ability for hand-on implementation.	4.5	0.603	18.615***	6.205***
A05) The process of project practice provided me with very important learning experiences.	4.63	0.524	23.189***	8.919***
A06) I would record the experimental process (e.g. turning it into data, texts, graphics, and charts).	3.39	0.705	4.168***	–6.442***

*** *p value* < 0.001.

4.1.2 Analysis of learning attitudes

As shown in Table 5, in term of the students' learning attitudes, the items all reached statistical significance. The mean of all of them was greater than 4.02 (except for B08 and B11), and the standard deviation of all of them was less than 0.859, suggesting that most of the students agreed with the items in the questionnaire (between Agree and Strongly Agree). The further analysis showed that the score of B10 (*Mean* = 4.43) was the highest, followed by B09 and B12 (*Mean* = 4.02). To summarize the above, this study found that the application of TRIZ to students' gaining of professional knowledge and the teaching design of the project activities for blended learning enabled students to engage in cooperative learning in activities to correct their learning attitude and make them become active learners. The findings are consistent with Lou *et al*. In addition to perceiving the usefulness and ease of use of knowledge, by participating in project learning students can further develop the ability to learn cooperatively and encourage one another to overcome difficulties when facing setbacks [18].

4.1.3 Analysis of application of learning platform

As shown in Table 6, in terms of students' application for the learning platform, the items all reached statistical significance. The mean of all of them was greater than 3.80 (expect B13), and the standard deviation of all of them was smaller than 0.834, suggesting that most of the students agreed with the items of the questionnaire (between Agree and Strongly Agree). The further analysis showed that the score of C15 was the highest (*Mean* = 3.96), followed by C14 and C17 (*Mean* = 3.82). This indicated that the students approve of and agree with using the learning platform, to cement and textualize knowledge or ideas. They also agree with the explanatory lectures and online teaching assistant consulting system in this study, as they can realize their functions so that students can have a quicker grasp of the techniques in operating the Internet platform and receive positive feedback and

Table 5. Learning attitude analysis on a single-sample t-test (test values = 3 and 4)

Items of various aspects	Mean	Std. deviation	t-test value = 3	t-test value = 4
B07) My learning attitude was more thoughtful than usual during the project practice.	4	0.739	10.132***	0
B08) During the project practice, I would enthusiastically participate in the discussion on the web-based platform and knowledge sharing.	3.66	0.859	5.758***	–2.957**
B09) During the project, I would actively consult with the teacher, friends, family, and experts when I encountered problems.	4.02	0.82	9.289***	0.163
B10) "Project learning course" was beneficial to the cultivation of students' cooperative learning.	4.43	0.599	17.856***	5.357***
B11) I would apply the project exploration skills to what I did not understand.	3.8	0.585	10.275***	–2.512*
B12) If there is a chance, I am willing to participate in project activities of different topics.	4.02	0.751	10.149***	0.178

**p value* < 0.01; ****p value* < 0.001.

Table 6. Platform application analysis on single-sample t-test (test values = 3 and 4)

Items of various aspects	Mean	Std. deviation	t-test value = 3	t-test value = 4
C13) The web-based teaching assistant could immediately solve my problem.	3.34	0.769	3.3**	–6.427***
C14) The web-based teaching assistant was beneficial to my participation in the "project learning course".	3.82	0.834	7.374***	–1.603
C15) The use of a discussion board and group discussions could help me turn knowledge or thinking into specific texts.	3.96	0.83	8.69 ***	–0.322
C16) The web-based platform could help me accumulate, share and obtain knowledge.	3.8	0.818	7.348***	–1.796
C17) Participation in the seminar enabled me to rapidly grasp the skills to operate the web-based platform.	3.82	0.811	7.575***	–1.647

* $p < 0.05$,** $p < 0.01$,*** $p < 0.001$.

assistance. In turn it helps students to quickly accumulate, share, and obtain knowledge. To summarize the above results, this study found that the application of the characteristics of blended learning could speed up students' aquiring of knowledge and sharing and could cultivate their ability to turn knowledge and thinking into specific texts and to effectively apply TRIZ to the innovation of project work to further improve their ability to think creatively.

4.1.4 Analysis on effectiveness of TRIZ creative learning

As shown in Table 7, in terms of students' TRIZ creative learning effectiveness, the items all reached statistical significance. The mean of all of them was greater than 3.55, and the standard deviation of all of them was less than 0.865, suggesting that most of the students agreed with the items of the questionnaire (between Neutral and Agree). The further analysis showed that the score of D21 was the highest (*Mean* = 4.05), followed by D22 and D20 (*Mean* = 3.95 and *Mean* = 3.86), indicating that the students agreed and approved of inspiring creative thinking potential and cultivating the ability to think creatively and establish concrete directions for thinking about innovation and invention. To summarize the above, this study found that the application of TRIZ to students' learning how to thinking creatively could effectively trigger their potential for creative thinking and further improve their creative thinking ability.

