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How to Improve Divergent Thinking Capability by Information Technology and Extenics

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Abstract

Divergent Thinking capability has become increasingly important for innovation and problem solving. We need efficient and effective ways to support the divergent thinking process. Based on Basic-element theory of Extenics, a new model to improve the divergent thinking capability has been developed using information management and extension transformation. With the guide of the extension innovation method, we collect attributes of different things through information technology on the web, and then extend many divergent thinking directions systematically. The case study shows it is helpful as a common innovative approach to improve divergent thinking capability by integration of information technology and Extenics.

Keywords: Divergent thinking capability, information technology, knowledge management, Basic-element theory, Extenics;

1. Introduction

As a kind of thought process or method, divergent thinking is useful to generate creative ideas by exploring many possible solutions. Divergent thinking is an important component of creative thinking and its process [1]. By divergent thinking, many ideas and possible solutions are explored in a short amount of time, and unexpected connections are drawn.

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However, divergent thinking typically occurs in a spontaneous, free-flowing manner, many ideas are generated in an emergent cognitive fashion. After the process of divergent thinking has been completed, ideas and information are organized and structured using convergent thinking[2].

There are several activities which promote divergent thinking including creating lists of questions, setting aside time for thinking and meditation, brainstorming, subject mapping / "bubble mapping", keeping a journal, creating artwork, and free writing[2] . But most of these methods are rely on one's experience and thinking ability, for example, in free writing, a person will focus on one particular topic and write non-stop about it for a short period of time, in a stream of consciousness fashion.[2]. These methods make use of a group of experts, along with amounts of time and depend on personal intelligence which would subject to limitations of individuals themselves[3].

A lots of personality traits also promote divergent thinking such as nonconformity, curiosity, willingness to take risks, and persistence[4]. But it's not easy to change a person's personality traits in a short time, human's divergent thinking capability still relies on experience knowledge or personality traits, there is no such efficient methods on which people can find out all possible ideas scientifically .

With the developing of information technology, especially the World Wide Web and its applications such as new social network and media, we live in a society with enough information to support generating of new ideas by divergent thinking[5]. For example, search engine, web crawler, data mining and knowledge management will benefit divergent thinking capability potentially. However, there is no enough research to explore the method to improve divergent thinking capability by information technology systematically.

To overcome such shortages, the purpose of this paper is to propose a new innovation method framework that would support our divergent thinking capability both theoretically and practically. The rest of the paper is organized as follows. Section 2 discusses the main existing methods on divergent thinking. Section 3 provides a framework and process to collect systematic information. Section 4 presents a transformation model to generate divergent thinking ideas and solutions. Section 5 introduces a case study of the method, followed by a brief summary and some future research scopes in Section 6.

2. Literature Review

Divergent thinking tasks usually involve thinking of as many possible solutions to a given problem as possible [6], Lewis and Lovatt found that participating in verbal and music improvisation increases scores on a divergent thinking task, suggesting that improvisation may enable people to break away from set patterns of thinking as influenced by schemas[6,7]. Twenty minutes of verbal improvisation or Twenty minutes of music improvisation significantly improved scores of divergent thinking.

Formerly there is a framework discusses five dimensions of thinking: (1) metacognition; (2) critical and creative thinking; (3) thinking processes, such as concept formation, problem solving, and research; (4) core thinking skills, the "building blocks" of thinking--including focusing, information-gathering, organizing and generating skills; and (5) the relationship of content-area knowledge to thinking [8].

There are also other methods can be used to improve divergent thinking, such as "5W2H" (Why, What, Where, When, Who, How, How much), Osborn Checklist method [9] and Attribute Listing Technique (ALT). Brainstorming can makes participants be enlightened by others [9,10] for creative problem solving and divergent thinking. On the contrary, Six Thinking Hats [11] combining with the idea of parallel thinking provides a means for groups to think together more effectively. It is effective in seeking a reasonable solution by analyzing some problems from a variety of views [12]. But the ideas created still mainly rely on participants' experience and knowledge.

Eight core processes for the effective execution of creative thinking are presented as: (a) problem definition, (b) information gathering, (c) information organization, (d) conceptual combination, (e) idea generation, (f) idea evaluation, (g) implementation planning, and (h) solution monitoring. Effective execution of these processes, in turn, depends on people applying requisite strategies during process execution and having available requisite knowledge [13].

Self–other integration and action corepresentation are controlled by domain-general cognitivecontrol parameters that regulate the integrativeness of information processing [14].

