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TRIZ，The Development And Dissemination In Industries In China

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Abstract: There are some obstacles in the process product innovations in industrial companies. It is important to develop innovative methods and disseminate them to the companies in order to improve the competitive abilities. This paper firstly identifies the obstacles in innovation processes and then introduces C-TRIZ that is development of TRIZ. MEOTM which is a mass-engineer oriented training model is then constructed to support the dissemination of C-TRIZ/TRIZ. Last some output of training classes are demonstrated. The study shows that the market of C-TRIZ/TRIZ dissemination in industrial is becoming big and big in China.

Key Words: TRIZ, C-TRIZ, Dissemination, innovative engineers, Training classes

1. Introduction

Innovation which is the implementation of new ideas is viewed as the key to both sustaining a competitive advantage and the lifeblood or the best hope for the growth of companies in any nation[1]. In China now many companies proactively introduce creativity techniques such as TRIZ into R&D activities to improve their innovative capabilities by training engineers. The governments, universities, companies are all together to carry out the introducing process. Our center was selected as one of the major institutions for the training program[2].

One of objectives of the training program is to train engineers for various industries and make them become innovative. In the literature[3], inventors are classified into five categories related to the innovation process, namely entrepreneurs with technology, industry-specific inventors, professional inventors, grantsmen, and inveterate inventors. We define that an innovative engineer is an industry-specific inventor, who has specific technical improvements for product designs or processes in their workplaces.

TRIZ[4-5], theory of inventive problem solving, developed by Altshuller, is as becoming increasingly popular knowledge system for creativity and innovation which is being transferred to the companies in the world. Kamal *et al.* [6] study the impact of TRIZ training on creativity and innovation of engineers in companies, and indicate that participation in TRIZ training led to short-term improvements in both the creative problem solving skills and motivation to innovate, and these are associated with longer term improvements in their idea suggestion in the workplace. Nakagawa[7] shows the experiences training engineers successfully to solve real unsolved problems using TRIZ in Japan. Lilly [8] state that training of TRIZ influence the two stages of innovation: idea generation and idea implementation. Hernandez et al [9] show that TRIZ does improve the ideation effectiveness metrics novelty and variety while slightly reducing quantity when compared to a control group using ad hoc ideation methods for university students. Through a survey, Imoh *et al.* [10] conclude that the application of TRIZ leads to more effective inventive teamwork, faster ideation, foreseeing how technical systems and technologies develop, but there are some challenges associated with TRIZ, and understanding TRIZ an "inordinate time requirement".

Our target of training classes is to train the engineers working in industrial companies and to improve their creative and innovative abilities. The engineers are different from lonesome inventors in society or the students of universities because the inventions from the classes are related the innovation processes applied in companies and their working places tightly. According to the characteristic this study presents obstacles of innovations in industrial companies, the development of TRIZ, training process model and results from the engineers who have attended the classes.

2. The obstacles of innovation in industrial companies

The typical innovation process in industrial companies is divided into three stages: fuzzy front end (FFE), new product development (NPD), and commercialization [11] as shown in Figure 1, which is also suitable for the companies in China. The fuzzy front end in the figure is considered as the first stage of the innovation process and covers the sub-processes from the opportunity identification, opportunity analysis, idea generation, idea selection, and concept definition [11]. The outputs of FFE are the ideas evaluated and as the input of NPD. In the NPD stage, the ideas from FFE are transformed into products. There are two sub-processes in NPD, design and manufacturing. In the design process there are four sub-processes, namely design specification, conceptual design, embodiment design, and detailed design [12]. In the manufacturing process, the first is to design the process and then actual manufacturing. The commercialization is the last stage, in which the products are put into markets. The engineers in workplaces are responsible for the different works which is also shown in the figure. The environments for fuzzy front end, new product development, commercialization and the sub-processes are the workplaces, where the engineers are supposed to find new or unsolved problems.

