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# Seven Stimuli to Identify Opportunities of Innovation: A Practice of Training Innovative Engineers and Some Findings in China

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## ABSTRACT

To transfer knowledge to companies by training engineers is directly related to identifying opportunities of innovation. This paper introduces the knowledge system of four levels and an interactive training model for innovative engineers. Training outputs of two classes as cases are analyzed in order to find some factors to affect the training activities. Seven stimuli to identify opportunities of innovation, which are implied in the knowledge system and the training process, are concluded from many face-to-face discussions with the engineers joining our classes. The application of the stimuli is also described, which should be applied in the future training process to improve the possibility to identify opportunities of innovation for innovative engineers.

**Keywords:** Training Innovative Engineers; Knowledge System; Interactive Training Model; Seven Stimuli

## 1. Introduction

Innovation, the implementation of new ideas is viewed by researchers as the key to both sustaining a competitive advantage [1] and the lifeblood or the best hope for their future growth for companies [2]. In China, the innovation capability to both leading domestic companies [3] and other companies [4] is also a key factor for their survival in facing the competition in the market. But most innovations result from a conscious, purposeful search for opportunities—within the company and the industry as well as in the larger social and intellectual environment [5]. Understanding the opportunities and their identification represents one of the core intellectual questions for creativity and innovation management [6-8].

Training or external learning for companies is directly related to identifying opportunities of innovation. Bozeman [9] shows that training as a kind of external learning is becoming more widely recognized for improvement of human resources of companies. Bauernschuster *et al.* [10] argue that if innovation is the weapon, education or, especially, training is the ammunition that renders it useful and effective. Bao *et al.* [11] find that external learning increases the opportunities of innovation for Chinese companies, which includes technical and administrative learning, learning technical knowledge or learning administrative knowledge.

In 2008, China government made a training plan to transfer the knowledge of creativity and innovation to the companies nationwide in order to increase their innovation capabilities. Our center was selected as one of the major institutions for the training program. We have carried out several classes to train the engineers from companies in the past years. The training activities are going on now.

One of objectives of the training program is to train many engineers for various industries and make them become innovative. But there is no definition for an innovative engineer in China. In the literature [12], 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. The improvements include ideations and inventions. The engineers to join the calsses should generate new ideas and push the ideas into inventions. The companies may form development teams to transform the inventions into innovations. As a result, the training becomes an activity to increase innovation capability of the companies.

In the past five years, we have carried out 20 classes. More than 150 companies from manufacturing, energy, materials, food and other industries in different regions of China joined the program. More than 500 engineers did follow the process and have been certificated to innovative engineers. Most of them have applied patents and some have developed new products which are being sold in markets now. A number of innovations of different types are emerging as a result of our training program.

Many discussions face to face with the engineers in our classes show that to identify opportunities for innovation is the most important step to follow the training classes for engineers. But we should analyze what stimulates them to identify an opportunity. This paper first presents the practice of our training process for classes. Then we make analysis for two training cases and try to locate some factors to affect training. Third, we present the seven stimuli for engineers to identify opportunities of innovation, which are the main findings from our training practices. Last, a new model of the stimuli application is outlined.

# 2. Literature Review

## 2.1. How to Identify Opportunities for Innovation

There are many studies related to the opportunity identification for innovation. Drucker [6] gives out seven key areas looking for innovation opportunities, and he argues that most innovative business ideas come from methodic analysis of these seven areas. Detienne and Chandle [8] indicate four ways in which opportunities are identified: active search, passive search, fortuitous discovery, and creation of opportunities. Koen *et al.* [13] show that formal or informal processes may be utilized for opportunity identification. Toubia [14] recommends four sources of opportunities: observational research, blue ocean strategy [15], disruptive technology [16] and lead users. The view of David [17] is that various tools and methods help to identify existing opportunities: lateral thinking; metaphoric thinking; positive thinking; association trigger; capturing and interpreting dreams. Robert [18] finds that pattern recognition is used for opportunity identifycation. Gregoire [19] explores that variations in the superficial and structural similarities characterized new technology-market combinations systematically influence the formation of opportunities. The studies show that there is some ways or processes for identifying opportunities of innovation, but the research in this area is going on.

## 2.2. Training and Identifying Opportunities

The research studies in the literatures [20,21] establish a positive linkage between training and innovation in companies. Vichet [22] reveals that majority of the training participants perceive that training contributed moderately, highly, or very highly to the company's innovation. Frazis *et al.* [23] analyze the data obtained from US companies and find that companies with more innovative workplace practices have a tendency to offer more training. Steven [24] finds that team training accelerates the pace of change in GE. Christian and Uschi [25] examine some companies in German speaking countries and find that high quality, curriculum-based training at the workplace is positively associated with general innovation, product innovation, process innovation, and patent applications, which makes the companies more innovative. Izyani [26] investigates some knowledge-based companies in Malaysia and shows that training activities positively influence innovation of them. Shohreh *et al.* [27] confirm that there is a statistically significant relationship between participation in training courses and numbers of innovations in food firms in rural Iran. Anja and Igor [28] show that in-house learning is not sufficient for generating innovation and that companies need to supplement internal knowledge with knowledge acquired outside the companies. Yannis *et al.* [29] support that both internal capabilities and openness towards knowledge sharing among companies are important for upgrading innovative performance.

All the studies show that training is positively relative to the innovations in companies by new or external knowledge which implies opportunities for innovations. To identify the opportunities is a start-up of innovations.

## 2.3. The Knowledge to Be Transferred by Training

Many companies have organized the training programs to uplift creative capabilities of their engineers [30]. In these programs creativity techniques are the knowledge to be transferred to the companies. There existed many creativity techniques [31,32], which are divided into two types, intuitive and logical [33]. TRIZ, theory of inventtive problem solving, is one of them, which is developed by Altshuller [34] in former USSR. Several countries, including China, have established National TRIZ Association, the main motivation in which is transfer TRIZ to companies. TRIZ possesses considerable advantages over other techniques in identifying problems and offering direct solutions to them with confidence [35].