4.2 Verification and Improvement of teaching model for blended TRIZ creative learning

This study further used a single-sample t-test (with a test value of 4) to test the results of the questionnaire survey to verify the effectiveness of the teaching model of TRIZ creative learning designed in this study and to further find out the items with significance differences in scores where the t-value was negative. In other words, this study analyzed the items to be improved where the t-value was negative with no significant difference to the proposed specific improvement measures to improve the students' learning effectiveness.

4.2.1 Verification and analysis of the teaching model

As shown in Tables 4–7, this study used a single-sample t-test (with a test value of 4) to analyze the results in detail. As shown in Table 8, there were four items where the t-value was positive with a significant difference (between Agree and Strongly Agree), and there were 12 items where the t-value was not significantly different (Agree), suggesting that the students' comments on 16 of the 22 items of the questionnaire was between Agree and Strongly

Table 7. TRIZ creative learning analysis on a single-sample t-test (test value = 3 and 4)

Items of various aspects	Mean	Std. deviation	t-test value = 3	t-test value = 4
D18) The course could help me understand the contents of TRIZ 40 inventive principles.	3.63	0.865	5.409***	–3.245**
D19) I would find out the corresponding inventive principles according to the contradiction matrix.	3.55	0.784	5.281***	–4.259***
D20) The course helped me develop more specific thinking direction for innovative invention.	3.86	0.773	8.299***	–1.383
D21) The course helped trigger my potential of creative thinking.	4.05	0.699	11.286***	0.574
D22) The course helped me cultivate the skills of creative thinking.	3.95	0.749	9.458***	–0.535

p *value* < 0.01,*p *value* < 0.001.

Table 8. Summary of the statistical analysis results

	Number of items in the questionnaire (Total number of items = 22)			
t-value	t-value was negative with significant difference	t-value with no significant difference	t-value was positive with significant difference	Agree + Strongly Agree
4	6	12	4	73% (16 items)
3	0	0	22	100% (22 items)

Agree. As many may 73% of them agreed with the teaching model. The analysis results of the t-test, with a test value of 3, showed that as much as 100% of them agreed with the teaching model (see Section 4.1 for the details of the analysis results).

Therefore, the verification and analysis of the teaching model, newly designed and introduced in this study, showed that most of the students were highly positive and affirmative about the learning effectiveness in various aspects of the "teaching model for blended TRIZ creative learning" designed in this study.

4.2.2 Improvement of teaching model

As shown in Tables 4 and 5, there were six items where the t-value was negative with a significant difference when the study used a single-sample t-test to analyze the results (where the statistical value was 4), including A06 ((I would record the experimental process), B08 (During the project practice, I would enthusiastically participate in the discussion on the web-based platform and knowledge sharing), B11 (I would apply the project exploration skills to what I did not understand), C13 (The Web-based teaching assistant could immediately solve my problem), D18 (The course could help me understand the contents of TRIZ 40 inventive principles), and D19 (I would find out the corresponding inventive principles according to the contradiction matrix).This study provided the feedback on the six items to be improved in the aforementioned four aspects of the design and the focus of the teaching model in order to re-review and completely analyze them, as well as to summarize their mutual correlation, as shown in Fig. 5. The explanations of the specific suggestions proposed in this study are as follows.

1. *Learning effectiveness (A06) improvement measures*: To strengthen and awaken students' prior knowledge associated with this project during the seminar, to guide them into connecting and deepening such knowledge, to provide relevant course resources online, to cultivate the students' ability to record the experimental process, to provide feedback and assistance in a timely manner, and to provide teaching with individual differences if necessary, in order to improve the student's required skills.
2. *Learning attitude (B08 and B11) improvement measures*: To analyze the connection between this project and actual conditions and the importance in a traditional class to trigger the