Extension innovation method [15] is used to improve innovation capability combines qualitative presentation and quantitative analysis together based on Extenics[16,17]. Since Extension innovation method is based on Mathematics

and information technology, it is a new way for improving divergent thinking capability. In the future, these methods need making further efforts to integrate with the usage of information technologies and the internet.

3. Information Preparing

3.1. Systematically Information Collecting Theory

Basic-element theory [17] defines basic elements of "matter-element", "affair-element" and "relation-element" for modeling the goal and conditions of innovation. It provides formalized languages that describe knowledge and information. The basic-element theory is a guide to collect information and think in a systematical way. Dynamic matter with multiple characteristics can be expressed as

$$M(t)=\begin{bmatrix} O_m(t), & c_{m1}, & v_{m1}(t) \\ & c_{m2}, & v_{m2}(t) \\ & \vdots & \vdots \\ & c_{mn}, & v_{mn}(t) \end{bmatrix}=(O_m(t),\ C_m,\ V_m(t)) \tag{1}$$

By web technology, we can collect more attributes from website or fill in by volunteers worldwide on the web, such as what Wikipedia do. *Volunteers worldwide collaboratively write Wikipedia's 30 million articles in 287 languages, including over 4.4 million in the English Wikipedia. Anyone who can access the site can edit almost any of its articles*. (http://en.wikipedia.org/wiki/Wikipedia)

As to a given matter, it has corresponding measure value about any characteristic, which is unique at any moment as shown in equation (1). The building of basic elements base can help us to thinking in multi-dimensions by using matters' multi-attributes and interactive relations among them.

3.2. Systematic Information Collecting Method

Any object or attribute can be classified into the *material* and *non- material*, the *soft* and *hard*, the *latent* and *apparent*, the *negative* and *positive* parts [17]. Based on extension methods, we collect information and knowledge related to the topic by information searching engine, keywords extraction or content management from the Web, local data base or knowledge base, and then save them in base of matter-elements, affair-elements or relation-elements. Then we extend attributes information to 8 aspects by conjugate analysis that is in the view of material and non-material, the soft and hard, the latent-apparent and the negative-positive parts.

Information benefit divergent thinking also has four parts and 8 aspects as following.

Information of material part and non-material part: For example, the demand for a product's entity is its *material* part, while its brand and reputation are its non-*material* part information.

Information of Soft Part and Hard Part: Considering a matter's structure, the matter's components are the hard part, the relations between the matters and its components are the soft parts. "Three heads are better than one", three persons are hard parts. Their cooperation relations are the soft parts.

Information of Latent Part and Apparent Part: things change continuously. Disease has its latent period; an egg can hatch into chicken at a certain temperature after a certain time. We need think both latent information and apparent information for innovation. For example, students in class currently will become teachers after ten years.

Information of Negative Part and Positive Part: The part act the positive role in the measure of matter about certain characteristic is defined as the positive part, and the part acting the negative role in the measure of matter about a certain characteristic is defined as the negative part. For example, side effect of medicine is negative part for patients.

The structure of matters guides us to build the information map by using matters' multi-attributes and interactive conjugations relations among them. Based on the basic-element theory, we can collect data and information systematically. Finally we can systematically generate a sub-set of extension information cube [18].

4. Divergent thinking on information Transformation

4.1. Basic Transformation Methods

Based on Extenics [17], we use 5 basic transformation methods to support our divergent thinking.

(1) Substitution transformation

$T\Gamma = \Gamma'$, i.e. As to basic-element $B_0(t)=(O(t), c, v(t))$, if there is certain transformation T that transforms $B_0(t)$ to $B(t)=(O(t), c, v(t))$, i.e. $T\,B_0(t)= B(t)$, then the transformation T is referred to as substitution transformation of basic-element $B_0(t)$.

$$T = \begin{bmatrix} \text{substitution}, & c_{T1}, & \Gamma \\ & c_{T2}, & \Gamma \\ & c_{T3}, & \Gamma' \\ & \vdots & \vdots \end{bmatrix} \tag{2}$$

(2) Increasing/Decreasing transformation

The increasing transformation refers to increase certain attributes of the element. For example, as to matter-elements M_0= (table A_1, height, 0.8m), M= (chair A_2, height, 0.5m), M is increasable matter-element of M_0, we make $TM_0=M_0 \oplus M$= (table $A_1 \oplus$chair A_2, height, 1.3m), then T is increasing transformation of M_0.

Decreasing transformation refers to decrease certain attributes of the element. In the production process, the reduction of redundant action or work procedures belongs to the decreasing transformation of event-element, which can significantly improve production efficiency.