TRIZ has been transferred to many companies in the world through training classes in the past years. Kamal *et al.* [36] 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 [37] shows the experiences training engineers successfully to solve real unsolved problems using TRIZ in Japan. In the practice, he integrates the TRIZ into Unified Structured Inventive Thinking (USIT) [38] in order to make the TRIZ simpler. Jun and Shin [39] state that TRIZ is used as an innovation tool more aggressively in SAMSUNG than any other company in the world and the training has been carried out in this company for years. Through a survey, Imoh *et al.* [40] 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".

Integrating TRIZ with other techniques, methods, and processes shows a trend for the easy application in the literatures. Axiomatic design (AD) is applied as a complementarily of TRIZ to find contradictions [41,42]. Stratton and Mann [43] show that TOC may be used together with TRIZ to find and solve contradictions. Cascini *et al.* [44] integrate TRIZ and optimization tools to form a systematic design. Tan *et al.* [45] apply TRIZ to the Pahl and Beitz's model [46] to form a new concept process model. Sun and Tan [47] connect the TRIZ with disruptive innovation process [16] to forecast. The integration may make up for some deficiencies of TRIZ, such as finding a problem.

Training as an external learning process has a positive linkage with the innovation in companies. But the literatures show that its process should be carefully designed for engineers of companies to overcome the difficulties in the study. The following factors must be considered in our training program in order to gain better results.

1) Select appropriate engineers from the companies to join the classes.

2) Design a knowledge system to be transferred to the companies, in which TRIZ is the core.

3) Design a training process to help the engineers to overcome the difficulties in the study.

4) Try to find stimuli for opportunity identification of innovation in order to improve the quality for training program nationwide.

## 3. Practice to Train Engineers into Innovative Ones in China

The objects for engineers to join our training classes are as follows:

1) Learn the new knowledge related to creativity, invention and innovations.

2) Identify new or unsolved problems in their workplaces.

3) Generate new ideas from solving the problems in order to improve designs, processes, or develop new products that are new in the companies or in the markets.

4) Transform the new ideas into inventions whose viabilities are proofed.

5) Push the team members to put the inventions into innovations in their companies.

As **Figure 1** shows the activities during, before and after a training class. The engineers to join a class from different companies or one company should be selected at first place. Then there will be the training activities: lecturing, identifying problems, discussing, generating ideas and making inventions. The last step is the activity after training in which the inventions may be transformed into innovations.

### 3.1. Selection of the Engineers to Join the Classes

The engineers to join the classes should identify new problems or unsolved problems in their workplaces, where the engineers work. There are diverse workplaces for engineers who work at different stages of the innovation in a company.

**Figure 2** shows an entire innovation process in a manufacturing company typically in China. The process is divided into three stages: fuzzy front end (FFE), new product development (NPD), and commercialization [48]. The fuzzy front end is considered as the first stage of the innovation process and covers the sub-processes includeing from the opportunity identification, opportunity analysis, idea generation, idea selection, and concept definition [48]. 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 [46]. 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 environments for fuzzy front end, new product development, commercialization and the sub-processes are the work-

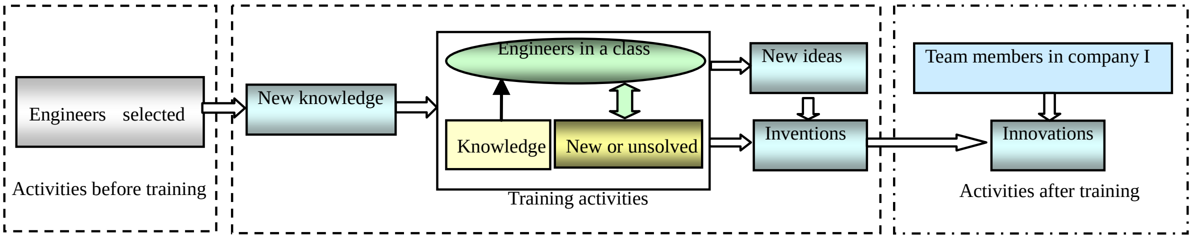



**Figure 1. Activities during, before and after training.**

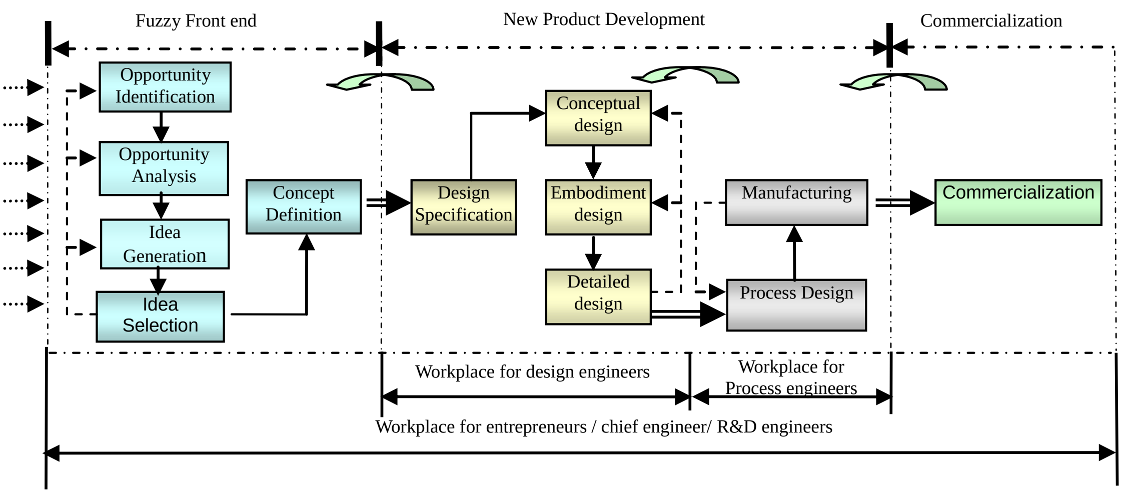



**Figure 2. An innovation process and workplaces for engineers in a manufacturing company.**

places, where the engineers are supposed to find new or unsolved problems.