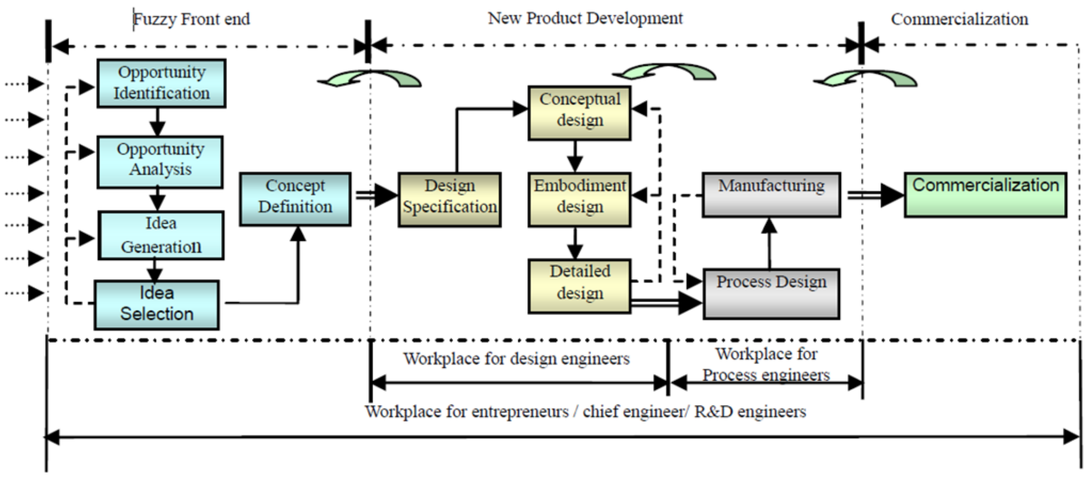

Figure 1 An innovation process and workplaces of engineers in companies

The engineers to attend our training classes must identify inventive problems from their workplaces which is a condition to follow the classes. From the engineers' typical cases in past years we find that the inventive problems may come from every phase of innovation processes as shown in figure 2 [13].

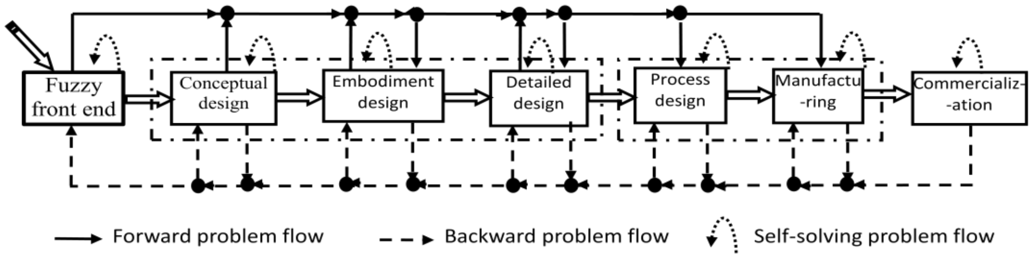

Figure 2 Problem flows in an innovation process

We divide all these problems into three types: forward flow, backward flow, and self-solving flow. A forward flow problem is one that should be solved in the next or a following phase. For example, it is that kind of problem in which the problem identified in embodiment design should be solved in process design. A backward flow problem should be solved in the upstream phases. For example, that the problem found in the process design should be solved in conceptual design is that kind of problem. That a problem in a phase must be solved in this phase is a self-solving problem. That the problem found in the conceptual design phase should be solved in this phase is a case. All these problems are divided into three types which are obstacles for fuzzy front end, design and manufacturing respectively. Table 1 shows the details of the obstacles.

Table 1 Obstacles in innovation process

Type	Name	Meaning
1	Obstacle of fuzzy front end	■ There are no suitable methods to be applied to generate only a few high quality ideas. ■ There are no suitable methods to predict the future needs or markets. ■ ...
2	Obstacle of design	■ There are no suitable methods to be applied to generate only a few high quality concepts. ■ One or more contradictions are included in the structures or parameters in designs, which should be removed but it is difficult. ■ ...
3	Obstacle of manufacturing	■ The processes must be modified to meet the precision needs but there is no methods. ■ The cost of a specific process is too high to be reduced but there is no methods. ■ ...

The main task for engineers is to identify inventive problems and solve them to form inventions and possible innovations. At first the engineers must find a type obstacle and then inventive problems. Generally it is not difficult for an engineer to find an obstacle by experiences of years working in a workplace. But it is not easy for them to identify an inventive problem from the obstacle let alone to solve it to form an invention, especially for the innovations which are urgently needed by the companies.

