China's Young Inventors:
A Systemic View of the Individual and Environmental Factors

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ABSTRACT

The focus of the current study is the individual and environmental attributes of inventiveness among children and adolescents. Research was conducted on the young inventors who were part of a nation-wide inventive ideation contest for children and adolescents in P. R. China. A total of 621 (303 boys, 318 girls, *Mage* = 13.9, *SD* = 2.5) 4^{th} to 12^{th} grade students from 112 schools all over China participated in the study. Among them, 38 (20 boys, 18 girls, *Mage* = 14.9, *SD* = 3.3) reported holding one or more patents. Independent *t*-test showed, compared to their lower-level counterparts, higher-level young inventors were more intrinsically motivated for inventive endeavours and were more open to new experiences. They also reported more encouragement and resources for invention from their schools. Logistic regression showed that school encouragement made the major contribution in discriminating these two groups. 2×3 MANONA revealed a significant main effect of gender and age group but no significant interaction between the two factors. Results of the univariate tests challenged the stereotyped view against the inventive ability of girls. Girls scored higher in Openness and lower in executive thinking style. The aesthetic appeal of their inventive products was also rated higher by experts. Albeit this superiority, girls, however, reported less encouragement from their parents to make inventions. Results of the cross-sectional study of the different age groups did not support a hypothesized growth of inventiveness from the lower to the higher grades. Instead, an uneven developmental pattern in inventiveness and the relevant domains were revealed, which was on the large part attributed to the influence of the educational environment. Taken together, the results of the current study highlight the important role the environmental factors play in fostering or hindering the development of inventiveness among children and adolescents.

***Keywords:* inventive creativity, inventiveness, systems approach, Investment Theory of Creativity**

"We live only by the grace of inventions: not merely by such invention as has already been made, but by our hope of new and as yet nonexisting inventions for the future."
(Wiener, 1993, p. 3)

INTRODUCTION

Human civilization is an accumulation of innovations, inventions, creations, and discoveries (Tan, 2000a). Inventions are regarded as the "keystone" and "life-blood" of the existence of human society (Rossman, 1964). From candles to electric light bulbs, from bicycles to airbuses, from paper clips to copy machines, our life is pervaded with inventions. Despite the unquestionable importance of invention, however, inventors and their social environments remain under-investigated in the field of psychology. A literature search (done in early 2009) in PsycINFO and PsycBOOKS with "inventor" and "empirical study" as key words resulted in only 63 entries. An examination of these pieces of literature revealed that while most of the studies were examining inventing individuals or processes from an industrial or managerial perspective, only very few focused on the psychological profile of the inventors (e.g., Colangelo, Assouline, Kerr, Huesman, & Johnson, 1993; Henderson, 2004a, 2004b; Rossman, 1964). So far our understanding of inventors from a psychological point of view remains limited.

There are several reasons why studies about inventors are underrepresented in the field of creativity research. One of the primary reasons lies in a range of myths about invention or inventors that most people hold. Among others, the view of "invention must be BIG" might be the most prevailing. Unarguably, it is great inventions, such as electricity, the steam engine, the airplane, and computers that have brought revolutionary changes to our society. But invention cannot be only viewed in such a narrow way. As a matter of fact, our daily life is full of more *small* inventions[1], such as postage stamps (invented by Rowland Hill in 1837), paperclips (patented by Johan Vaaler in 1901), coat hangers (patented by O. A. North in 1869), blue jeans (co-patented by Levi Strauss and David Jacobs on May 20,

[1] All the examples of the small inventions were retrieved from http://inventors.about.com/. This website rather than others was quoted because of the recommendation of Henderson's (2004b).

1873), and the portable hair dryer (patented by Harriet J. Stern in 1962), and so on. It is only because we are so used to the small inventions that we no longer see them.

Another myth that is closely related to the "BIG" myth is that "invention is an adult (particularly male adult) thing". The conclusion is made predominantly on the basis of the cognitive presumptions of creativity, which are: the production of effective novelty, which is essential for creative achievement, requires formal operations or even metasystematic operations (Cropley, 1999) and self-evaluation (Rosenblatt & Winner, 1988). Due to his low level cognition, a child's creative production may be novel, spontaneous, uninhibited, and even aesthetically pleasing, but often lacking accuracy and effectiveness. These theories, however, ignore the fact that most inventors started their inventing endeavors when they were very young and some even made real inventions in their teens. For example, it was reported that by his early teens, little Edison had already designed and perfected his first real invention - an electrical cockroach control system. It was also reported that at the age of 14, Bell invented a rotary brush device to remove husks from wheat in the flour mill run by his friend's father[2]. Besides these well-known cases of prominent inventors, there is also empirical evidence for the existence of young inventors. Among the 710 subjects of Rossman's (1964) study about adult inventors, most of them had obtained their first patent between the ages of 15-30 (quoted by Henderson, 2004b, p. 110). In their biographical study of 34 adult inventors who received agricultural and industrial patents, Colangelo and his colleagues (1993) asked the adult inventors to describe their family and school life. All inventors reported making some gadgets or modifying tools or toys (these are sort of "little-c" inventions) by the age of eight.