**Figure 2** also shows that the engineers at different stages have corresponding responsibilities. The job for design engineers is to make design specification, conceptual design, embodiment design and detailed design. The process engineer will design the process for manufacturing, control the quality, test for the products, etc. Chief engineer/R & D engineers may generate new ideas in fuzzy front end and solve difficult problems in design, manufacturing or marketing. The entrepreneurs may pay more attention to all the activities happen in the innovation process. Ideation [49,50] in fuzzy front end, conceptual design [51,52] and embodiment design [2,53], process design [54,55] in NPD are key activities in the innovation process. The engineers related to these activeties which are the core for innovation processes should be selected to join our classes. In practice, there are indeed some entrepreneurs working in middle or small companies joining our classes. So we should also consider their needs for the classes.

The companies to join the classes should also be selected. They must have strong demands for innovation and will assist the engineers to join the classes for the whole training process.

## 3.2. The Knowledge System for Training

Training is a process to transfer external knowledge into companies. The knowledge to be transferred with the knowledge existed in companies will inspire the engineers to generate new ideas in workplaces [56]. A key attribute of a new idea is novelty, which is the first statement of something not previously known or demonstrated. That a selected idea is embodied in a tangible yet provisional form–a proof of its viability is an invention worth a key attribute of feasibility [57]. That inventions will be further refined and reach some final form with commercial intent, such as a functional device or service, are innovations with the key attribute of utility, in addition to the novelty and feasibility. Transferring external knowledge into companies, as a result of training, is an object of our training classes.

**Figure 3** shows the knowledge system for training, which will be transferred to the companies. This system is divided into two parts, the knowledge of four levels and application cases. The four levels are basic concepts, basic methods, systematic methods and computer-aided innovation (CAI). The first level knowledge is about the definitions, such as creation, invention and innovation, well structured and ill structured problems [58,59], routine and inventive problems [60], process of innovation

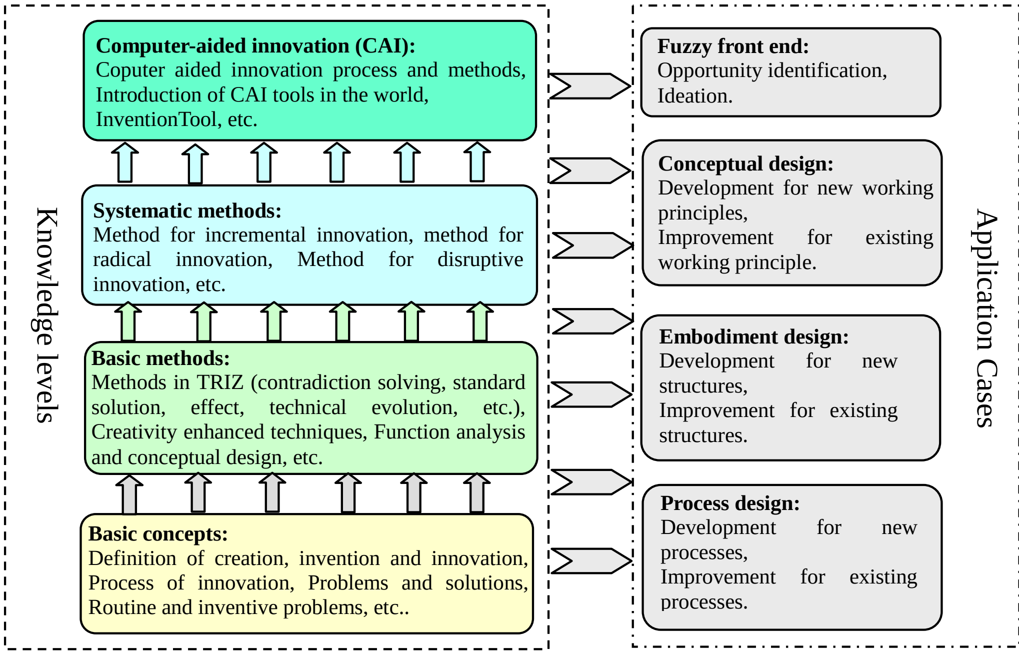



**Figure 3. Knowledge system for transfer in the training process.**

[61,62], etc. The second level is the basic methods, such as the methods in TRIZ [63,64]: contradiction solving, standard solution, effect, technical evolution, and some other creativity techniques. The third level is the systematic methods, such as a method for incremental innovation, radical innovation [65], disruptive innovation [47,66,67], patent round innovation [68], analogy-based design [69], etc. The fourth level is about the computer-aided innovation, including CAI tools and application process [45,70,71]. In the training process we present many cases which show the applications of the knowledge step by step in different level as the application cases. It is a significant training activity that the engineers imitate the processes in those cases.

### 3.3. A Training Process Model

New or external knowledge should be transferred into a company which is integrated with the knowledge existed in the company in order to support the process of innovation. The knowledge system in **Figure 3** is new to Chinese companies and should be transferred into them. These knowledge must also be integrated with the knowledge existed in these Chinese companies. The training process should be designed to satisfy the need for knowledge transfer and integration.

TRIZ is the core in the knowledge system in **Figure 3**. The training processes for TRIZ in companies have been studied for years. Rantanen and Domb [72] have developed a flowchart or a model for TRIZ training in a company. Jun and Shin [39] have also developed a flow chart for training TRIZ in Samsung. These flowcharts show that the TRIZ experts outside the organization should carry out a TRIZ pilot project to show that it is powerful for innovation in a company. This process is not suitable for the situations faced in China. We have no time to carry out a pilot project for every company to test TRIZ because the local governments push many companies to join a training class at the same time. Before the beginning of the training, most of the companies do not know what TRIZ is. A new model for this situation is needed in China.

We put forward an interactive model for training innovative engineers, as in **Figure 4**. There are four main parts, 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 contained problems. The companies selected to join the class may be one or more. A class lasts 6 to 15 months accordingly.

