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Study on Innovation Capability of College Students Based on Extenics and Theory of Creativity

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Abstract

Individual innovation capability is a principal element in enterprise independent innovation and new state construction. College students are the major force of the future innovations. However it lacks feasible means and methods to promote college students’ innovation capability. In this paper, the functions and performances of Creativity theory and Extenics are analyzed, and the existing major innovation methods are compared from the perspective of capability promotion. Then we present a combined training model for promoting students’ innovation capability, in which the advantages of Creativity Study and Extenics are integrated and support each other. The effects of our model are proved by our teaching practice cases. This paper also provides a reference as a guidance to improve postgraduates’ innovation capability.

Keywords: Theory of Creativity; College Students; Innovation Capability; Extenics; Internet

1. Introduction

Along with the trend of economic globalization in the information age, all countries are gradually strengthening their protection and utilization of intellectual property rights. The value of intangible assets such as invention patent, software copyright and brand, is prior to that of tangible assets such as equipment and workshop. Therefore, the innovation capability has increasingly become the vital part of a nation's comprehensive strength and the core competence of the corporations. The key factor for a country or region to maintain long term economic growth is that the corporations can enhance their core competence independently.

Continuous rapid economic growth relies on a transfer from the extensive growth merely based on factor inputs, to the intensive growth based on factor combinations with improved efficiency. The efficiency can only be achieved on basis of continuous rapid enhancement of the corporations' independent innovation capability. When the corporations no longer lack of motivation to innovate, the lack of methodology will become the new bottleneck that impedes the enhancement of innovation capability.
The independent innovation capability of the nation and corporations rely on individuals. While the corporations are increasing investments on research and development, the ranking of China's innovation capability is constantly falling (Qiu and Chen, 2007). Creativity research (Saaty, 2010) and Extenics (Yang and Cai, 2007) are major methods to promote the innovation capability of undergraduates, but both have some shortcomings. To solve the "Qian's question" on lack of innovation in college education, enhance the independent innovation capability of corporations and build an innovative country, there is dramatic theoretical and practical significance in comparatively studying Extenics and creativity research, investigating their mechanism and functions in enhancing the innovation capability of undergraduates, and building a training system with Chinese characteristics for innovation capability.

The purpose of this paper is to propose a combined method for college students to improve their innovation capability. By analyzing the shortages and advantages of Extenics and Theory of Creativity, and sharing knowledge from teaching practice, we put forward a combined innovation training model that will benefit the students to improve their ability of solving the problem and apply for patents. The rest of the paper is organized as follows: in Section 2 we introduce the theories and methods of creativity and Extenics for preparing our solution. Section 3 describes a combined model for enhancement of innovation capability of college students. Section 4 presents a case study to show the practice results. Section 5 concludes the paper with future research directions.

2. Theories and methods of creativity and Extenics

2.1. Theory of Creativity

Generally, creativity is defined as the creation of novel and useful ideas or solutions (Amabile, 1988). There are two indispensable keywords in the definition: novel and useful. Plsek (1997) regarded creativity as a combination and rearrangement of knowledge - in the head of people who allow flexible thinking - to create novel ideas which are surprising but useful. Heap (1989) explained that creativity is to integrate new ideas and concepts through fundamental reconstruction and re-imagination of existing objects. He considered innovation as implementation of creativity.

Amabile (1988) broke down creativity into three parts: professional knowledge, innovative thinking skills and motivation. Individual creativity is influenced by personality factors, cognitive style and capability, skills of disciplines related to the task, motivation and impacts from social contexts (Woodman et al., 1993); and thus cannot be promoted rapidly in a short period of time. The researches on creativity techniques can just be adopted to enhance individual creativity to some extent.

Summarizing the findings of Chinese researchers, creativity research is a new comprehensive cross-discipline built on the most up-to-date research findings from disciplines such as philosophy, psychology, brain science, futurology, sociology and science of personnel (Liu, 2001; Fu, 2003; Zhuang, 2006; Gan, 2010). The research object of creativity research includes human's creative activities, process, thinking, psychological qualities and environments, etc. Its major goal is to stimulate people's potential and cultivate creativity. Creativity research consists of the following three parts:

1) Theory of creativity: it is based on Marxist creative philosophy and summarizes the creative psychology, thinking and techniques of people, especially the famous scientists and inventors, during the process of invention. It is human-oriented theory on development of creativity.

2) Creativity development science: it is created to provide creative education, psychology, thinking, environment, techniques and assessment of creative findings for human's projects of invention.