Although the creativity of very young children might be only a total "expressive spontaneity" (Taylor, 1975), there seems to be no proof that a child older than ten cannot create things that are both original and useful. In contrast, developmental psychologists have found that with increased experience with the external world and the development of formal operational thinking, children older than ten, in the main, are able to take account of external constraints and conventional values and they are able to transcend these constraints and make effective creativity (Rosenblatt & Winner, 1988; Smith & Carlsson, 1983). Meanwhile, literature about inventors has provided evidence that children and adolescents do invent. This fact is of particular importance to primary and secondary

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[2] Information retrieved 18 March 2008 from http://inventors.about.com/od/articlesandresources/a/great_thinkers_2.htm

education, as creativity among children is something that usually remains hidden unless it is identified and fostered. Compared to the limited knowledge about adult inventors, our ignorance of young inventors is even greater. More research is needed to help us fill in this knowledge gap, thus enabling us to better prepare our future inventors at an earlier age.

To gain a better understanding of the young inventors, a systemic approach is necessary. Although different scholars have varying preferences to name this approach, such as "congruence" (Sternberg & Lubart, 1991), "interactionist" (Treffinger, Sortore, & Cross, 1993), "systems" (Csikszentmihalyi, 1988; Shi, 1995) or "synthetic" (Heller, 2007; Heller, Perleth, & Lim, 2005), there is a common consensus among the scholars that an excessively individualistic perspective is insufficient to reveal the complex nature of creativity. Creativity of a person involves an interaction of multiple factors in and outside the person and can, therefore, be optimally examined only if both the *individual* and the *environmental* variables are taken into account. Among others, the Componential Theory of Creativity (Amabile, 1983a/b, 1996), the Systems Theory of Creativity (Csikszentmihalyi, 1988, 1994, 1999), and Investment Theory of Creativity (Sternberg and Lubart, 1991, 1992, 1995, 1996) are the most influential systems models of creativity.

At the individual level, the importance of intrinsic motivation has long been recognized. From the humanistic perspective, creativity is a manifestation of self-actualization (Maslow, 1976). Intrinsic motivation is identified as an integral component of many creativity models, including the componential model of creativity (Amabile, 1983a/b), the investment theory of creativity (Sternberg & Lubart, 1991, 1992, 1995, 1996), and the interactionist model of creative behavior (Woodman and Schoenfeld, 1989, 1990). In the interactive approach, which focuses on the development of an individual's creativity within society, Csikszentmihalyi (1990a) and Gardner (1993) both included intrinsic motivation as a personal characteristic that contributes to creativity. In the field of invention, love for work, passion, and enjoyment have been mentioned by many inventors as their major reasons to invent (Colangelo, Kerr, Hallowell, Huesman, & Gaeth, 1992; Colangelo et al., 1993; Henderson, 2004a, 2004b; Rossman, 1964). Intrinsic motivation is of particular importance for invention maybe because invention is a highly challenging and recursive process which does not necessarily lead to an immediate reward, thus requiring a great deal of motivation to persevere in the effort.

In close relation to intrinsic motivation, there exist creative personality traits. Numerous studies have shown that creative individuals share some common personality traits, including openness to experience (Dollinger, Urban, & James, 2004; Helson, 1999b; MacKinnon, 1992; McCrae, 1987), tolerance of ambiguity (Barron & Harrington, 1981; Golann, 1963; Sternberg & Lubart, 1995; Urban, 2003), and risk-taking (Barron, 1963; Getzels & Jackson, 1962; Kaplan, 1963; Zuckerman, 1979). These personality traits are of particular relevance to inventors, because, unlike scientists who mostly deal with an *ideal* world and artists with an *imaginary* world, inventors predominantly deal with a *practical* world, where trade-off between novelty and practicality as well as estimation of cost-effectiveness are essential to determine the value of an invention. In other words, compared to other creators, inventors are more subject to the evaluation and scrutiny of society. Therefore, personality traits such as openness to experience, tolerance of ambiguity, and risk-taking are of particular importance for inventors.

While motivation concentrates on an individual's source of drive and personality on specific trait, cognitive style is defined as a complex characteristic related to information processing (Zelniker, 1989) and one's perceptual orientations to the physical and social environment (Haensly, 1999). Most importantly, cognitive style is conceptualized to be an *interface* between cognition and personality (Sternberg & Grigorenko, 1997). Based on the Theory of Mental Self-government, Sternberg (1988, 1997) proposed 13 different types of thinking styles, which were categorized by later studies into three major types. These types include thinking styles which generate creativity, such as legislative, judicial, and liberal thinking styles (Type I), thinking styles that are norm-favoring, such as executive and local thinking styles (Type II), and finally thinking styles which may manifest the characteristics of Type I and Type II thinking styles depending on specific tasks (Type III) (Zhang & Sternberg, 2005). Creativity-generating (Type I) thinking styles donate higher levels of cognitive complexity and have been found to be positively related to creativity (Niu, 2007; Sternberg, 1988; Sternberg, 1996; Zhang & Sternberg, 2005). With regard to invention, however, there seems to be no study examining inventiveness from the perspective of thinking style.