**Step 1: Selecting companies**

The companies to join the class are selected. Some institution of a local government, or an organizer, is responsible for the organization and selection of the com-

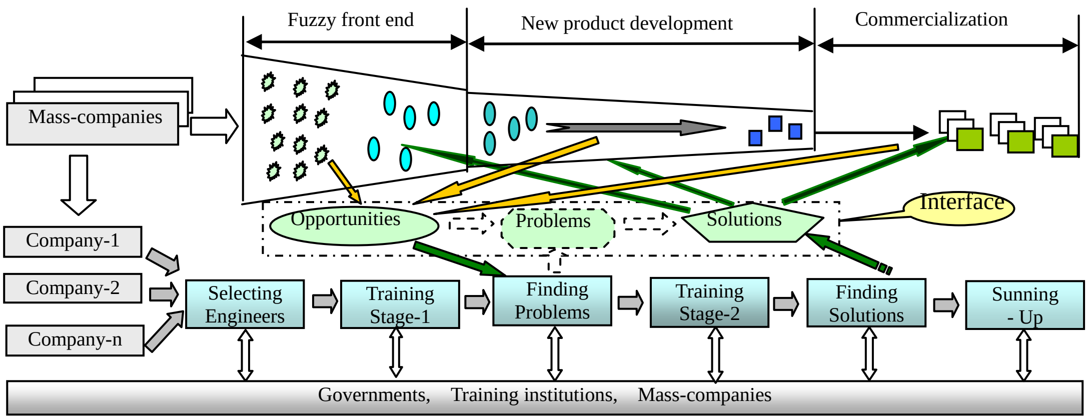



**Figure 4. An interactive training model for innovative engineers in China.**

panies to join the class for a region. For example, the Productivity Promotion Center of Guangdong (PPCG), which is an institution supported by Guangdong Science and Technology Department in Guangdong province, was responsible for the selection of the 19 companies from the province to join the first training class held from August of 2010 to March of 2011.

**Step 2: Selecting engineers**

The companies selected make recommendation for a list of engineers to join the class and the organizer of a class is responsible for the final selection of the engineers. We make suggestions that the engineers with bachelor degrees should have almost ten years work experiences and with master or doctor degree may be unrestricted.

**Step 3: Training stage-1**

Our teacher team gives lessons to the engineers. In this stage, the major knowledge is the level one and two, that are basic concepts, basic methods. The most methods in TRIZ, such as contradiction solving, standard solution, effects and technological evolution etc will be taught. Many cases applying these methods are also demonstrated. The knowledge transferred in this stage will provide a background to identify opportunities, problems and solving them for engineers.

**Step 4: Finding a problem**

Every engineer joining the class must find an inventive problem from the innovation process or the workplace of the companies for innovative activities. The problems are implied in opportunities found. An engineer needs to understand the theories or methods in depth and to connect them to the situations of workplaces and identify an opportunity and a problem implied.

**Step 5: Training stage-2**

Again, our teacher team gives lessons to the engineers for the level three and four knowledge, which are systematic methods and CAI. The major methods in this stage are extended methods of TRIZ. Such as anticipatory failure determination (AFD) [73] is a methods to be trained, which is an application of I-TRIZ to risk analysis and prediction developed by Ideation International Inc in USA. Some cases applying these methods are also demonstrated. The knowledge transferred in this stage will provide a background to solving problems for engineers.

**Step 6: Solving problem**

In this phase, every engineer must develop at least one accessible technical solution for the problem in a few months, at the same time they should work. At the beginning, the solutions are ideas. After that ideas should be transformed into inventions, which may be a new design prototype, new process in the form of a patent application, or a new concept accepted by the company.

**Step 7: Summing up**

Summing Up is the last phase, in which the final oral examination is made and engineers will present their results with slides. Members of a committee specific in charge of the examination make discussions with them. An evaluation is made and a certificate is presented to some qualified engineers who are innovative.

Finding a problem or an obstacle in the innovation process in step 4 is a key activity to follow the training process for an engineer. If he or she does find a problem the knowledge system studied in step 3 and 5 are very useful for them to solving it and to get the solutions. The solutions are returned to the innovation process, in which the obstacle is eliminated. If an engineer cannot find a problem he or she will be sifted out in the middle of the training process.

In the past five years, we have carried out 20 classes for more than 150 companies nationwide. More than 500 engineers did follow our training process shown in **Figure 4** and have been certificated as innovative engineers. Most of the engineers who finished the processes did have applied patents and some of them have been developed to new products which are being sold in markets now. Several innovations in companies are introduced as a result of our training program.

## 4. Analysis of the Training Outcomes

Every engineer who finishes the training process does have one or more inventions. Some of the inventions have been developed to innovations in companies. The first step in the process for an engineer is to identify an opportunity for innovation. More than half of the engineers joining the classes do pass successfully the step. The major factors for them to identify opportunities should be studied for the future training activities.

### 4.1. Case 1: GD-1

GD-1 was the first training class organized by Guangdong Science and Technology Department in Guangdong province from August of 2010 to March of 2011, which is the organization of local government for the development of sciences and technologies. Our center carried out the training process.

75 engineers were selected from 19 companies in Guangdong province, including BYD, BROAD-OCEAN and GAC *et al.* 52 passed the final examination. 30 of them were certificated as Innovative Engineers Level 2, while the others were Level 1. 23 engineers did not follow the training process and dropped out in the middle. All the 52 engineers found out 52 inventive problems from the innovation processes of 17 different companies and solved them at last. As a result, 52 inventions were formed, in which 36 had patent applications, which were 22 patents for inventions and 14 patents for utility models. They have been sent to SIPO (State Intellectual Property Office of the PRC) and all application numbers have been got the end of the class. Problems in different stages and the methods to solve them for this class are shown in **Figure 5**.

**Figure 5(a)** is the relationship between the numbers of the problems and innovation stages or sub-processes. The most problems, which are 18, are found from manufacturing. The least problems, which are 4, are in fuzzy front end. The problems from design process are total 30, in which the problems to the conceptual design, embodiment design and detailed design are 10, 15, and 5 respectively. **Figure 5(b)** shows the relationship between the numbers of the problems and the methods to solve them. The method for solving contradictions is mostly used by 42 engineers. Standard solutions and trimming are used 3 times respectively. Four methods, ideal final result, resources, AFD (anticipate possible failures) and technology evolution (evolution lines), are applied once.

