

Training Method of Innovation Ability of "New Engineering" Integrating TRIZ Theory

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Abstract—On the basis of TRIZ innovation theory, this paper makes a useful exploration on the training method of innovation ability of "new engineering". This method integrates TRIZ engineering innovation concept, starts from teaching content, engineering practice, ability training and other aspects, cultivates students' innovative thinking mode, and strengthens students' ability to solve engineering problems with innovative methods. In the teaching process of "Double Creativity" course, this method plays the leading role of TRIZ theoretical tools and methods. It organically integrates TRIZ problem solving mode, inventive principle and evolutionary theory into the whole teaching process of "new engineering". Through the teaching practice of "General Design and Innovative Design Method", it shows that the "new engineering" Double Creativity Course, which integrates TRIZ innovative ideas, effectively improves teaching. The innovative consciousness and ability of students ensure the continuity and efficiency in the process of expanding and cultivating students' professional ability.

Keywords—integration; TRIZ theory; problem solving model; evolutionary theory; segmentation principle; innovation ability; training

I. INTRODUCTION

At present, the state promotes innovation driven development and implements major strategies such as "one belt and one road", "made in China 2025" and "Internet +". With the vigorous development of the new economy represented by new technologies, new formats, new modes and new industries, higher requirements for engineering science and technology personnel have been put forward. It is urgent to accelerate the reform and innovation of engineering education. In order to adapt to the new round of scientific and technological revolution and industrial transformation and support service innovation-driven development, professional innovation and entrepreneurship education needs to train students' innovative thinking and practice throughout the whole teaching process, establish a systematic "new engineering" education and teaching process, and cultivate talents' innovative ability.

Against the background of "new engineering" education in colleges and universities, TRIZ theory, as a systematic innovation method, plays an important role in training innovative talents and improving students' innovative

thinking. Aiming at specific engineering problems, TRIZ engineering innovation theory and method, with its unique innovative thinking, can effectively solve the key technical problems in engineering innovation design, and its application effect is particularly prominent. The core idea of "new engineering" lies in inheritance and innovation, cross and integration, coordination and sharing. Then, whether it has a deep connection with the "new engineering" and "double creation" education? How to make use of the engineering innovation advantages of TRIZ theory to improve the teaching practice of specialized courses and effectively enhance the engineering practice innovation ability of students?

In the exploration and practice of the integration of TRIZ engineering practice theory and professional innovation teaching, many experts and scholars at home and abroad had made systematic analysis and Research on improving the teaching of TRIZ engineering practice theory. Victor Berdonosov et al. [1] proposed the teaching opportunity of Triz, which enabled the concept of Triz evolutionary method to be implemented in the field of education. At the super system level, TRIZ teaching system is mainly about creative imagination of teaching, especially in the field of TRIZ, namely the development of creative imagination. Pavel Livotov et al. [2] put forward that at the highest level, TRIZ teaching method can be applied to realize TRIZ evolutionary method in the field of education. A method of measuring educational efficiency is introduced and compared. Studying and analyzing learning experience, identifying the factors that affect students' ability to innovate and solve problems, and emphasizing the main factors that students are facing difficulties in the curriculum. Pascal Sire et al. [3] noticed that a new assessment, based on the contradictory parameters of the "two-dimensional radar", explored the key factors of success, the next steps and a series of issues related to the implied actors: teachers and students, as well as the education system, highlighting students' creativity. In view of the fact that there are fewer software nodes, more students and difficulties in computer experiment in teaching, Through the development of computer-aided system of TRIZ invention principle, Liu Xuntao et al. [4] improved the project teaching method and examination mode under TRIZ theory, integrate experiment with theory teaching, cultivate students' self-learning ability, scientific thinking ability and improve students' comprehensive quality. Zhang Mingqin et

al. [5] showed that, starting from the training objective of innovative talents, using the teaching system method guided by TRIZ theory, the construction of "multi-level, modular and menu-based" TRIZ theoretical teaching system can provide strong support for the training objective of innovative talents. Based on the experimental teaching research of multi-level mechanical principle of TRIZ theory, Jiangfan, etc. [6] discussed the teaching content, teaching methods, teaching means and teaching evaluation of TRIZ theory in many aspects, and comprehensively improves students' innovative ability. Thus, strengthening the practical guiding significance of TRIZ engineering theory to innovative teaching, establishing a omnidirectional and Matrix innovative teaching mode of engineering specialty with the guidance of innovative ability output, can fully enhance the cultivation of innovative ability of courses, strengthen students' innovative consciousness and help students improve their innovative ability.