For decades, researchers have been seeking to reveal the relationship between intelligence and creativity and different types of relationships have been assumed (see Sternberg & O'Hara, 1999). Though the complex relation between these two constructs has not led to an overall agreement on the intelligence-creativity relationship, one of the robust findings in the literature seems to be the *threshold* theory: the two are moderately positively related (r of approximately +.20 to +.30) up to about 1 standard deviation above the mean in IQ (approximately 115-120) and then the relation becomes essentially zero (Albert & Runco, 1989; Barron, 1957; Barron & Harrington, 1981; Eysenck, 1995; Getzels, 1987; Gough, 1976; Helson & Pals, 2000; Jensen, 1996; MacKinnon, 1978; Simonton, 1999a; Sternberg & O'Hara, 1999; Torrance, 1980; Wallach & Kogan, 1972). Meanwhile, Simonton (2000) summarized that there is a clear shift of psychologists from the traditional investigations of superior intelligence (e.g., Galton, 1869; Terman, 1925) to a minimal relation of intelligence and creative work (e.g., Barron & Harrington, 1981) and further to multiple perspectives for all (e.g., Gardner, 1983, 1993; Guilford, 1967; Sternberg, 1985a). Regarding the specific aspects of intelligence that might be related to inventiveness, Colangelo et al. (1992) stated that mechanical inventiveness constitutes its own set of skills and abilities, which might compose *spatial, logical-mechanical,* and *bodily-kinesthetic intelligences*.

Examining the relationship of knowledge and creativity, another *threshold* notion has been suggested (Sternberg & Lubart, 1991). That is, one needs to know enough about a specific field to make creative achievements and below certain level of knowledge creativity is not possible. In the field of invention, there seems to be an agreement on the importance of domain-specific knowledge among professional inventors (Henderson, 2004b; Lemelson-MIT Program[3], 2003, 2004; Rossman, 1964). But it is worth noting that knowledge from other disciplines can also be conducive for invention. One of the most famous examples is the invention of telephone. Born into a family of authorities in elocution and the correction of speech, Alexander Graham Bell got systematic education in the same specialty and was pursuing a teaching career in a school for deaf people before he invented the telephone. It is believed that the knowledge of the nature of sound led him to the invention of the telephone.

[3] The Lemelson-MIT Program was established in 1994 at the Massachusetts Institute of Technology by one of the world's most prolific inventors, Jerome Lemelson (1923-1997) and his wife, Dorothy. The content quoted in this dissertation is mainly from two reports of this program, including "*The architecture of invention" (2003)* and "*Invention: Enhancing inventiveness for quality of life, competitiveness, and sustainability*" *(2004).*

Social environments refer to the characteristics of family, school, community, and culture that surround the individual (Niu, 2007). Over the past decades of research, a number of developmental antecedents (including those at home and school) of creativity have been documented by adopting a case-study or a retrospective design with eminent creative achievers (e.g., Gardner, 1993; Gruber, 1988; Simonton, 1997, 1999a). Referring to the examination of the family and school environments for the creativity of children and adolescents (little-c), there are only a handful of studies, most of which were carried out two decades ago. These studies show that creative individuals typically come from families or schools that stress independence, flexibility, and self-exploration (Heck, 1978; Kaur, 1986; Misra, 1987; Olszewski, Kulieke, & Buescher, 1987). Few, if any, studies have been conducted in recent years to examine the family and school environmental attributes of creativity among children and adolescents (e.g., Niu, 2007). As a systems approach attaches great importance to the environmental factors, our view of inventiveness would not be complete without taking the environmental factors into consideration.

The perspectives discussed above are the six sources of creativity proposed by the Investment Theory of Creativity (ITC; Sternberg & Lubart, 1991, 1992, 1995, 1996). The design of the current study is based on this theory with the aim to examine inventiveness among children and adolescents in a systemic way. Since this model has not yet been applied to any studies about inventiveness to date, one of the prime tasks of this current conduct is to verify its applicability to such a study. Nevertheless, it is hardly feasible to propose a working, yet not tested model and immediately embark on an international comparative level. It is, therefore, more reasonable to limit the scope of the study. Chinese is a language that I command as mother tongue, so my personal background contributed to selecting China as the place of research. The study was so designed that it particularly befitted young inventors and their individual and environmental attributes of inventiveness for the course of this research.

Before moving on to the next chapter, it is necessary to state some of the principle assumptions which constitute basic premises for the current study:

(1) Creativity in the current study is perceived as a specific giftedness. This assumption draws its basis from the mainstream theories developed in the 1980s and 1990s about giftedness, which incorporates creativity as an independent talent factor of a multi-dimensional and typological ability constructs of giftedness (see Heller, 2007 for a review). This assumption provides justification for the application of a giftedness model – Munich Model of Giftedness (MMG; Heller, 1992; Heller et. al, 2005) to provide a structure mode for the current study.

(2) Inventive creativity or inventiveness is conceptualized as a distinct form of creativity. This assumption is in line with the existing concepts and theories about invention/inventors that have been constructed both by psychologists (e.g., Colangelo et al., 1993; Tan, 2005; Taylor, 1975) and researchers from the disciplines outside of psychology, including engineering, technology, history and physics, advertising and public relations, etc. (Lemelson-MIT Program, 2003, 2004; Perkins & Weber, 1992). The major implications of this assumption are: (a) inventiveness shares some basic criteria with creativity, for example, originality and usefulness. Of course, besides these two criteria, inventiveness also emphasizes other criteria which will be described in detail in the next chapter; (b) Inventors share with creators of other fields some distinct cognitive and non-cognitive personal traits. This assumption makes it legitimate for the current study to refer to literature about creativity studies in other fields.