Most companies to join the class are belonging to manufacturing industry. The problems found by engineers are mainly in manufacturing, embodiment design and conceptual design. The major methods to solve these problems are contradiction solving, trimming and standard solution of TRIZ. **Figure 5** shows that to find contradictions in manufacturing processes, embodiment design or conceptual design process, is certainly an opportunity of innovation for engineers.

### 4.2. Case 2: LF-1

LF-1 was the first training class organized from July of 2012 to January of 2013 by Hebei Science and Technology Department in Langfang, a city between Beijing and Tianjin. Our center carried out the training process.

41 engineers were selected from 17 companies in Langfang to join the class. 22 passed the final examination and certificated as Innovative Engineers. 19 engineers did not follow the training process and dropped out in the middle. All the 22 engineers found 22 inventive problems from the innovation processes of different companies and solved them at last.

**Figure 6** shows the results. 10 problems are found from conceptual design process in **Figure 6(a)**, while the only 1 occurs in detailed design process. The problem numbers from design processes are 17. This also illustrates that there are the most opportunities for innovation from designs processes. **Figure 6(b)** presents that the methods for solving contradictions are also mostly used by 10 engineers. S-field analyses and standard solutions are used 6 times. Ideal final result and trimming are applied twice.

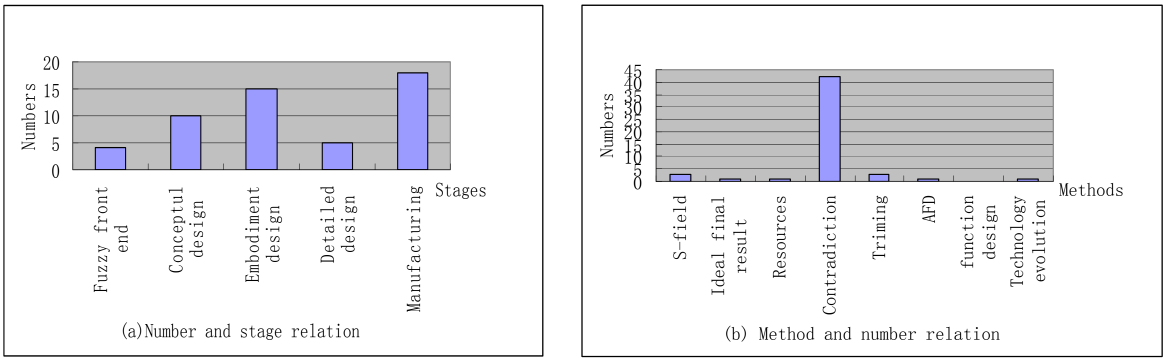
The companies in this class are from different field, such as geology. Most problems are found in conceptual and embodiment design. The contradiction solving and standard solutions are still the major methods to solve problems. To find problems in design stages is also an opportunity of innovation for engineers.

### 4.3. Major Factors for Successful Training

The training activities for trainers mainly include giving lectures, discussions of all possible opportunities and problems, making suggestions and debating, etc. Discussions can be carried out in classrooms, in workplaces, by e-mail, on telephones, and by text massages etc. From several years training activities we summarize that 4 factors are major for successful training, which are the experiences in workplace for engineers, the knowledge system to be transferred, the pressure and responsibility for engineers, the stimuli for identifying opportunities of innovation.

**Factor 1: The experiences in workplace for engineers**

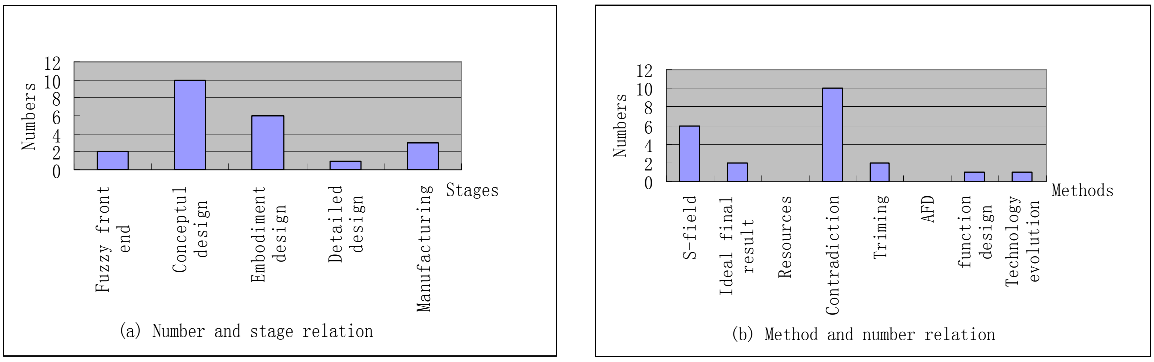
**Figures 5(a)** and **6(a)** show that the inventive problems are directly related innovation stages or sub-processes. The experience in workplaces is the first factor for engineers to identify an opportunity and find the prob-




(a) Number and stage relation

(b) Method and number relation

**Figure 5. Relations between problems and stages or methods from GD-1.**




(a) Number and stage relation

(b) Method and number relation

**Figure 6. Case2: analysis of inventions from LF-1.**

lems. Several years work in one or similar workplaces make the engineers to understand the situation in depth. They know that there are certainly some problems because of ***chaotic situation***. They estimate that something should be changed.

**Factor 2: the knowledge system to be transferred to the engineers**

Why have some changes not happened for a long time? One reason is that the engineers lack the suitable knowledge to push the change to happen. So the knowledge system to be transferred to the engineers by training should be carefully designed in the creativity and innovation domain. We select TRIZ as the core knowledge and others as periphery one. The core and periphery knowledge need to be integrated and developed carefully in order to be accepted easily by the engineers.