Therefore, this paper will focus on the integration of TRIZ engineering theory and professional teaching, use TRIZ engineering theory to guide teaching, and explore the teaching methods and application ways to enhance students' innovation and entrepreneurship awareness and professional learning ability.

II. INTEGRATED TEACHING MODE

To improve the relevance of innovative TRIZ theory in the teaching of "new engineering", break through the limitation of focusing only on knowledge and experience accumulation in the past, start with the crux, change the traditional teaching methods, and establish the "new engineering" TRIZ teaching problem-solving model. Because of the increasing demand for innovation, in order to meet the requirements of absorbing, mastering knowledge and cultivating students' innovative ability, the effective integration of innovative methods and curriculum teaching can highlight the innovative content of "new engineering" curriculum teaching and increase the innovative connotation of curriculum teaching.

TRIZ (Teoriya Resheniya Izobreatatelskikh Zadatch) is an innovative theoretical system. It is a systematic innovative methodology that guides people to invent and solve engineering problems after analyzing and refining 2.5 million high-level invention patents by G. S. Alt shuller and his research team. In order to ensure the continuous and efficient expansion and development of the teaching content, the TRIZ theory on accumulation, migration, segmentation and integration should be introduced into the teaching. The innovative teaching theory of TRIZ engineering, including thinking, tools and methods, should be integrated to promote the development of students' thinking and ability in the process of knowledge transfer.

The core of TRIZ theory is not to solve problems directly, but to transform general problems into standard problems, establish problem models, and then use corresponding tools to solve them. Developed countries such as Europe, America and Russia have launched innovative education based on TRIZ theory. Most colleges and universities have offered

relevant courses. An experimental data from MIT shows that students who have learned to integrate TRIZ paradoxical problem-solving mode for three days have twice the innovative ability of other groups of students. Launching the teaching process of "problem-centered" course and establishing a new problem-oriented learning model are totally different from the thinking method of "try and fail again and again" based on the existing system. TRIZ problem-solving model is a contradictory way of thinking and is the result of systematic action and synthesis of various factors. Integrating TRIZ problem-solving model with "new engineering" teaching will help to break through the shackles of thinking, cultivate students' innovative thinking.

III. INTEGRATED TRIZ EVOLUTION THEORY

The training of engineering innovation ability of "new engineering" originates from the thinking of backward engineering education mode, obsolete education content and single teaching method in Colleges and universities. The essence of cultivating innovative thinking and improving students' innovative ability is to overcome all kinds of thinking inertia and think and solve problems from a new perspective. TRIZ theory just provides us with an effective search method and solution tool.

At present, engineering students are not lack of innovative spirit to explore and challenge authority, but they lack innovative thinking methods, and the cultivation of innovative ability is relatively lagging behind. If they want to be innovative and challenging authority, it is needed to first achieve effective "challenge". Authoritativeness is not equal to truth, but authority has its own premise. Challenging authority requires challenging thinking and innovation courage, and more importantly, an effective tool to challenge authority. Only by giving students effective judgment of different thinking nodes, thinking results and real-time measurement, can students question their views and get enlightenment in the debate and the game between experts. Only by mastering knowledge can they "turn over the classroom" and achieve unexpected learning results.