(3) Inventiveness, like creativity, is a product of the interaction between a variety of individual and environmental factors. This assumption is a manifestation of a multi-dimensional view of inventiveness and is consistent with a systems approach to creativity that the current study takes (see above).

(4) In the current study, invention is defined as a creative daily problem solving process leading to a product that has the potential to be patented according to the existing patent law. The underlying assumption of this definition is that inventiveness is a special kind of real-world problem solving or product design ability. It is a combination of Taylor's (1975) conceptualization of "inventive creativity" as solving old problems in new ways and Weber's (1996) systematization perspective of viewing invention as also including design. This assumption extends the traditional concept of invention which has an exclusive emphasis on engineering and technology to the broader sphere of daily life, thus making it possible to examine this phenomenon among children and adolescents whose cognitive level related to engineering and technology are relatively lower.

(5) Young inventors share a majority of commonalities with adult inventors. Therefore theories about adult inventors are applicable to young inventors. This assumption is based on a series of studies that Colangelo and his colleagues (1992; 1993; 2003) have done about adult and young inventors. Their investigations show that young inventors are similar to adult inventors and different from adult and young non-inventors in terms of personality, biographical, and behavioral characteristics associated with inventiveness. These results provide a justification for literature reviews about adult inventors as a compensation for the lack of literature about young inventors.

To conclude, the literature review of psychological studies of creativity has revealed two obvious gaps. Firstly, the existence of a young inventor group seems to be neglected and few studies have been conducted to examine inventiveness among children and adolescents. Secondly, in spite of the call of the creativity research field to study creativity by applying a systems approach, studies taking such an approach are hard to find. The current study is designed to fill in these gaps and help us gain understanding of a group of China's young inventors in a systematic way. To be more exact, the current study seeks to answer the following research questions:

1. How the individual and environmental factors are related to one another in predicting the inventiveness of young inventors?

2. In which individual and environmental aspects do the higher- and lower-level young inventors differ?

3. In which individual and environmental aspects do male and female young inventors differ?

4. In which individual and environmental aspects do young inventors of various age groups differ?

Apart from comparing higher- and lower-level young inventors, a descriptive analysis of the biographical data of the patented inventors (higher-level group) as well as their inventions will be presented, with the aim to provide answers to the following question:

5. Who are the young inventors and what do they invent?

Due to the lack of literature of systems studies about young inventors, the current study primarily serves the purpose of exploring the hitherto questions raised above.

CHAPTER 1 - REVIEW OF LITERATURE

1.1 Inventive creativity (or inventiveness) and relevant concepts

The focus of the current study is a special kind of creativity that is closely related to the process of invention. Invention involves creativity. Researchers agree that invention is a manifestation of creativity (Tan, 2000a; Udell, Baker, & Albaum, 1976; Westberg, 1996). This chapter will review the major literature in the psychology field about the conceptions of creativity, invention, inventive creativity, and the relationship and differences among these concepts.

1.1.1 Definitions of creativity: Controversies and agreements

Creativity is regarded as "one of the most complex and fascinating dimensions of human potential" (Treffinger et al., 1993, p. 558). Maybe because of its complex nature, there is no universal definition for creativity yet. Parkhurst (1999) summarized the major controversies in the field of psychology about the definitions of creativity, which can be categorized as follows:

Controversy 1: Creativity as divergent thinking. Guilford (1956, 1986), in his well-known theory of the structure of intellect, defined creativity as divergent thinking, with which an individual generates responses of both high quantity (fluency) and quality (flexibility and originality) to a question. Assessments based on this concept of divergent thinking, such as the Torrance Tests of Creative Thinking (TTCT; Torrance, 1974), have long been widely used in the studies of people's creative potential. In a recent report on the 40-year follow-up study about the predictive validity of TTCT for real-world creative achievements, researchers found that TTCT scores could explain 23% of the variance in creative production (Cramond, Matthews-Morgan, Bandalos, & Zuo, 2005). On the other hand, newly developed theories about creativity, such as creativity is domain-specific (Tardif & Sternberg, 1988) and creativity involves both problem finding and problem solving (Wakefield, 1991) showed that divergent thinking and creativity are not completely synonymous. Divergent thinking is a necessary but not sufficient element of creativity. With his two-dimensional model of the problem space, Wakefield pointed out that divergent thinking tests tap the type of thinking for dealing with problems whose solutions are open but the definitions of the problems are prescribed (closed). Creative thinking, in contrast, involves the "double open" situation in which both the solutions and definitions of the problems are open. This model suggests the important roles of both *problem finding* and *divergent thinking* in creativity, thus explaining why divergent thinking per se does not equal creative thinking. In the empirical field, Hany and Heller (1993) compared the engineering students from the West (USA and Germany) and the East (Japan) and found a positive combination of convergent and divergent thinking processes in the Japanese sample. They attributed the highly developed technical creativity of Japan to its talented people's ability of combining convergent and divergent thinking skills. These results imply that, to get a better understanding of creativity, both divergent and convergent thinking process should be taken into consideration.