3) Creativity engineering: it is an engineering science providing creative design, decision consulting, planning program, tracking analysis, operating process and methods, and assessment standards for discoveries, inventions, creations and creative findings.
2.2. Extension Theory — Extenics

Extenics is constituted of Element theory, extension methodology and extension engineering (Yang and Cai, 2007). It is a new discipline for dealing with contradictory problems with formulating model and produces novel ideas (Cai, 1990, 1999). A matter has many characteristics. Each matter has four extensibilities: the divergent nature, the conjugate nature, the correlative nature and the implicative nature. As to the conjugate nature, there are four pairs of conjugate parts including the real part (the entity of a matter’s existence, such as a pen) and the imaginary part (the spirit of the element, such as brand of the pen), the soft part (relation structure between parts of a system) and the hard part (each part in a system), the latent part (unnoticeable element or forthcoming change) and the apparent part (noticeable element), and the negative part (the part creating positive value to the goal) and the positive part (the part creating negative value to the goal). A matter can be expressed as an ordered triad

\[ R = (N, c, v) \]  

(1)

\( R \) is the matter-element, \( N \) represents the matter, \( c \) is the characteristics, and \( v \) is the \( N \)'s measure about the characteristics \( c \).

Moreover, Extenics establishes matter-element \( R = (N, c, v) \), affair-element \( I = (d, b, u) \) and relation-element \( Q = (s, a, w) \) (each has attributes/characteristics and their measure) to describe matter, affair and relation. Matter-element, affair-element and relation-element are collectively called basic elements. A matter with many characteristic elements can be described by n-dimensional matter-elements.

\[
M = \begin{bmatrix}
N_1 & c_{n1} & v_{n1} \\
c_{n2} & v_{n2} \\
\vdots & \vdots \\
c_{nm} & v_{nm}
\end{bmatrix} = (N_m, C_m, V_m) \]  

(2)

Extenics also presented transformation methods. By certain transformation, one thing that doesn't have property \( P \) can be turned into another thing that has the property \( P \). Extension set can describe this kind of transformation quantitatively. So the extension field can be recognized as a set of things that doesn't have the property \( P \) but can be changed into those with the property \( P \) (Cai, et al, 2008). Up to now a series of particular extension methods have been developed and applied in many fields (Yang and Li, 2012).

2.3. Comparing on Extenics and Theory of Creativity

Creativity research studies people's creativity. It promotes the creativity of creation subject (i.e. individuals) mainly through studies on creation itself (Suler, 1980; Plsek, 1997). Amabile (1988) broke down creativity into three parts: professional knowledge, innovative thinking skills and motives. Individual creativity is influenced by personality factors, cognitive style and capability, skills of disciplines related to the task, motives and impacts from social contexts (Woodman et al., 1993); and thus cannot be promoted rapidly in a short period of time.

The researches on creativity techniques can just be adopted to enhance individual creativity to some extent. Many techniques such as brainstorming and the Delphi technique are known to all. Krohe (1996) summarized 22 creativity techniques, such as bug listing, goal/wish, manipulative verbs, nominal group technique, wildest idea, wishful thinking, etc. Zhou and George (2003) indicated that leaders may influence the creativity of staff
directly or indirectly through environment or culture. There are five means to arouse the members' creativity: identifying the problems and opportunities, gathering information and resources, creating ideas, assessing, modifying, and exchanging ideas. Amabile (1996) listed five stages for innovation: problem or task presentation, preparation, response generation, response validation and outcome. Based on her theory, Chen et al (2008) partitioned the corporation's occasional innovative procedure into five related stages: occurrence and capture of an occasional phenomenon, observer's interest generation, continuous individual investigation, internal development inside the corporation and product marketing. They described the different responsibilities and behavioral characteristics displayed by individuals and the corporations during the whole process from the occurrence of an occasional phenomenon to the implementation of achievement.

Techniques such as trial-and-error, brainstorming and six thinking hats, rely more on personal psychological factors and intelligence. However, the individual intelligence has large randomness and contingency, and cannot fundamentally solve the comprehensive problems of divergent thinking. For this reason, the effectiveness of innovation cannot be guaranteed.

To sum up, there are still the following three limitations to the research on enhancing the creativity of undergraduates. Firstly, most studies investigated individual creativity from one aspect, and thus we lack systematically integrated studies. Secondly, we are short of studies using information techniques to enhance innovation capability. Thirdly, we lack studies on innovation methodologies with Chinese characteristics, and thus have few feasible methods and tools for innovation.

3. A Combined Model for Enhancement of Innovation Capability

Investigating methods and tools for creativity enhancement will provide theoretical references for the relevant departments of the state to make policies, and guiding the corporations and organizations to improve innovation capability, and then provide theoretical and practical guidance to build an innovative college. The combined model is presented as following.