The traditional engineering solution method is first of all a wide range of problem solving and space search, but its real-time and effectiveness are not strong. The TRIZ theory of creative thinking techniques, inventive principles and various tools to solve technical contradictions are perfect problem solving systems. As the law of technological evolution points out, system evolution includes demand evolution, function evolution and system evolution, but it first meets the basic needs, and then meets the needs of intelligence and creativity. From the aspects of idealization of demand, dynamic growth of demand, coordination of demand, merger and specialization of demand, different perspectives may be constructed, and integrated solutions may be obtained through in-depth and systematic understanding of one side. The essence of TRIZ theory to cultivate innovative ability is to give challengers real-time reference test standards and provide real-time direction for problem judgment. TRIZ theory not only provides

innovative methods and tools to solve problems, but also creatively provides many ways to overcome the inertia of thinking, which is of great significance to cultivate innovative thinking.

The TRIZ theory, which integrates innovative ideas, subverts the traditional educational concepts and methods in Colleges and universities. It endows students with innovative thinking tools and methods of "challenging authority" from the perspective of innovation in new engineering, large projects and multi-disciplines, cultivates students' innovative consciousness, exercises students' innovative thinking and makes students' thinking "live". Therefore, the application of TRIZ theory can be an effective means to improve the innovative ability of "new engineering" College students.

IV. INTEGRATED TRIZ INVENTION PRINCIPLE

As the tool and method of TRIZ theory core, the invention principle mainly uses the game result of technical contradiction between the two sides of the problem, and obtains the innovative solution of technical problem through the form of innovation principle. Similarly, it is necessary to skillfully apply the idea of TRIZ theory innovation principle to classroom teaching, and divide the role, content, space and so on of teaching activities. In the course of teaching general design and innovative design methods, TRIZ related principles was applied to carry out teaching reform and practice, and achieved good results.

A. *Developing the Ability of Thinking Segmentation*

In the process of teaching basic knowledge, the innovative ability of "new engineering" engineering should always be permeated with the improvement of students' innovative consciousness and cultivation of creative thinking. College students' innovative ability includes their ability to learn, to find problems, to put forward solutions to problems, and to practice their plans. The cultivation of innovative ability must run through the whole process of college students' cultivation.

In top-level design such as personnel training program and curriculum system, it is needed to pay attention to the construction of the system of cultivating students' innovative ability. Under the systematic overall design, it is necessary to shape students' innovative quality, cultivate students' thinking segmentation ability, and achieve the rational division of key nodes. Therefore, through the cultivation of innovative thinking, cultivate students' ability to separate knowledge points of concept, viewpoint and creativity, so that students can learn to think with new methods and perspectives, and put forward unique solutions. Enriching students' innovative knowledge and enhancing students' innovative practical skills are effectively combined.

1) Cultivating students' thirst for knowledge: The division principle of TRIZ theory, or the separation principle, is the No.1 Principle in TRIZ theory. The principle of segmentation can be divided into three main aspects:

- Dividing objects into independent parts.

- Make the object dis-assemble.
- Increase the degree of object segmentation.

Using the division principle of TRIZ's invention and creation principle, reasonable innovation thinking division can stimulate students' curiosity, cultivate students' curiosity and stimulate students' curiosity.

Fully mobilizing the enthusiasm and initiative of learning is an important condition for cultivating and developing innovative ability. Learning motivation and thirst for knowledge depend on certain situations. There are two kinds of teaching situations: injection and heuristic. The former is that students rely entirely on teachers' explanations to learn passively, while the latter is to create a problem situation, mobilize the enthusiasm and consciousness of students' thinking activities, and let students participate in classroom discussions, from teachers' speeches alone to teachers' and students' co-construction of classes, so that the learning process becomes a proactive exploration process.

At the same time, open topics are set up according to the content of the course, and around the topics, students are guided to conduct research, analysis, discussion, decision-making and evaluation so as to cultivate students' thinking mode of solving problems systematically. For example, "Designing an object requires energy conservation and environmental protection". On the basis of defining the topic, through the division of design concepts, students will be given a broader and freer thinking space, and their innovative consciousness and creative thinking ability will be improved.