**Factor 3: the pressure and responsibility for engineers**

The engineers to join our classes are selected as excellent ones from companies. They all have pressure and responsibility to follow the training process. The pressure makes the engineers in tension states. They must concentrate all the vigor on study and research activities during the training process. The responsibility makes the engineers consider seriously what kind of problems should be found and solved for innovation of the companies.

**Factor 4: Stimuli for identifying opportunities of innovation**

How to define a problem from a ***chaotic situation of a workplace is the most important step to follow our classes. Why do the engineers not define a problem for a long time in the workplaces?*** For many discussions with engineers face to face we find that the stimuli for opportunity identification are an important factor. The stimuli are contained in the knowledge system that is transferred to the engineers in our training. Such as, **Figures 5(b)** and **6(b)** show that engineers frequently apply the method of contradiction solving. They try to find a contradiction which is an inventive problem in workplace. So to find a contradiction is a stimulus for identifying opportunity of innovation. We need to identify other stimuli for the future application in the training classes.

## 5. Seven Stimuli for Identifying Opportunities

The engineers selected to join our classes do have in-depth experience and long-term focus in product or process designs in different workplaces, which are the playground for creativity and innovation in the domain. But stimuli are also needed for them to identify opportunities for innovation. The knowledge system shown in

**Figure 3** and the training process in **Figure 4** imply some stimuli. We find that there are seven stimuli, which excite the engineers to identify opportunities of innovation in our classes.

**Stimuli 1: Be close to an Ideal System**

Any system, whether it is a technology, product or process, is in evolution to the direction of ideality. One way to define ideality is the ideal system, which occupies no space, has no weight, requires no labor or maintenance, etc. The ideal system delivers benefit without harm and solves its own problems. The current state of any system is not an ideal system, but it is final state for the system evolution. So an innovative engineer's job is to push a system to be close to the ideal system at least a little step. The step will result in an innovative solution for a product or a process. Making an imaginary ideal system and considering how to be close to the system for an innovative engineer is opportunities for innovation.

**Case 1: A new switching power supply**

Golden Field Industrial, Located in Dongguan, Guangzhou, China, is a company producing computer gadgets and accessories - PC case, switching power supply, multimedia speakers, mouse and keyboard, etc. Four engineers in this company joined the first training class conducted in Guangzhou from August, 2010 to March, 2011. One of the engineers has gotten a patent for a new switching power supply which reduces the power loss to zero in the standby mode for computer gadgets. The new supply will help computers to save energy which is meaningful for industries, offices, families. The opportunity for this new technology is stimulated by Stimuli 1.

In the standby mode for a computer the power loss is from 0.4 W to 6 W. This is a huge energy loss for the whole China or the world. The opportunity for a producer of computer peripherals is to develop an energy saving supply, which is a small step to the direction of an ideal system. Being stimulated the engineer does develop a new supply to reduce the loss to zero.

**Stimuli 2: Use unexpected resources**

A resource is anything in and around a system that is not being used to its maximum potential. Substances, fields, functions, information, time and space are all possible resources. Some resources are explicit but others are tacit. One of the key concepts in TRIZ is that the strongest solutions transform the unwanted or even harmful elements in a system into useful resources. The suitable application of any resource might lead to discovery of an opportunity for innovation.

Engineers working in a company for several years may be familiar with the surroundings and all the resources but they are not used to applying some resources in innovation process especially tacit once. When they studied the different viewpoints for resources and some application cases, some resources are unexpected treasure and may stimulate some opportunities for them.

**Case 2: Fresh keeping wolfberries**

Qinghaiqing, a company located in Qinghai province, China, produces wolfberry and buckthorn based products. Three engineers in this company joined the first training class conducted in Xining, Qinghai, from January, 2011 to May, 2012. One of the engineers has gotten a patent for a fresh keeping technology for wolfberries and also a new product for the company. The people outside Qinghai, such as Shanghai or Beijing, can taste the fresh wolfberry produced in Qinghai in the near future. The wolfberries are traditionally dried, packed and transported to different places to be sold. Fresh wolfberries are not only tasted good but also full of nutrition. The new product has made the company to have competitive ability in this market. The opportunity for this new technology is stimulated by Stimuli 2.

There is a kind of resources called evolutionary resources, including the knowledge developed in the given area, or other areas, sociology, marketing and psychology etc. According to the concept of the evolutionary resources, the storing technologies in low temperature, the storing film, and the storing technologies using controlled air in other areas may be resources for storing the fresh wolfberries. But resources need integrating into new system for the specific application. This is stimulation for the engineer to identify an opportunity for development of a new technology and new product for fresh keeping wolfberries.

**Stimuli 3: Find a contradiction**

In TRIZ, contradiction is one of the core concepts, which is used to formulate problems and guide towards innovative ideas. A contradiction arises when two mutually conflicting demands are put on in the same system or a situation. This happens quite often in product design and manufacturing processes. To evolve a system or technology further contradictions should be resolved. TRIZ offers 40 inventive principles, a matrix and 39 parameters to solve contradictions. Using these principles engineers may come up breakthrough solutions but not compromises, or trade-offs. The solutions always result in an incremental innovation.

The engineers in china have studied the concept of universality of contradiction in their educations from middle schools to universities. But Chinese way of dealing with contradictions is seeking a "middle way" that is retaining basic elements of opposing perspectives. In our class we pay more attention to find and solve contradicttions in the specific process for innovation. Solving a contradiction means to eliminate it but not to find a middle way. Most of the engineers could use this stimulus more easily for opportunity identification.

**Case 3: A new processing method for chestnuts**

Liyuan, a company located in Tangshan, Hebei province, China, produces chestnuts, cereals and other agricultural by-products, by industrial deep processing methods. One engineer in this company joined the training class conducted in Baoding, Hebei province, from May, 2011 to January, 2012. The engineer has gotten a patent for a new processing method of chestnuts which have a constant mouth feel. The opportunity for this new technology is stimulated by Stimuli 3.

Some consumers complain that the sweetness level of the chestnuts produced in this company is lower and the hardness level is higher. In the past several years the company has not made improvements for the product to meet the needs. The engineer made an analysis and found that there were two contradictions for the quality problems of the product. The matrix and inventive principles were applied to solve the contradictions. At last a new processing method was formed and the experiment for the improved chestnuts showed that the processing was right. An improved product has been put into the market. The Stimuli 3 inspired the engineer to make this innovation happen.