Controversy 2: Is something new to the person or to society? There seems to be no objection to the definition of creativity as something new, novel, or original. This consensus, however, triggers another controversy: Is this novel criterion in relevance to the person or to society/culture? Views about this question are divided into two opposite groups. Represented by Guilford (1950), Thurstone (1952), Torrance and Goff (1989), and Runco and Sakamoto (1999), one group hold that creativity exists at the personal level. When a person comes up with an idea, a product, or a way of solving a problem which is new to the individual, it can be regarded as creativity. At the opposite end of the spectrum is the definition offered by Stein (1953) and Nicholls (1972), who felt that creative products must be novel or new to the culture in which they were produced. Acknowledging the importance of both, Csikszentmihalyi (1997) differentiates between Big-C creativity and little-c creativity. The *Big-C* creative person is eminent, a person who makes great contribution to a field or whose work leads to the transformation of a domain. In contrast, the *little-c* creativity is used in everyday life, particularly in problem solving. Everyday creativity recently has received a great deal of attention (Minsky 1988; Runco, 2004; Runco & Richards, 1997). In addition, some researchers have lately revived the view of Jean Piaget and J. P. Guilford that learning itself is a creative process and have referred to this level of creativity as "mini-c creativity" (Beghetto & Kaufman, 2006). Though the little- and mini-level creativities do not satisfy the criteria of domain specification, according to Runco (2007), it is conceptually useful and practically important. These views are of particular importance for education, in that by recognizing different levels of creativity, educators can move away from the common pitfall of believing that Big-C creativity is the only level of creativity that matters and can recognize that all students have creative potential (Beghetto, 2007). On the other hand, the controversy about this issue implies that while doing creativity research, it is very necessary to state clearly which level of creativity a researcher is examining. Preferably, a clear description of the measurement of creativity should be given.

Controversy 3: Can a person be regarded as creative without a product? One of the most controversial points about the conception of creativity is whether one can be regarded as a creative person without a creative product. It seems less convincing if we say somebody is creative, but are unable to point to any concrete products. In this sense, the so-called creativity seems to not be pure creativity any more. It is more like what is called "creative potential (Cropley, 2000) or "creative giftedness" (Runco, 2005a). However, even if we do introduce a product that has been evaluated as creative as one essential criterion of creativity, controversies still remain regarding whether or not the judgment is objective enough, particularly if the judgment is made by psychologists rather than authorities of the relevant field. This dilemma has perplexed the psychologists for a long time. In his "constructionist approach to psychological assessment", Westmeyer (1996; 1998) gives some insights about the reasons for this dilemma. According to him, creativity is a socially constructed concept that is reinterpreted by the psychologists as if it is a construct that can be psychologically defined. It is the discrepancy between the nature of creativity and the way how it is assessed that causes the controversial and dilemma. For these reasons, Westmeyer prefers the use of expert judges in assessing creative product, though the effects of using expert judges has also been questioned by some psychologists (e.g., Baer, 1994; Runco & Chand, 1994). In reality, the experts of a certain field will decide if a product will be accepted to that domain as creative product or not. So it seems more logical to use the expert assessment instead of psychologist assessment.

Controversy 4: Creative problem-solving vs. creativity. Some researchers tended to focus on the problem-solving aspect of creativity when trying to formulate a definition. Wallas (1926) is generally credited with providing the first influential model of creative problems solving process, including *preparation, incubation, illumination,* and *verification*. Another example is Torrance (1965). In his definition of creativity, he listed steps which could constitute a process but did not define either creative thinking or creativity. He defined creativity as "a process of becoming sensitive to problems, deficiencies, gags in knowledge, missing elements, disharmonies, and so on; identifying the difficulty; searching for solutions, making guesses, or formulating hypotheses about the deficiencies; testing and retesting these hypotheses and possibly modifying and retesting them; and finally communicating the results"(Torrance, 1974, p. 8). This process-oriented definition put creativity within the reach of everyday people in everyday life rather than in the realm of the highest creative accomplishment experienced by so few.

Newell, Shaw, and Simon (1962) claimed that creativity is merely a "special class of problem-solving activity characterized by novelty, unconventionality, persistence, and difficulty in problem formation" (p. 66). If creativity is merely problem-solving, it is likely that almost everyone is creative. Such a focus on problem solving, however, is applicable only to those types of creative thinking or demonstrations of creativity for which problem-solving is the impetus. As Leddy (1990) and Runco (1996) pointed out, this would not necessarily seem to be the case for artistic creativity, which is simply a reflection of self-expression but not problem-solving. However, there seems to exist a sort of creativity that neither belongs to pure problem-solving nor pure self-expression. Instead, it comprises both. It is similar to what Hill (1998) called "technological problem solving situated in real-world contexts" (p. 203), which is guided by "design processes". This special kind of creativity is called "inventive creativity" whose definition and characteristics will be discussed in detail later.

Despite the controversies listed above, literature review of the late 20 years revealed two perspectives, on which a high degree of consensus does seem to exist.