2) Introducing innovative thinking into the classroom:

In the classroom, it is needed to guide students to cultivate innovative thinking consciousness and learn to use innovative tools. There are many kinds of innovative thinking, such as divergent thinking, reverse thinking, intuitive thinking...

a) Developing divergent thinking method: Divergent thinking, also known as divergent thinking, refers to thinking from a goal, along a variety of different ways to think and explore a variety of answers. Many psychologists believe that divergent thinking is the most important characteristic of creative thinking and one of the main indicators of innovative ability. In the teaching process, it is necessary to choose questions with multiple answers, encourage students to explore and think from different angles, guide students' thinking fluency, flexibility and independence, so as to train students' divergent thinking.

b) Developing intuitive thinking method: Intuitive thinking is an active expression of creative thinking. It is not only the forerunner of invention and creation, but also the fruit of sudden birth after puzzlement. It occupies an important position in the process of creation and invention. To develop intuitive thinking, first of all, it is needed to guide students to practice boldly and bravely. Because intuitive thinking is based on innumerable practices, intuitive thinking itself is the product of practice. Secondly, it is necessary to carefully grasp the basic theory and system

of a discipline, which is the basis of developing intuitive thinking. Because intuitive thinking is always based on the familiarity with knowledge and its structure. At the same time, students should be encouraged to speculate and guess on the problems, to make "bold assumptions, careful verification" on scientific problems, and to cultivate good intuitive "habits".

c) Introducing the contradictory thinking method: TRIZ means the theory of solving the problem of invention. It successfully reveals the law and principle of the inherent contradiction of invention. Its goal is to completely solve the contradiction, so as to obtain the ultimate ideal solution and the optimal innovation method. Therefore, TRIZ, as a set of mature theory of creativity, should be applied to the teaching and training of creativity through effective curriculum design.

TRIZ theory is extensive and profound, with 40 inventive principles. These contradictory thinking principles include several specific innovative methods. Among them, innovative thinking methods such as multi-screen method, STC operator method, goldfish method, dwarf method, and ultimate ideal solution can help designers diverge their thinking quickly, play an important role in finding resources and changing their thinking, and improve the efficiency of innovative design of institutions. It can be used in all aspects of mechanism design.

B. Classroom Teaching of Role Segmentation

Taking students as the center, using the division principle of TRIZ invention and creation principle, the classroom teaching role of classroom teaching activities is divided and switched. Through role exchange and experiential teaching, the ability of innovation and teamwork is enhanced in "learning by doing, learning by doing". The main body of teaching activities should be students. Classroom teaching should not be a teacher's "one-man play". Teachers' dominance and students' subjectivity should be corrected, with students' autonomous learning as the main body and teachers' puzzlement as the supplement. The responsibility of students' learning engineering, science and management should be transferred from teachers to students, so that students can participate in the learning process more actively. At the same time, students should be encouraged to actively participate in various projects and competitions, so that students can learn to "learn by doing", so as to form a benign interaction between theoretical learning and engineering application.

1) Group cooperation to enhance team cooperation ability: In the teaching process, real projects can be set up. The staffing of the simulation project company divides the students into several groups, and the group members discuss and complete the tasks together. This way can guide students to conduct research, analysis, discussion, decision-making and evaluation around the project, and cultivate students' thinking mode of solving problems systematically. In the process of discussion, students can actively interact, work division and cooperation, and inspire each other, so as

to mobilize students' enthusiasm to participate in solving problems, and cultivate students' innovative ability and team cooperation ability.

If students can find and solve problems in practical projects by using innovative methods of mathematics, physics, engineering and TRIZ, they will be able to stimulate their learning motivation to the greatest extent. Because it is not the teachers who "tell" them, but they themselves, through participating in the project, to the greatest extent, apply their knowledge to the design of a product, tool or a combination of theory and practice. At the same time, it can give full play to its potential in the process of participating in the project practice, and comprehensively improve its comprehensive quality and innovation ability.