In the field of management of technology(MOT) the innovations are divided into several types such as radical innovation [14] and disruptive innovation[15-16]. Managers of industrial companies know the types because they always study management theories from several routes in China. When we have discussion about the innovations with them they think that radical or disruptive innovations are most important for their development of the companies. But they have no idea how to make the two types of innovations be happen. Chinese government also pushes the implement of "breakthrough innovation" in industrial companies. In the home page of GEN3 PARTNERS [17] there are some information for the breakthrough innovation. But there are almost no innovation methods for engineers which can directly be applied to the two types of innovations now in literatures.

There are new TRIZ methodologies after classical TRIZ, such as I-TRIZ[18], xTRIZ [19]. They do help engineers and managers to find and solve more inventive problems. But they are all not directly been applied into the development of radical and disruptive technologies and innovations. The innovation methodologies which are radical or disruptive innovation oriented are the high lands for the researchers of creative and innovative methods, at least in China.

3. C-TRIZ

In order to meet the needs to train engineers in China we have been developing C-TRIZ as shown in figure 3 which is based on the classical TRIZ and has absorbed many ideas from TRIZ and MOT communities. It is different from other kind of methodologies in which some methods are radical or disruptive-oriented once. InventionTool which is a computer-aided innovation software (CAI) developed in this center is a supporting sub-system. MEOTM which is a mass-engineer oriented training model is as other sub-system to support C-TRIZ. C-TRIZ, CAI and MEOTM all form the C-TRIZ system.

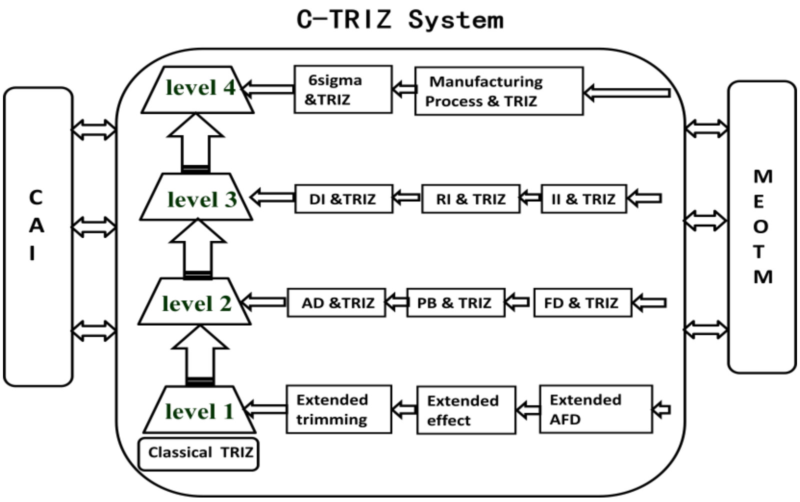

Figure 3. C-TRIZ and its supporting system

There are four levels in C-TRIZ. The Level 1 is the classical TRIZ and its extensions. Level 2, Level 3 and Level 4 are integrated methods, fusion methods and super methods respectively. The most important level is Level 3 in which the methods for radical, incremental and disruptive innovations are being developed and integrated. Every level is independent with each other but the classical TRIZ is the base of all level. Figure 4 shows the detailed information of each level.

Table 2 4 Level methods in C-TRIZ with research cases in this center

Level	Method types	Study on this type
1	Extended methods	The methods to extend the classical TRIZ Cases: 1) Yue et al[20] develop a multi-level, multi-angle trimming method set which is the integration of the existing trimming methods with the TRIZ knowledge-based problems solving principles. 2) Liu etal [21] apply multi biological effects into the process of inventions. 3) Xu and Tan[22] develop a systematic methods for failure analysis of mechanical systems based on TRIZ.
2	Integrated methods	The methods to integrate AD, PB,FD with classical TRIZ Cases: 1) Tan et al [23] give A human-oriented eight-process step model for conceptual design, in which UXDs are the driving force for generating new ideas. 2) Zhang et al [24] apply design-centric complexity to define contradictions and TRIZ to solve them. 3) Cao and Tan [25] develop a systematic method for function design.
3	Fusion Methods	Innovative Goal-oriented methods Cases: 1) Guo et al[26], show a quantitative model to evaluate the disruptive innovative designs. 2) Sun et al[27], set up a method for roadmapping mutational innovations. 3) Tan and Sun [28] develop a systematic method for developing disruptive technologies based on TRIZ.
4	Super Methods	Wide application-oriented methods Cases: 1) Chen and Tan [29] develop systematic method to connect TRIZ and six-sigma. 2) Jiang et al[30] set up a process model for product innovation which is driven by FFE and its base is TRIZ. 3) Guo et al[31] show a analysis method for needs that is driven by design.