Agreement 1: Novelty and usefulness as two defining characteristics of creativity. The character of *novelty* has been especially mentioned in the definitions of creativity in psychology from 1950s to 1980s. Torrance (1988) reviewed the definitions of creativity existing at that time and found creativity defined as something new (Thurstone, 1952), something contrasting with conformity (Crutschfield, 1962), or something that breaks out of a mould and is surprising in light of what was known at the time of the discovery (Bartlett, 1958). The criterion of "being novel" was extended to "being novel and appropriate" in the 1990s. Mayer (1999) while synthesizing the definitions given by the authors of the *Handbook of Creativity* (edited by Sternberg in 1999), found that *originality* and *usefulness* were identified as the two defining characteristics of creativity. *Usefulness* means that the creative product must be given value according to some external criteria

(Gruber & Wallace, 1999); must be an adaptive solution to a problem (Feist, 1999); must be something of usefulness, appropriateness, or social value (Nickerson, 1999). As a reflection of this agreement, literature published after 2000, tend to define creativity as one's ability to produce ideas or products that are judged by a group of people to be both novel and appropriate (e.g., Amabile, Barsade, Mueller, & Staw, 2005; Feist & Barron, 2003; Niu & Sternberg, 2001).

Agreement 2: Creativity should be related to some product or action. Differentiation of product from other strands of creativity can be traced back to Rhodes' (1961) well-known "4P's Model". This theory conceptualized creativity as a whole entity which was composed of four strands, namely *person* (the traits, characteristics or attributes of the creative individual), *process* (the operations or stages of creative thinking or action), *press* (the nature of situations and context within the creative press; environment or culture), and *product* (the concrete outcome of a creative behavior). As early as in 1982, upon publishing the influential "consensual assessment technique" (CAT) of creativity, Amabile (1982a) gave a consensual definition of creativity and defined creativity as "the quality of products or responses judged to be creative by appropriate observers, and it can also be regarded as the process by which something so judged is produced" (p1001). This definition is based on the creative product rather than other aspects. According to Amabile, such a *product-centered* operational definition is most useful for empirical research in creativity, because it is the manifestation of creative personality traits and the creative process as well as the outcome of the interplay of these constructs with the component of press. This emphasis on product has been echoed by other researchers who extended the concept of product to a solution to a problem, a completed and communicable idea, or something tangible like an invention or work of art (Everett & Lippert, 1994; Ford & Harris, 1992; Mayer, 1989; Milgram & Hong, 1993).

The focus of the current study is inventive creativity (or inventiveness) in children and adolescents. As is indicated by its name, inventive creativity is closely related to invention as the end product of the inventive process. The concept of invention and inventive creativity as well as their relations to creativity will be discussed in the following part.

1.1.2 Invention and creativity

Similar to the plethora of definitions of creativity, there is a co-existence of different definitions of invention in the literature. Udell, Backer, and Albaum (1976), in their publication about creativity and its multiple manifestations, stated "invention is a manifestation of creativity which is often conceived as the ability to bring something new into existence and sometimes thought of as the psychological process of processes by which novel and valuable products are created" (p. 93). In the *Encyclopedia of Creativity*, Hertz (1999) provided three definitions of invention. One definition of invention, as quoted from the Webster's dictionary, is "a device, contrivance, or process originated after study and experimentation" (p.95). Another definition coming from the Patent Office states "invention is something that is novel and useful: novel, meaning something that someone skilled in the particular field would not know, and useful, meaning that it has some practicality" (p. 95). The third is an operational definition that provided by the author: "invention can be defined as object, idea, or process that is protected by a patent" (p. 96). Henderson (2004b) gave a more comprehensive definition of invention as follows: "An invention is created through the production of novel ideas, processes, or products that solve a problem, fit a situation, or accomplish a goal in a way that is novel, implementable, useful, and cost-effective and alters or otherwise disrupts an aspect of technology" (p105). The World International Property Organization (WIPO; 2008) defines invention as "a product or a process that provides a new way of doing something or offers a new technical solution to a problem". Taken together, the existing definitions of invention tend to define invention as (a) a distinct form of creativity, (b) stressing both problem solving and problem finding, (c) having a close relation to patent, and (d) being subject to unique criteria and evaluation process.

(a) Invention as a distinct form of creativity that is closely related to routine problem solving and design. Tan (2000a) stated that creativity is a human asset which appears in numerous forms, with varying degrees, and across different domains or disciplines. Depending on the domain or discipline to which it applies, creativity can be termed differently, such as discoveries in the scientific field, innovations in the economic or social field, revolutions or reforms in the political field, and evolutions at the cultural level. With regard to invention, an exclusive definition would link invention only to the field of engineering and technology. This association is reasonable in that ours is a highly developed society in which technical inventions are playing an important role. This

definition, however, is too strict to represent the real nature of invention which is, as reported by the Lemelson-MIT Program (2004), "Invention rests at one end of the spectrum of *design*, and at the other end rests *routine problem solving*" (p. 9). This *inclusive* definition of invention as also including design has been more explicitly stated by Hertz (1999) with the assertion that "to design is to invent" (p. 97), because designing often entails taking objects that already exist and arranging them into some sort of useful object. It has, therefore, been suggested that anytime someone looks at an object and thinks of how the parts could be arranged into different forms and adopted into a "reasonably obvious alternative", they have both designed and invented an object. Weber (1996) held the similar view by saying "All invention involves design tradeoffs: perhaps cost against quality, power against portability, aesthetics against functionality" (p. 362). By definition, design is regarded as a contingent and creative process in which the designer's imagination is required whenever a contingency occurs (Ferguson, 1993).