2) Improving the actual combat ability: Simple theoretical study cannot enable students to grasp the course content comprehensively and efficiently. The purpose of learning innovative methods such as TRIZ theory is to invent and create creative products and improve their innovative ability. Therefore, from the beginning of the freshman year, students should be encouraged to participate in all kinds of competitions in our school, the whole country and even the world, such as creative competitions, production competitions, patent competitions and so on. Competition can effectively mobilize students' enthusiasm, open up their thinking, cultivate students' practical ability, let students get experience in the process of actual combat, test their knowledge, explore the problems encountered, and then enhance the ability of systematic thinking, innovative design and teamwork.

C. Separation and Integration of Theory and Practice

Using the principle of space division in TRIZ division principle, the teaching place is divided from space, and the classroom is extended to real practice places such as enterprises, design companies and cooperative organizations, so as to deepen students' understanding of theoretical knowledge and perfect combination of professional knowledge and practical ability. Dewey, an American educator, believes that modern education should break through the traditional model of classroom, book and teacher-centered education and attach importance to the cultivation of students' personal experience and ability. Education should be regarded as a continuous reorganization or transformation of experience. Knowledge lacking practical experience cannot be regarded as knowledge in the true sense. Similarly, education lacking practical experience cannot be regarded as knowledge. It is regarded as education in its true sense. Waterloo University has successfully validated this theory and trained talents with unique qualifications and comprehensive qualities. The practice of cooperative education at Waterloo University has proved that higher education cannot and should not be confined to the classroom. If academic knowledge is experimented and experienced, learning will become more effective and the value of education will become more prominent.

Therefore, it is necessary to draw lessons from: regularly let students to cooperate institutions to participate in full-

time work practice, time is not less than 30% of classroom learning. Cooperative organizations should supervise students' development and progress, alternately integrate students' classroom learning with relevant work practice, and let students improve their creative ability by solving practical problems. During this period, students participate in the real engineering practice, will experience the misguided distress and excitement after solving problems. At the same time, work practice is carried out outside the school. It is precisely because of the effective separation and integration of theory and practice places, and also the excellent opportunity for students to gain social experience. Therefore, the students will benefit a lot from the practical engineering teaching.

V. ACHIEVEMENTS

A. Improvement Contrast

This paper applies TRIZ theory and method to the teaching of general design and innovative design course, uses various thinking techniques and innovative tools synthetically, establishes a stratified test of students' innovative ability before, during and after the course selection, analyses the derivative process of TRIZ theory and method in teaching, and traces the survey data of single index of competition results. A group sampling of 100 people and 10 people and 1 group is adopted. The average lifting analysis is shown in "Table I".

From "Table I", it can be seen that the average scores of students' abilities have been greatly improved by using TRIZ theory in teaching practice. Especially, students' innovative thinking and innovative consciousness have been significantly improved. The average degree of improvement has been raised from 0.7 to 7.57 before choosing courses, which shows that TRIZ theory has significant effect in improving students' innovative ability.

TABLE I. CONTRAST TABLE OF INNOVATIVE ABILITY

Scheme Design Ability	Number of programs			
	Before selection	in the Course	After selection	Mean
Design and Analysis Ability	1.5	2.56	9.06	4.37
The ability to design reasonable	1.5	3.39	9.19	4.69
The capability of the overall solution	1.2	3.41	7.06	3.89
Optimizing and Evaluating Ability	0	3.62	8.82	4.15
Ability of Integrating Innovative Thinking	0	4.00	7.13	3.71
Competition results	0	2.46	4.17	2.21
mean value	0.7	3.24	7.57	3.84

B. Dynamic Evaluation

Using the platform of double-creation curriculum education, introducing TRIZ theory and other innovative thinking methods, encouraging students to learn by doing,

actively participate in various projects and competitions; students' innovative ability has greatly improved. Taking the year of 2018 as an example, the students' works were successively won in the 6th "TRIZ" National College Student Innovation Competition, the 7th National Marine Vehicle Design and Manufacture Competition, the 11th National College Student Energy Conservation and Emission Reduction Social Practice Competition, and the 11th International Aquatic Robot Competition.