Ten enabling technologies for innovation are being developed now as a part of C-TRIZ.

Function design，disruptive innovation process, radical innovation process, patent around design, integration design process etc are part of them. Every enabling technology is consisted of process models and concept knowledge. The process models connect concept knowledge together, which are applied as a whole in an innovative process.

4. Dissemination Model of C-TRIZ/ TRIZ

For dissemination of TRIZ and C-TRIZ the governments including local governments and intermediary agencies are necessary in the situation of China. The local government for a region has big impact to the companies located inside the region. As integration of enabling technologies for innovation the TRIZ and C-TRIZ should be disseminated into companies by some routes. The main rout now in China is from source institutions to companies through the bridge of local government and intermediary agencies, as shown in figure 4.

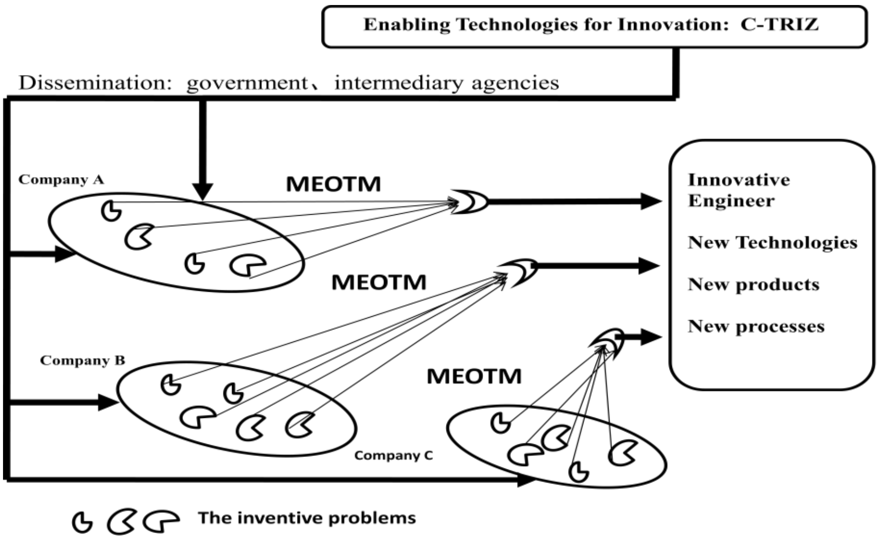

Figure 4 One rout to disseminate C-TRIZ/TRIZ to companies

The source institutions are universities, research agencies or consultancies which have ability to provide high quality training courses of TRIZ and C-TRIZ. The institutions which are regularly work as trainers are selected by a big market. Our center is a kind of the source institute for providing TRIZ and C-TRIZ training courses which is evaluated and selected by the training market in China.

MEOTM in the figure 5 developed in this center is a mass-engineer oriented training model (MEOTM) for guiding the training process. The process includes seven steps and the process is interactive with the main innovation process which are currently applied in companies. The engineers to attend the classes must connect the training contents to the R&D or innovation processes of their companies in order to find or construct inventive problems.

There are four main parts in figure 5, an innovation process, a training process, an interface between the two parts, and the companies to join the program. The innovation process includes fuzzy front end, new product development and commercialization. The training process are seven steps which are selecting companies, selecting engineers, training stage-1, finding problems, training stage-2, finding solutions and summing up. In the middle of the two parts is an interface, which includes opportunities and solutions for innovation, also the implicated problems. The companies selected to attend the class may be one or more at same time. A class lasts 6 to 15 months accordingly in practices. Table 3 shows the detailed activities of each step in the training process.