**Stimuli 4: Trim some elements**

A product consists of several elements and links among them. An element is defined as a physically distinct portion of the product that could not be divided further for analysis. A link is kind of relationship between two elements, which is an action. Two elements and a link between them make up a function under TRIZ concept. All the functions for the product form the function model which is a function net. There are four kinds of actions which are useful, harmful, excessive and inadequate. If one of harmful, excessive or inadequate actions is identified the link and the two elements are a problematic function. There may be one or more problematic functions in the function model for an existing product. One or some problematic functions should be eliminated for the improvement of the product performance.

Trimming in TRIZ is a kind of operation to cut off some elements relating to the problematic functions by some rules. Basic principle of trimming is simplification for an existing product which reduces the cost, size, weight, or simplifies the operations that make the products easy to be used. As a result, trimming is an opportunity of innovation for innovative engineers.

**Case 4: A new structured motor**

Broad-Ocean, a company of Guangzhou, China, is a producer of micro-motors. Two engineers in this company joined the first training class conducted in Guangzhou from August, 2010 to March, 2011. One of the engineers has gotten a patent for a new structural design for the one-way asynchronous motor produced in this company. The efficiency assembling process for one motor is improved and the cost is reduced by the new design. The opportunity for this engineer is stimulated by Stimuli 4.

In the traditional design the rotating magnetic field in one-way asynchronous motor is produced by a capacity connected outside the shell of the motor. The module of the capacity is located to the shell by screws that lead to some harmful results. That the module may fall off in the operation is a clear weakness. According to the basic idea of the Stimuli 4, the capacity should be trimmed off. This is an opportunity for the engineer. The engineer did take advantage of the opportunity to develop a new structure that the capacity is not outside the shell. New products using the structure have been put out.

**Stimuli 5: Anticipate possible failures**

To anticipate possible failures for products or processes are certainly a kind of opportunities for innovation. Anticipatory failure determination (AFD) may be applied for this purpose, which is an application of TRIZ to risk analysis and prediction. There are two templates, AFD-1 and AFD-2, for applications. AFD-1, failure analysis, applies to find the cause of a failure that has already occurred but is not yet understood. AFD-2, failure predicttion, is to identify possible failures that have not yet occurred for a new system design or for any system in which negative effects or drawbacks have not yet manifested themselves. The basic concepts and methods of TRIZ, such as resources and contradictions solving, may be used in the process of AFD. The application of AFD for both existing and being designed products is an opportunity of innovation for the engineers in the classes.

**Case 5: New currency recognition modules**

GRGBanking, a company located in Guangzhou, is a provider of currency recognition and cash processing solutions in the market. Automatic Teller Machine (ATM) is a major kind of product in this company. More than 20 engineers in this company joined our two training classes from August, 2010 to December, 2012. One of the engineers has gotten several patents for different currency recognition objects in ATM. The new ATMs using the patents have been operated in several cities. The opportunity for this engineer is stimulated by Stimuli 5.

One challenge for the company is to recognize the counterfeit cash in or out ATM in high precision. Precisions for recognition used to be a problem in this company. The engineer applied the AFD-1 and AFD-2 to identify the root causes of old designs and put forward new principles and formed new modules for ATM. The AFD stimulated the engineer to find problems and solutions.

**Stimuli 6: Add another purpose function**

A function for a product is *what does.* There are two kinds of functions, purpose and operation. The purpose function is a description of a users' intention or the purpose of a design, and the operation function is a description of the intended operation of the design. Users can understand the usefulness of the purpose function for an existing product. That is the reason why users buy this product. Maybe some users hope to buy products with more purpose functions. Multi-function is an evolution trend for some products. So to add another purpose function is an opportunity for innovative engineers.

**Case 6: New structured headstock and tailstock of EMU**

Tangshan Railway Vehicle (TRC) located in Tangshan, Hebei province, China, produces electric multiple units (EMU), passenger coaches, etc. We organized a class for this company from May, 2012 to December, 2012. At first 60 engineers in different workplaces were joined the class and 28 engineers followed the whole training process. One engineer has gotten a few patents for the new structured headstocks and tailstocks of EMU. The opportunity for the new technologies is stimulated by Stimuli 6.

The headstock and the tailstock in an EMU are of the same structure. The headstock in one running direction is the tailstock for the reveres running. The air dynamics for the headstock and the tailstock are different because of the state change for running condition. The air resistances are not in optimal condition for the same structures for both sides. Adding a function to reduce resistance for headstock and tailstock is an opportunity for the new design of EMU. Stimuli 6 makes the engineer to design new dynamic structures for headstock and tailstock to adapted different conditions. The new technologies reduce energy loss when the EMU is running. The inventions of the engineer are quite important for the company, also for the industry.

**Stimuli 7: Change behaviors**

A behavior for a product is *how does*. Behaviors can be regarded as actions or physical state transitions among the elements of a product; or it can be regarded as the physical interactions including the input actions and output actions to or from elements. These actions can be both the intended and unintended, such as side-effects. If one or some physical state transitions are substituted by new ones the performance of the product may be better. This will result in a kind of invention and innovation. So to change some behaviors for selected products is an opportunity for innovative engineers.

**Case 7: A new testing instrument for solar cell modules**

Qinghai Tianpu Solar Energy Company, located in Qinghai province, China, is a producer of photovoltaic products for west China. Three engineers in this company joined the first training class conducted in Xining, Qianhai, from January, 2011 to May, 2012. One of the engineers has developed a new product, a testing instrument for solar cell modules for the company. The opportunity for this new product is the application of changing behaviors.

The voltage, current, and peak power for a solar cell module should be tested by instruments for evaluating the performance. The instruments existing in the market now are used in house of module producers. But the modules are operated in open countries, which are outside the workshops of the producers. The existing instruments are not suitable to some customers' new needs for operations in some locations. Changing the behaviors of the existing instruments is an opportunity for development of a new one which can serve better in different locations. The LabVIEW and Matlab are used and the reliability is increased in the new design. The new product has been developed and tested successfully in this company.