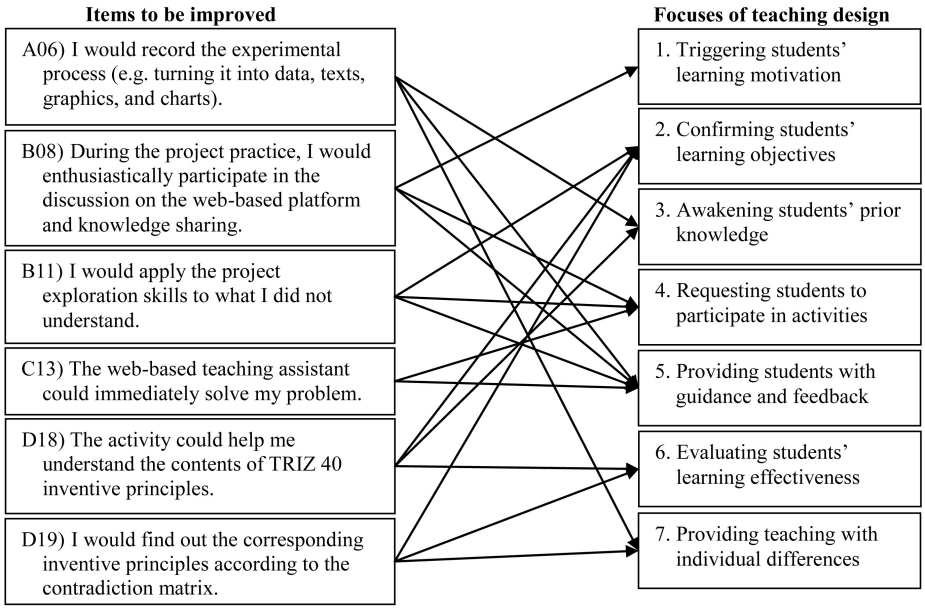


Fig. 5. Correlation diagram of teaching design focuses and items to be improved.

motivation of the students for learning, to inform them of the main learning objectives, and to use an online feedback mechanism to encourage them to enthusiastically participate in online discussion activities and knowledge sharing in order to enable them to apply project exploration skills to what they do not understand and to establish an accurate learning attitude.

3. *Learning platform (C13) improvement measures*: To collect the statistics on popular hours of platform discussion activities and to use the reminder function of the learning platform to increase the instantaneity of the teaching assistant' feedback consultation to strengthen the function of the web-based teaching assistant to instantaneously solve the problems encountered by the students.
4. *TRIZ creative learning effectiveness (D18 and D19) improvement measures*: To enable students to clearly understand the learning objective of this project, to use the connection of prior knowledge and platform learning resources to enable students to easily understand the contents of the TRIZ 40 inventive principles, and to enable them to learn to use the contradiction matrix to find out corresponding inventive principles through learning effectiveness evaluation, to provide teaching with individual differences if necessary to improve students' creative thinking ability.

To summarize the above, this study found out the items to be improved in the teaching model that was newly designed in this study, and provided the feedback to teaching design focuses to re-review and analyze the mutual correlation and develop specific measures to improve the teaching model, in order to further achieve the pre-established teaching objective of this study.

5. Conclusion and suggestions

According to the purposes of the research, the conclusions and suggestions of this study are described as follows, based on comprehensive analysis and discussion.

5.1 Conclusions

This study aimed to develop a feasible instructional model of blended TRIZ creative learning based on a literature review and summary. The conclusions are: (1) blended TRIZ creative learning had a significantly positive effect on the learning effectiveness of students. That is, the teaching of "blended TRIZ creative learning" enabled students to fully and actively apply relevant knowledge and bring their creativity into full play to complete works; (2) blended TRIZ creative learning had a significantly positive effect on students' learning attitudes. The students' learning intentions were developed through the guidance of teachers and activities. Their learning attitude was enhanced and they were able to actively collect and analyze data to further find out about problem-solving methods; (3) the application of the blended TRIZ creative learning could speed up students' knowledge learning and sharing, as well as the effective application of TRIZ to the innovation of project works, to further improve their creative thinking ability; (4) the application of TRIZ to students' learning the ability to think creatively could develop their potential for creative thinking and further improve their creative thinking ability; (5) the verification mechanism could help to understand the distribution of the students' agreement with the newly introduced teaching model. Students were positive and affirmative about four aspects: learning effectiveness, learning attitude, learning platform application, and TRIZ creative learning; and (6) the verification mechanism was beneficial to the improvement and progress of the marginal utility of the teaching model.

5.2 Suggestions

Based on the findings of the study, some suggestions are provided as follows: (1) schools should adopt the blended TRIZ instructional model to inspire students' intrinsic learning interests, cultivate students' pleasure in innovation, and enhance students' creative ability; (2) teachers should pursue advancement to enhance professional knowledge in TRIZ, become familiar with the blended TRIZ creative instruction model, and enhance the counselling role of teachers; and (3) a long-term follow-up study should be conducted to further investigate students' learning effectiveness, learning attitude, and learning motivation as an important reference for future promotion of creative teaching.

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