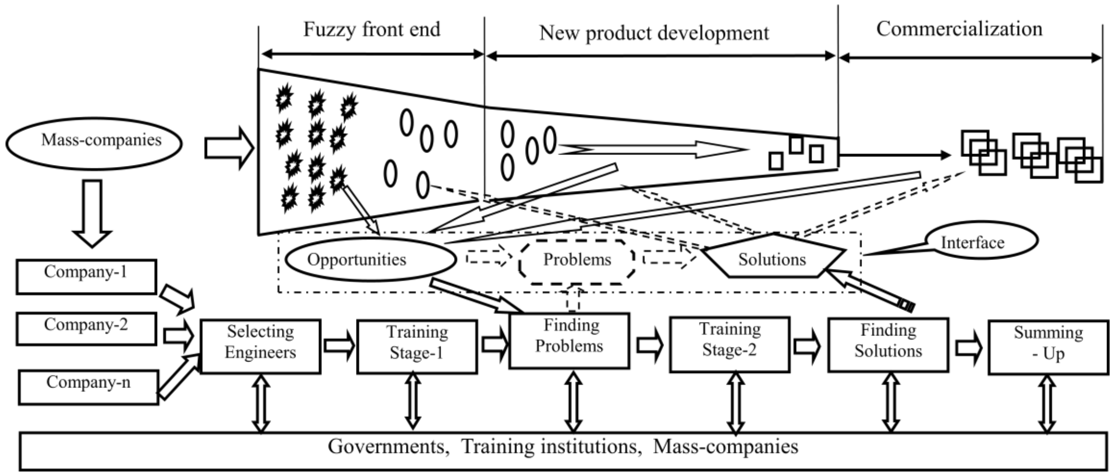

Figure 5 mass-engineer oriented training model

Table 3 The training steps and activities

Step	Name	Activities
1	Selecting companies	The companies to attend the class are selected. ● Some institution of a local government, or an organizer, is responsible for the organization and selection of the companies to attend the class for a region. ● The center or organizer selects the companies directly.
2	Selecting engineers	The engineers to attend the class are selected. ● The companies selected make recommendation for a list of engineers to join the class. ● The organizer of a class makes is the final selection of the engineers.
3	Training stage-1	The teacher team in the center gives lessons to the engineers. ● The basic concepts, methods of TRIZ will be taught. ● Many cases applying these methods are also demonstrated.
4	Finding a problem	Each engineer of the class must identify an inventive problem from his or her workplace. ● Engineer finds an inventive problem from a stage of innovation processes of their companies. ● Engineer constructs an inventive problem for the situation of his/her workplace.
5	Training stage-2	The teacher team in the center gives lessons to the engineers again. ● The systematic methods, such as ARIZ, are the contents. ● A systematic process model for finding and solving inventive problems are demonstrated.
6	Solving problem	Every engineer must solve the inventive problem and identify an invention. ● Every engineer finds new ideas. ● Every engineer develops the ideas and transform the them into at lest one

		invention.
7	Summing up	Examination and evaluation are made. ● The final oral examination is made and engineers will present their results with slides. ● An evaluation is made and a certificate is presented to some qualified engineers who are innovative.

The dissemination of TRIZ and C-TRIZ in industries relates to the creative and innovative knowledge and the needs for the current and future market as shown in figure 6. The results of the dissemination are the generation of innovative engineers, new technologies, new processes and/or some new products for companies attended.

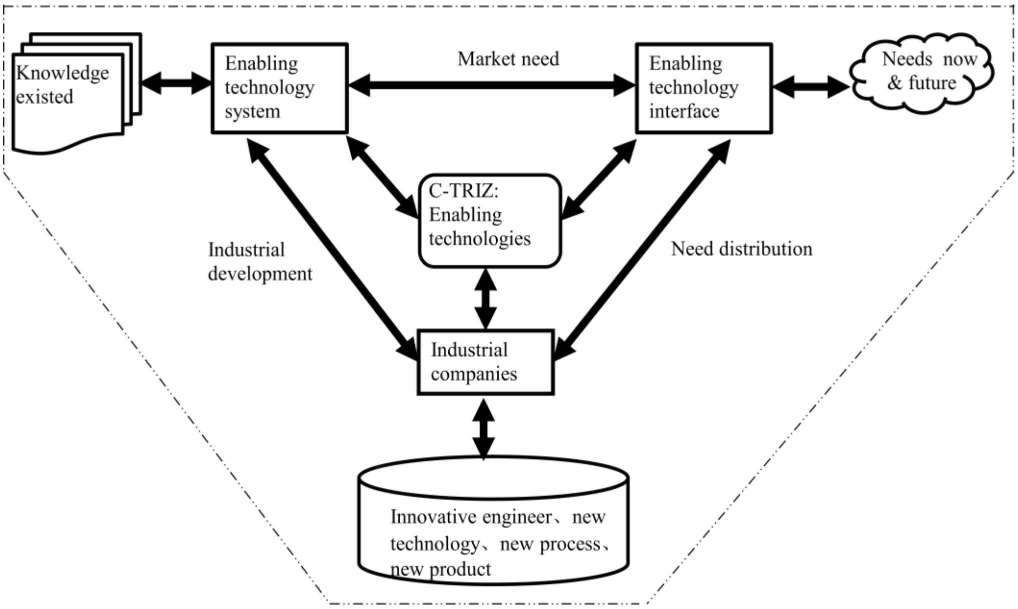

Figure 6 Dissemination Framework of TRIZ/C-TRIZ to the industries

The innovative engineers are the most important achievements for dissemination of TRIZ/C-TRIZ and new technologies, processes are accessories. Sometimes quit a few products are also flashing outputs at the end of the training classes, which are lucky events.