(b) Invention as stressing both problem solving and problem finding. The attribute that probably most distinguishes inventors from other creative people is their orientation toward problem solving (Faste, 1972). Although accidents have inspired many inventions (e.g., Silly Putty, Post-it Notes, and the microwave, etc.), most inventions are *deliberate* solutions to problems in the current state of technology. For this reason, Henderson (2004b) calls the inventors "deemed expert problem solvers in the physical world" (p. 107). In parallel to problem solving, the importance of problem finding for creativity has been stressed by many researchers (e.g., Barron & Harrington, 1981; Brown, 1989; Csikszentmihalyi & Getzels, 1988; Kabanoff & Rossiter, 1994). In the invention field, while most inventions require systematic problem solving, problem finding in several senses plays a critical role. Successful inventors identify problems and opportunities, isolate important sub-problems, re-frame, re-define, and re-represent problems along the way to an invention (Lemelson-MIT Program, 2003).

(c) Invention as having a close relation to patent. What makes invention unique and in which it has no analogy to other types of creativity is its close relation to patent. Almost every country in the world grants patents to inventions. A patent, according to the definition of the World International Property Organization (WIPO; 2008), is an exclusive right granted for an invention. A patent, once granted, will protect the invention from being commercially made, used, distributed or sold without the patent owner's consent during the

patent tenure. By International Patent Treaty (IPT), most of the rules for granting a patent for an invention are consistent from one country to another. It is emphasized that the subject matter must be accepted as *patentable* under law. For example, in many countries patent can be granted only for art (i.e. method or process), machine, manufacture, composition of matter, ornamental designs, and certain types of living plants. Scientific theories and mathematical methods, for example, no matter how original and practical, are generally not patentable. The State Intellectual Office of the People's Republic of China distinguishes three types of patents: (1) The patent for invention, which means "any new technical solution relating to a product, a process or an improvement thereof that can be used for production"; (2) The patent for utility model, which means "any new technical solution relating to the shape, the structure, or their combination of a product that is fit for practical use"; (3) and the patent for design, which means "any new design of the shape, pattern, color, or their combination of a product that creates an aesthetic feeling and is fit for industrial application". The focus of the current study is the potentially patentable inventions of the children and adolescents in all the above mentioned categories. In this sense, it covers both the *problem-solving* and the *self-expression* aspects of creativity.

(d) Invention as being subject to unique criteria and evaluation process. WIPO describes three criteria to identify a patentable invention. Firstly, an invention must be of *practical use*. In other words, the invention must be able to be applied in society to meet some form of needs or solve a certain problem. Secondly, the invention must show an element of *novelty*. Novelty means that the invention carries some new characteristic which is not known within the body of existing knowledge in its technical field. Thirdly, as already discussed above, a subject matter must be accepted as *patentable* under law. These exclusive criteria raise the issue of how a creative product shall be evaluated as an invention. Undoubtedly, normal nonprofessionals will find it very difficult to associate an artifact or object with the previous technology and make estimations about its potential social value. This justifies the existence and function of the patent examiners, whose major responsibility is to review patent application. This review is the search of patent and scientific literature databases for "prior art" (all information that has been made available to the public in any form before a given date that might be relevant to a patent's claims of originality) and the substantive examination as to whether the claimed invention meets the patentability requirements before it is determined whether it should become a patent or not. The work of patent examiners is technically complex, which involves knowledge of

technical processes used in industry and advances in scientific research. Additionally, it involves making legalistic decisions based on their knowledge of patent law. Patent examiners usually have a natural science, engineering or computer science background and only through consistent in-house training about patent law and patent examination procedures will they finally become professional patent examiners. Typically, patent examiners begin as a trainee or associate and, when deemed able to work fully independently, they progress to become a full patent examiner. The State Intellectual Property Office of the People's Republic of China reports that this procedure often takes around one to two years. From this description we can conclude that patent examiners are carefully chosen and well trained professionals, who do not only have sound expertise in a certain field but also have got special training in order to make decisions with regard to patentable or non-patentable inventions. Because of this, we have reasons to believe that patent examiners are the most eligible and reliable "gatekeepers" (Csikszentmihalyi & Wolfe, 2000, p. 89) of the field of invention.