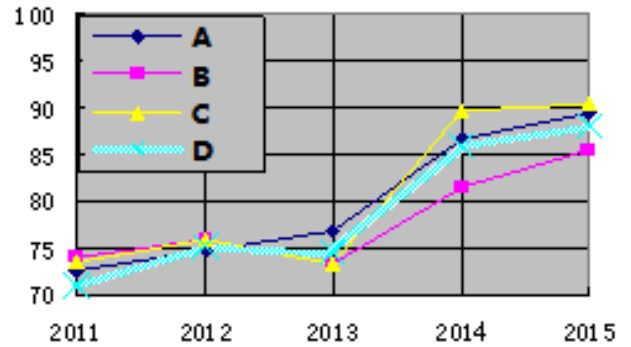


Fig. 1. Simple sampling of course utilization rate.

The dynamic evaluation uses the GPA statistical method to quantify the experimental results, such as the utilization rate of courses and the number of selected courses, and carries out comparative analysis to determine the causal relationship between the overall curriculum teaching, curriculum design, curriculum implementation, curriculum function dimension and educational phenomena. In the course of general design method and innovative design method, a simple sampling chart of curriculum utilization rate and a histogram of innovative ability are established. The comparative analysis results of different teaching modes are shown in "Fig. 1" and "Fig. 2" (TRIZ theory model was not used in the previous three years).

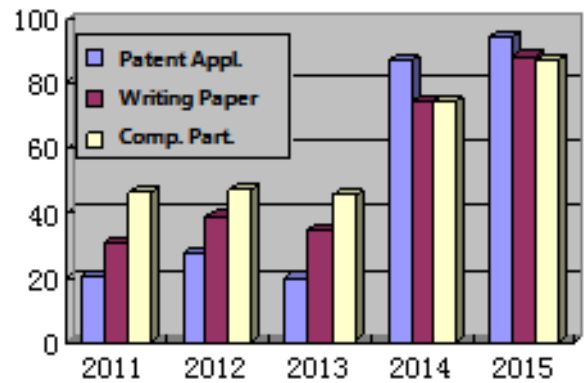


Fig. 2. Innovation ability histogram.

In five consecutive years, 15% of the samples were sampled to track and analyze the effect of online evaluation courses for mechanical engineering students after graduation. Data collection, random sampling, continuous tracking and statistical analysis were carried out for the utilization rate of the following three professional courses.

TABLE II. THE EFFECT OF INTEGRATING EDUCATION MODEL

Mixed educ.	Annual	Written result	Net result	Participation Achievements (Comprehensive rate (%))		
				Patent Appl.	Writing Paper	Comp.Pa rt.
No	2011	83.1	85	20.4	30.6	45.9
	2012	81.4	84	27.4	38.6	46.9
	2013	82.5	88	20.0	34.6	45.0
Yes	2014	91.1	95	87.0	74.0	74.0
	2015	92.2	96	94.0	88.0	87.0

From the analysis of the effects of the integrated and non-integrated education modes, it can be seen that: the utilization ratio of subjects in learning courses; the ratio of innovative ability effect and other three indicators, after adopting the theoretical mode of integrated innovation training, the comprehensive achievement ratio has been significantly improved, and the integrated innovation education has achieved a certain satisfactory effect, which ensures the continuity and high-efficiency expansion of the curriculum design content. The numerical value is shown in "Table II".

VI. CONCLUSION

The organic integration of TRIZ theoretical model and "new engineering" teaching is an important measure for universities to carry out innovative education and deepen the reform of Engineering education. It provides a good method and way for training innovative skilled talents.

In the teaching process of "new engineering", the integration of TRIZ innovation theory's problem-solving mode, invention principle, basic law, various innovation methods and double-innovation curriculum can effectively cultivate students' innovation consciousness and spirit, and promote students' innovation and entrepreneurship ability.

Therefore, it is of great significance and far-reaching influence on the cultivation of innovative talents for college students to promote the concept of "new engineering" and "double innovation" curriculum construction and to integrate TRIZ theory innovation methods and techniques with specialty in the teaching of specialized courses and personnel training mode in Colleges and universities.

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