The managers of companies to send engineers to attend our classes pay more attention to the improvement of their creative and innovative abilities because creative and innovative professionals are the most important resources for the further development of the companies. In the training process we afford process and concept knowledge of TRIZ/C-TRIZ to engineers. Case teaching method is applied and group discussions are organized in the training process. The most important training content is that every engineer must identify an inventive problem from the innovation opportunities that the companies face and solve it to form inventions. To identify an inventive problem independently by himself or herself is a big challenge because this is the first time for them to apply the basic concepts of TRIZ or C-TRIZ to analyze and pick out the flaws from the familiar situations or environment. The observing inertia for them should be overcome first.

In order to guarantee the quality of the training processes the accessories as outputs are needed. They are the engineers' inventions which are new technologies or new processes. After the training classes the companies may invest money to develop engineers' inventions to form products and innovations.

There were some new products which were formed at the end of training classes in the past years. The engineers grasped the main problems of some old products rapidly and formed new ideas and implemented them in a few months. Also the managing team made decisions to invest money to the implement processes rapidly. As the result some new products were pushed into the market in a short time.

The training process itself should be controlled jointly by the companies in which some engineers are sent to the classes. Some managers of companies also need to make an evaluation for making decision and discussion with our team. If we assume that an evaluation or examination is a gate there should be 6 gates in the training process with a management involvement of companies, as shown in figure 7.

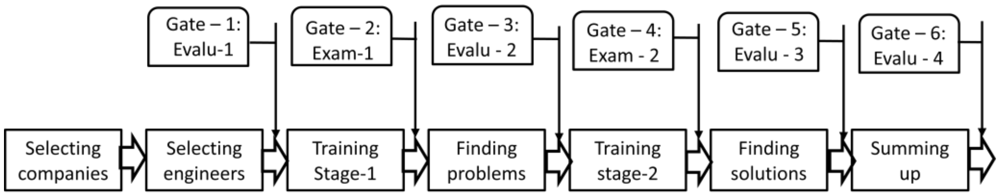

Figure 7 Training - gate system

The functions of all gates in figure 7 are as following:

Gate -1: The function is Evalu -1, in which some manager makes an evaluation about the appropriateness of every engineer selected to attend the training classes.

Gate -2: The function is Exam -1, in which the trainers make examination to evaluate the knowledge level studied for all the engineers in classes.

Gate -3: The function is Evalu -2, in which the engineers to attend the class find inventive problems, which are domain problems, and the solutions of the problems are inventions

Gate -4: The function is Exam 2, in which the trainers make examination to evaluate the knowledge level studied for all the engineers.

Gate -5: The function is Evalu -3, in which some manager and trainers make evaluations whether the problems are really solved or not and recognition that there are some opportunities for innovation or not.

Gate -6: The function is Evalu -4, in which every engineer in a class must make an open reply for his or her projects. The trainers make decisions about their level. Some manager makes decisions whether the inventions are opportunities of possible investment for following innovations of the company.

Figure 5-7 also show that the training process for innovative engineers is not independent activities from the management activities of the companies. The managers in the companies in which some engineers attend the training class should pay more attention to the steps of the process and make evaluations at proper gates. The engineers attending our training classes should always make contact with their managers to exchange information of training and find and solve right inventive problems and obtain high quality inventions effectively.

5 Dissemination C-TRIZ/ TRIZ In China

From 2013 to 2016 we have carried out 40 classes to train engineers for 721 companies which are located in 13 provinces or cities. The 3173 engineers attended the training classes. Among them 1471 did pass all the process and were certificated to be innovative engineers in this center. The 1471 engineers applied 1218 patents during the training processes and among of them 648 are patent for innovations. A part of the patents have been developed to be new products in these companies.