(3) Expansion/Contraction transformation

$T\Gamma = \alpha\Gamma$, i.e.

Quantitative expansion transformation is multiple quantitative expansion of basic-element. As for matter-element, its quantitative expansion transformation will inevitably lead to expansion transformation of the matter. For example, the volume expansion of a balloon will inevitably lead to expansion of the balloon itself.

$$T = \begin{bmatrix} \text{expansion} \vee \text{contraction}, & c_{T1}, & \Gamma \\ & c_{T2}, & \alpha \text{ multiples} \\ & c_{T3}, & \alpha\Gamma \\ & \vdots & \vdots \end{bmatrix}, \tag{3}$$

It is expansion transformation when α>1, and contraction transformation when 0<α< 1.

(4) Decomposition/Combination transformation

$T\Gamma = \{\Gamma_1, \Gamma_2, ..., \Gamma_n\}$, wherein, $\Gamma_1 \oplus \Gamma_2 \oplus ... \oplus \Gamma_n = \Gamma$, i.e.

$$T = \begin{bmatrix} \text{decomposition}, & c_{T1}, & \Gamma \\ & c_{T2}, & \Gamma_1 \oplus \Gamma_2 \oplus ... \oplus \Gamma_n = \Gamma \\ & c_{T3}, & \{\Gamma_1, \Gamma_2, ..., \Gamma_n\} \\ & \vdots & \vdots \end{bmatrix}. \tag{4}$$

Decomposition transformation refers to divide one object or attributes into several pieces. On the contrary, Combination transformation refers to combine several objects or attributes into a whole one. For example, one action can be executed in several steps.

(5) Duplication transformation

Duplication is a special basic transformation extensively applied in the field of information, such as photo-processing, copying, scanning, printing, disc carving, sound recording, video recording, the method of reuse, and reproduction of products, etc. After implementation of duplication transformation, the object is transformed to at least two objects, i.e. the original object and the duplicated object, or to multiple objects.

4.2. Framework of Divergent Thinking Model

According to basic-element theory, conjugation analysis and basic transformation methods as shown in equation 2-4, we designed a framework of divergent thinking model as showing in figure 1.

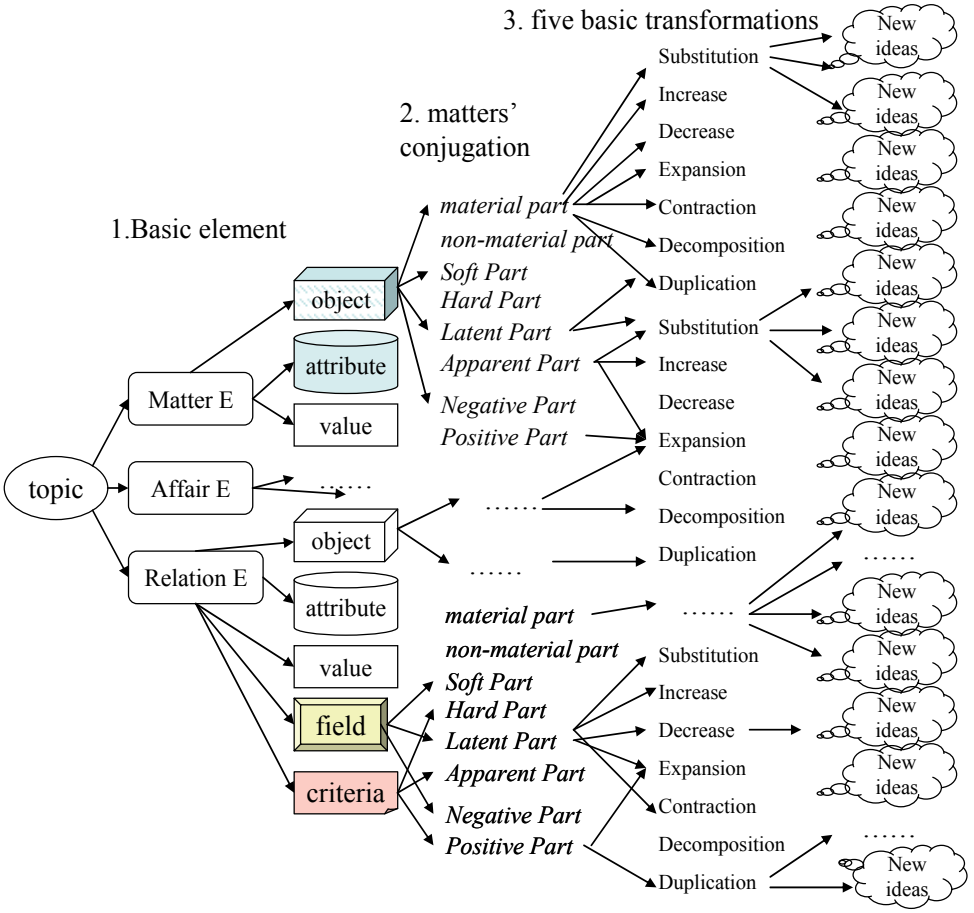

Fig. 1. a framework of divergent thinking model.