## 6. Possibility in Applying the Stimuli

The stimuli are concluded from the knowledge system in **Figure 3** with the help of training practices. One stimulus may or may not be used in a stage of innovation. **Table 1** shows the possibility of the application for every stimulus in different stages or sub-processes of innovation. There are three types of possibilities, high, middle or low. High or low possibility means that the result to find an opportunity could happen or almost could not happen. Middle possibility is between high and low.

The table also shows the following features:

1) Every stimulus may be used to identify opportunities in fuzzy front end.

2) Every stimulus may be used to identify opportunities in conceptual design.

3) To find a contradiction is an important activity in opportunity identification for fuzzy front end and new product development.

There is no any symbol in the right commercialization column of the table. In practice we find that a few entrepreneurs, chief engineers or R&D engineers do find opportunities in commercialization stage. But we have not concluded one or two stimuli for them to use. This will be a research topic in the future.

**Figure 7** is a process model for applying the 7 stimuli. First, the engineer selects one or more stimuli and then applies them to a stage, such as fuzzy front end. If an opportunity is identified the engineers find the implied problems. There are two possible paths to manage the problems which are called self-circled or passing on. In the first path, the engineers solve the problems in their

**Table 1. Possibility between stimuli and opportunities for innovation.**

| Possibility / Phases / Stimuli | *Fuzzy Front End* | New Product Development: *Conceptual design* | *Embodiment design* | *Detailed design* | *Manufacturing* | *Commercialization* |
|---|---|---|---|---|---|---|
| Be close to an Ideal System | ◎ | ◎ | △ | △ | ◎ | |
| Use unexpected resources | ◎ | ◎ | △ | △ | ◎ | |
| Find a contradiction | ◎ | ◎ | ◎ | ◎ | ◎ | |
| Trim some components | ◎ | ◎ | ◎ | ○ | △ | |
| Anticipate possible failures | ◎ | ◎ | ○ | ○ | ◎ | |
| Add another purpose function | ◎ | ◎ | ○ | ○ | △ | |
| Change behaviors | ◎ | ◎ | △ | ○ | △ | |

◎ High △ Middle ○ Low.

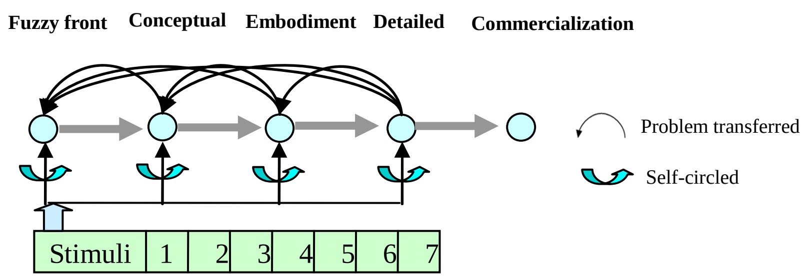



**Figure 7. A process applying the stimuli.**

workplace. In the second the problems are passed on other engineers who are working in relevant workplaces. The second path shows that some problems in one stage or a sub-process should be solved in another stage or sub-process. 7 stimuli are not many enough to make a difficult process of being chosen one by one for engineers.

Now we have added the 7 stimuli as new knowledge in the training stage-1 and stage-2 of **Figure 4**. We hope that they will assist the engineers to join the classes to identify opportunities a little easier.

## 7. Discussions

An interactive model is developed in this study for training innovative engineers for a variety of companies in China. The specific feature for this model is that the engineers must find and solve inventive problems in their workplaces during the training process. The solutions from the problems are new ideas which are improved to form some inventions. Experiences show that engineers and their companies make high evaluation about the training process.

To organize the companies and engineers to join the classes are the job of local governments but the lecturing and other activities are the job of our center. The advantages of two sides are brought into play. This is feasible model for transferring creativity and innovation knowledge to companies in China.

The knowledge system transferred in the training process is specially organized at four levels, which are basic concepts, basic methods, systematic methods and computer-aided innovation. TRIZ is selected as the core knowledge and the others dealing with creativity and innovation are supplementary in this system. TRIZ is strong in solving difficulties or inventive problems but other techniques are needed to find problems and integrated into an innovation processes. The integration of two kinds of knowledge forms a whole knowledge system from finding to solving a problem for an innovation process. The knowledge system is different from only TRIZ and is a key factor for successful training.

From many discussions face to face with the engineers in the training process, 7 stimuli are found, which excite them to identify opportunities for innovation in our classes. The knowledge system of four levels is pregnant with all the stimuli. The stimuli are directly related with fuzzy front end, new product design and manufacturing. That the engineers apply them one by one to workplaces may help them to identify opportunities and the problems contained.

The knowledge system is an open system, to which new relevant knowledge could be enriched. The classes are organized in more and more provinces in China and the experiences are accumulated. Some new stimuli may be concluded and should be added to the stimulus set of this study.

It needs our attention whether the stimuli may excite the engineers to identify opportunities in the stage of commercialization.

The stimuli are suitable for adding to the interactive training process for engineers. But for a long term consideration they should be applied in the process of creativity and innovation management for companies. We are trying to make experiences in one or two companies now in this direction and hope to have some results in the future.

## 8. Conclusions

The practices show that improving the innovation capability is possible through training engineers in China. More than half of the engineers having joined our classes do pass the training process though some engineers drop out in the middle.

TRIZ, which is the core technique in knowledge system with four levels, is particularly useful for the engineers to make inventions. Because learning TRIZ is not easy, the training process should be developed carefully. The interactive training model for training innovative engineers in this study is a possible selection.

The knowledge to be transferred and the process used imply some stimuli to identify opportunities of innovation, in which problems are contained. Seven stimuli are concluded by many face to face discussions with the engineers to join our training classes. A possible process to apply them is also described.

There will also be some researches for future work, such as adding new knowledge to the system, finding new stimuli and applying them into commercialization in companies for a long term management.

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