3.1. Stimulation by Theory of Creativity

Trainings in creativity curriculums can enable students to update their mind, waken their attention to things' defects and their sensitivity to problems, and stimulate their sense of innovation. It can shift their minds and destroy their thinking paradigm; so that they can develop creative thinking, and provide novel and special trains of thought for problem solving. Through trainings they master the rules, principles, techniques and methods of creativity, and improve the efficiency in solving problems creatively. The scientific training in creativity can stimulate students' abilities in imagining, understanding, organizing, converting, self-criticizing and self-inspection.

Common people used to think that only the scientists, inventors, and artists can make the inventions. Now application of creativity makes it no longer mysterious, and effectively helps inventors work actively, clearly, and precisely; rather than passively, blindly, and vaguely. Therefore, creativity science is referred to as an "invisible guide". Its function grants it the scientific value in promoting innovation of knowledge.

On the elements of innovation capability, however different scholars have different statements, the basic spirit is consistent. Creative ability mainly consists of the three parts: related professional knowledge and skills, corresponding creative things and creative personality trends. From the point of promoting individual innovation capability, we integrate the achievements of Creativity Study, and get the formula: innovation capability= K × (creative personality+ creative thinking + creative techniques) × knowledge& skills.

In the formula, K refers to human’s creative potentiality which is a recessive creative ability. It is a nature every human brain has. It is naturally formed with brain evolution in the long human evolution progress, which is inborn. According to the theory of Creativity, we design some topics to train students on personality, process,
psychological preparation, confidence, motivation, risk-taking, willpower and creative spirit.

3.2. Optimization of Creative Environment

Creativity research revealed the rules behind creative activities, and indicated the principles and directions that creative activities should follow. Creativity research not only revealed the rules of creativity theoretically, but also indicated the practical methods and techniques stimulating re-invention. Though we can create things without learning creativity, the efficiency and quality are usually not satisfactory.

Intentionally using creativity theories and methods in creativity training, can fully stimulate the creative intelligence hidden deeply in the brain, inspire people, accelerate thinking, and approach the goal of invention or innovation more rapidly. Hence creativity research can "stimulate intelligence" in application. This function brings about educational value in promoting people's mentally and physically development.

Creativity research did specific studies on creative environment, revealed the relationships among creative subject, object and environment, and offered advice in principle on how to optimize creative environment.

Oriented to cultivating innovation spirit and creativity, we apply creativity research to education in the following three ways:

1) Theories of creativity: introduce fundamental questions such as the basic concepts, creative process, creative personality and creative talent; and help people understand fundamental theories of creative activities.

   Every ordinary person has creativity and the potential to create. The creative capacity can be enhanced through education and training.

2) Intelligence of creativity: expounds the fundamental intelligence, mainly the creative thinking, needed for creative activities.

3) Common creativity techniques: introduce the common techniques used to solve problems.

3.3. Enhancing Innovative Practical Ability by Extenics

Innovation in essence is a solving process of the contradictory problems, which the condition is unable to meet the goal. For this field, Extension methods provide a basic matter-element model that combines qualitative presentation and quantitative analysis to solve contradictory problems of innovation, rhombus thinking way to explore innovative propositions and a transformation tool to get available innovation blueprints based on the inherent extensibility of elements. Therefore, the innovation methods based on Extension Theory would take advance of specific extension methods to generating new innovative ideas or solutions for the problem solving. According to the framework of Extension theory based innovation methods (Zhou and Li, 2010), we list relevant steps as following:

Step 1. Information & knowledge collection

   Collect information and knowledge related to the innovation goal and practical condition and describe them as matter-elements, affair-elements or relation-elements. Then, utilize the methods of Extension Theory to systematically analyse the goal and condition matter-elements to generate corresponding extension network for further discovering creative solutions that could overcome a dilemma or a trade-off between two contradictory elements. After this step, we could get a systematic cube for integrated information (Li, Qu, et al. 2009).

Step 2. Innovation path choosing

   Figure out the way along with the goal, condition, or both to search feasible propositions that would overcome the contradiction of the innovation problems.

Step 3. Transformation and find primary solutions

   Apply basic transformation method, combination transformation method or transforming bridge method to transform the area (or range) of the innovation goal/condition matter-elements that are already explored by Step 2, or the evaluation rules.
Step 4. Integration and evaluation of primary solutions
Evaluate the solutions which are generated through Step 1 to Step 3 by Appraisal method, resulting in trustworthy innovation proposals.

3.4. Solutions for Implementation

Creative capability is a dominant creativity, a kind of human social nature, and is formed through kinds of postnatal educations and trainings, and is closely related with human’s knowledge and experiences, that is postnatal training.