After a topic is put forward, we describe it in matter element, affair element or relation element, and search all attributes and possible values from data base. Then extend them to 8 aspects by conjugation analysis. Besides basic elements, we also think about the field (or domain) where and when the topic belongs to, and the criteria (the rules to judge what is good or bad for the topic). Finally, we obtain several new ideas by transforming the objects, attributes, value, field and criteria with five basic transformation methods one by one.

4.3. Steps to Obtain new Ideas by Basic Transformation Methods

Step 1. Build basic-element model as the base for transformation by methods introduced in section 3.
Step 2. Collect as many as values for certain attributes.
Step 3. Try to do five basic transformations on each attributes one by one, and write down innovation ideas.

For example, using the value of shape V_s and materials V_m, we can obtain several ideas by substitution transformation:

$$M_0 = [flowerpot_0, shape, \text{circular}]$$

$$\left\{ \begin{array}{l} M_1 = [flowerpot_1, shape, \text{elliptical}], M_2 = [flowerpot_2, shape, half-\text{circular}] \\ M_3 = [flowerpot_3, shape, \text{square}], M_4 = [flowerpot_4, shape, \text{star}] ..... \end{array} \right\}$$

A half-circular shaped flowerpot can be hung on the wall, which can surprise new comers by looking like it is embed in the wall.

A star-shaped flowerpot can plant 6 flowers together and leave more innovation spaces. As for the materials,

$$M_0 = [flowerpot_0, material, \text{ceramic}]$$

$$\left\{ \begin{array}{l} M_1 = [flowerpot_1, material, \text{paper}], M_2 = [flowerpot_2, material, plastic] \\ M_3 = [flowerpot_3, material, \text{wood}], M_4 = [flowerpot_4, material, \text{glass}] ..... \end{array} \right\}$$

We can design a flowerpot made of glass, the roots of flowers will be observed clearly.

By combination transformation and conjugate analysis, we can get an idea of art fashion flowerpot made of stainless steel as following.

$$M_5 = \left[\begin{array}{lll} flowerpot_5 & function, & \text{art fashion} \\ & filling, & water \\ & material, & \text{stainless steel} \end{array} \right]$$

By increasing transformation, we can add an indicator of humidity of soil to the flowerpot, which will tell us if it needs to water. Also, water supply degree will display by different colors.

We also use the framework of the model in public classes. One of the results is presented in Section 5.

5. Case Study

In classes we designed two questions to test the divergent thinking capabilities of sophomores. One question is "A junior school student only got 56 scores in his English examination, but his father treated him a big dinner in Macdonald happily. That's strange. Please give explanations as many as possible in 10 minutes."

We tested students in 6 groups at the first lesson before our training; most students can only find 3-9 reasons. After 5-week-lesson, we tested students with another question which has the same difficult degree and as many as the same elements.

Lifting degree indicate the improving degree, define D_{old} as the value of the former one, D_{new} as the new one, Lifting degree l denotes as

$$l = (D_{new} - D_{old}) / D_{old} \times 100\%$$

By testing on 185 students in NIT, Zhejiang University, The average lifting ratio is 157.82%.

The second question is "please think about the functions of a cup made of glass as many as possible in 15 minutes". Without the model, the students present 9.1 functions averagely. After training, most of them can think out 18-28 reasons.

6. Conclusions and future work

The paper presents a framework of divergent thinking model and its process based on Basic-element theory and transformation methods of Extenics. It helps us think from 3 directions and 8 aspects by conjugate analysis. Based on the model, we successfully helped students think in formularized expression rely little on their experience and enlarge their view with support of a thinking tool. The practices in class proved its effectiveness.

However, we only use a small part of Extenics. More theories will be applied further in innovation educations, such as extension set theory and extension logic. Since the significant importance of information management and knowledge management, the research on combination of Extenics with web information technology, data mining or intelligent knowledge management would be further explored.

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