Figure 8 shows the relationship between the 1471 engineers who were certificated to innovative once and the regions that the engineers come from. The numbers of Hebei is the first which shows that the center servers the province first. The reason is that the university is belong to the province. The number of Tianjin is the second which shows that the center pays more attention to the city located in. The third is Beijing which is near to Tianjin.

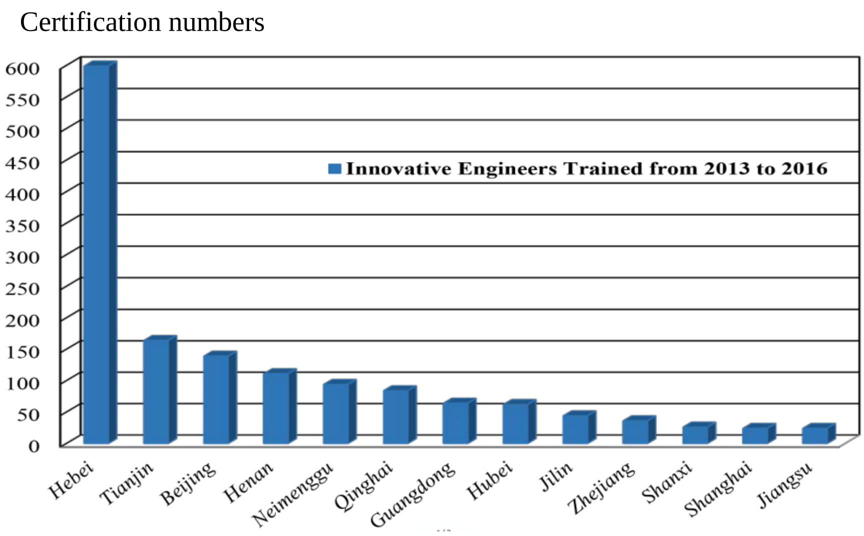

Figure 8 Certificated engineers in different regions from 2013-2016

Figure 9 shows the relationship between patent numbers applied by innovative engineers during the training processes and the regions that the engineers come from. The numbers of Hebei, Tianjin and Beijing are the first three regions. The reason is the same with that in figure 8.

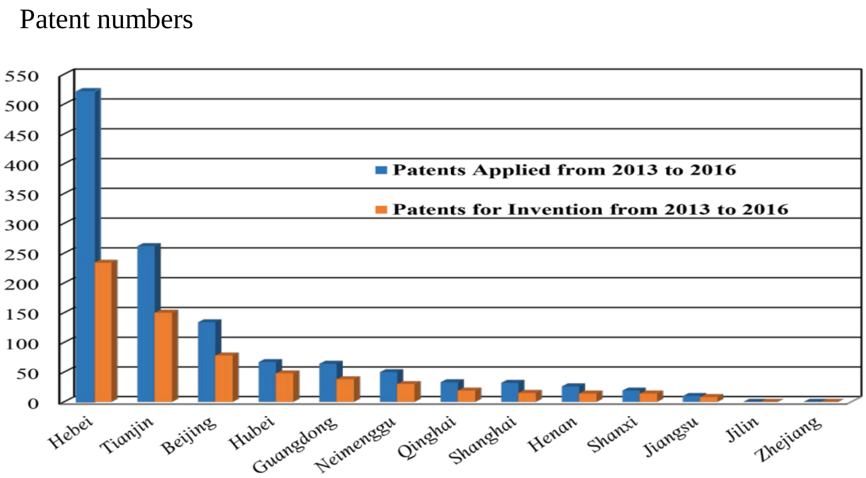

Figure 9 Patent numbers in different regions from 2013-2016

Because of the better training output our training program is developed steadily in China. Some companies directly visit this center and discuss the cooperation with my training team. Big training market is appeared.

6 Conclusions

C-TRIZ has been being developed under the guidance of innovation needs from the big market of China. MOETM is a supporting training process model for C-TRIZ/TRIZ which has a feature of mass engineer-oriented from different companies at same time and long training period. The outputs of training classes are innovative engineers, accessories and lucky events which are new technologies or processes and new products respectively and all is needed urgently in companies in China.

The general evaluation for our development of TRIZ and the dissemination activities from industries and society is a positive feedback. More industrial companies begin to pay attention to the training program and a bigger market is being formed in China. This is an opportunity to disseminate TRIZ into more companies and accelerate their development in this country.

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