Innovation capability refers to the ability that a person (innovation subject) is able to get novel achievements through some activities in an ideal environment. The so-called ideal environment is a kind of imaginary “a path strewn with roses” on which “everything goes well” and there isn’t any negative effect for the innovative subject. The purpose of making such an assumption is to limit those uncertain changeable quantities, so as to easily get close to the essence of innovation capability. But actually, a person’s ability to comply with or transform environment should also be included in innovation capability. It is in the adversity that perseverance and willpower are necessary and meaningful.

We extract the elements affecting innovation capability promotion, integrate the methods and means in Extenics and Creativity Study and present a Creativity training model. Its five stages for solving problems are:

- Problem finding: including preparation, discovery of problems or difficulties, insight into the problems, etc.
- Seeking solutions: including incubation, looking for applicable materials, information, resources, analysis, memory deposit and assessment, processing, brainstorming, exploring, and experiments on various ideas, etc.
- Select the best solution: including illumination, integration, verification, generation of new answers, discovery of solution, and perception, etc.
- Assessment and validation: including verification, evaluation, accomplishing, acceptance, and generation of theories or framework, etc.
- Publishing and application: including communicating the results, putting into practice, explanation and utilization of the results, etc.

4. Case Study

Based on sufficient surveys and arguments, Hebei Chemical & Pharmaceutical College started the teaching and experimental research program, in which the college offered training courses to cultivate students’ innovation capability. The program goes through two stages: Creativity Study Theory mainly used; and “Creativity Study + Extenics” theory comprehensively used.

Stage 1 started from 1998 to 2009, in which the courses constructed by using human creativity development theory of Creativity Study.

The Course Contents are as following:

2. Barriers of Creation and Sweeping Barriers.
3. Creative Thinking and Creative Thinking Training.
5. Evaluation of Creative Achievement and Parent Application.

Classroom teaching and creative extracurricular activities were carried on and formed a mode including the following five steps:

1. Motivate Creative Consciousness.
② Understand Knowledge of Creativity Study.
③ Develop Creative Thinking and Cultivate Creative Personality.
④ Impart Creative Principles and Techniques.
⑤ Organize practical activities focusing on solving problems. The research focus of this mode is to develop creative thinking and cultivate creative personality.

The teaching actual effects proved that offering foundation courses of Creativity Study complied with students’ individual development. Through learning foundation courses, students’ concepts were updated. Their awareness on matters’ shortcomings and their sensitivity to problems aroused, and their creative consciousness inspired. Changing thinking patterns, breaking with the thinking set and developing creative thinking provides a novel train of thought to solving problems. Creative rules, principles, techniques, methods are mastered by students, which consequently promote the efficiency of creatively solving problems. However, we found that some ability trainings need to be further improved, such as the ability of comprehensive divergent thinking, association, solving problems, and network resource integration. Therefore, we started the second stage.

Stage 2, from 2009 to the present, Extenics is used to enrich the existing course. Concerning the major influential factors, the course combines Creativity Study and Extenics, chooses the suitable, practical and available parts according to the students’ features to design the course contents. And teaching experiments has been carried on for three years. In the recent 3 years, students have got 46 awards in National Invention Cup, 36 awards in Hebei “Challenge Cup” (Extracurricular Academic Works Innovation Contest) and obtained 42 authorized patents.

Our practical results prove that comprehensively using “Extenics plus Creativity Study” can more efficiently train students’ comprehensive divergent thinking, associative ability, problem solving ability and the ability to use and integrate network-based information resources, which will be helpful to comprehensively promote college students’ innovation capability as well as their learning ability.

5. Conclusion and Further Research Directions

In this paper, we systematically analyzed individual innovation capability form the angles of micro-foundation, thinking methods and innovation methods, and studies the features of Creativity Study and Extenics in promoting individual innovation capability. We draw the following conclusion: there are complementary advantages in Creativity Study and Extenics; Creativity Study has the functions, such as “invisible guide”, “intellectual excitation” and optimizing the creation of environment. Meanwhile Extenics has the specialties, such as information primitives, systemic thinking, and routing innovation. At the present, the combined method of Extenics and Creativity Study is simple, at the lowest cost and the most sufficiently in promoting innovation capability of college students according to our practice.

Our practical results prove that comprehensively using “Extenics + Creativity Study” can more efficiently train students’ comprehensive divergent thinking, associative ability, problem solving ability and the ability to use and integrate based on network information resources, which will comprehensively promote college students’ innovation capability as well as their learning ability.

In the following research, we will design a systematic program form ideas and theories to methods and tools. We will operate the program in teaching practice, and compare more groups and analyze the efficiency through practice.

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