1.1.3 Inventive creativity (or inventiveness): A Gestalt view

Invention is different from inventive creativity. While invention refers to the end production or the inventing process of the product, inventive creativity encompasses the cognitive ability, motivational attributes, and the evaluation system that lead to the recognition of such creativity. "Inventive creativity" seems to be rather rarely used in the education and psychology field. A literature search (done in early 2008) in ERIC and PsycInfo with "inventive creativity" as the key word in both the title and abstract areas located only five entries. A literature search with "inventiveness" as the key word in both the title and abstract areas produced a total of 210 entries. A further examination of these entries revealed that inventiveness was mentioned in these studies either as a criterion of creativity (e.g., it was used in parallel to novelty, originality, flexibility, fluency, etc., which are typical criteria in assessing creativity) or inventiveness was used as a synonym of creativity. For example, among the list of literature, there exist studies about mathematical inventiveness (Davies, 1980; Dugdale, 1994), musical inventiveness (Hermelin, O'Connor, & Lee, S., 1987), and visual inventiveness (Jones, 1976) etc. For the purpose of this study, inventive creativity and inventiveness are treated as synonyms.

Among the authors, it seems only Taylor (1975) has differentiated inventive creativity from other forms of creativity. According to him, there are five levels of creativity, including *expressive, productive or technical, inventive, innovative,* and *emergentive creativity*. Expressive creativity is the lowest level of creativity, which involves unhindered productivity without regard to reality. The important characteristics of this level of creativity are spontaneity and freedom in one's creative expressions. Examples of this type of creativity are doodles or drawings of young kids. The next level is the "productive or technical creativity", which is "characterized by proficiency in creating products and is essential at the technical production level. The emphasis is on skill at the expense of expressive spontaneity. It is essentially concerned with novelty although it does involve the achievement of a new level of proficiency by the individual" (p. 306). After "technical creativity" comes "inventive creativity", which is "characterized by a display of ingenuity with materials. It involves insight into unusual combinatory relationships between things previously separated, for the purpose of solving old problems in new ways. Creativity at this level does not result in new basic ideas, but in new usages of old parts and new ways of seeing old things" (p. 306). From a cognitive psychological point of view, both of these activities produce novelty based on direct application of what already exists and require at least concrete or formal operational thinking (Cropley, 1999). The final two levels of creativity are "innovative creativity", which is the modification of alternative approaches and extension of existing systems, and "emergentive creativity", which involves the most abstract ideational principles to produce something that is substantially different. These two types of creativity are the highest level creativity and entail more complex cognition and heuristics. Comparing the definitions of technical creativity and inventive creativity, we can see that the difference between these two types of creativity lies in the specific aspects that each stresses. While technical creativity lays emphasis on creating new products, inventive creativity stresses making use of the already known in new ways. Taylor's description of inventive creativity fits well with the definition that Fleming (2007) gave for invention which is "a new combination of components, ideas or processes" (p. 69).

Both Taylor's and Fleming's conceptualizations can find their basis on Gestalt psychology. Gestalt psychology proceeds from the observation that the mind commonly perceives things as wholes rather than as a chaotic flux of sensory stimuli. Applying Gestalt theories to invention, Usher (1929) proposed that the inventor "sees" a solution to the specific problem, and it occupies his mind at the instant of insight. The problem serves as a focal point for organizing bits of information into a pattern that potentially resolves it.

Drawing on a graphical device used by Gestalt theorists to illustrate the "law of closure", Usher compared the moment of insight to mentally arranging a set of broken arcs into a circle, thereby satisfying the desire for completion stimulated by the problem. Looked at in this way, invention is necessarily contextual, because in order to be solved the problem has to be specific enough to support a solution. Extrapolating from Koehler's experiments on cognition in higher primates which suggested that to achieve a satisfactory solution serendipitous concatenation of the elements are needed, Usher posited that the elements must be actively present in the inventor's mind for insight to occur. He further stated that "Invention finds its distinctive feature in the constructive assimilation of pre-existing elements into new syntheses, new patterns, or new configurations of behavior" (Usher, 1929, p.9).

Such a Gestalt view of invention is most relevant to children and adolescents in that for children and adolescents, the real-world contexts, including those of their home, family, school and classroom, etc., are their personal world as a whole. And the inventive creativity is a way that they express their understanding and manipulating intention of the everyday life. Apart from it, children's *uninhabitation* and *spontaneity* may prevent them from early closure, thus helping them come up with inventive products.

1.1.4 Inventive creativity (or inventiveness) and mechanical inventiveness

In most cases, "inventive creativity" is concealed by other terminology, such as "mechanical inventiveness", defined as the conception and development of new devices which require use of mechanical principles (Colangelo et al., 1993), "technical creativity" (Hany, 1995) or "scientific creativity" (Heller, 2007), conceptualized as individual and social capacities for solving complex scientific and technical problems in an innovative and productive way. Among others, what is meant in this study is similar but not identical to what is called by Colangelo and his colleagues (1992, 1993) as "mechanical inventiveness". In accordance to their definition of inventiveness, they focused their studies on the adult inventors with an agricultural or industrial patent (Colangelo et al., 1993) or young inventors who were winners of the Invent Iowa Program (Colangelo, Assouline, Croft, Baldus & Ihrig, 2003). Though I have no objection to their applying "mechanical inventiveness" to the adult inventors who have got patented for their inventions in the agricultural or industrial field, it is suspicious in regard to the appropriateness of applying the same concept to the "young inventors" whose inventions cover in actuality rather broad areas, but not only the mechanical field. For example, in answering the question "What do young inventors invent?" Colangelo and his colleagues (2003) did a systematic analysis of the types of inventions that were displayed at the State Invention Convention in 2001. They used the general categories developed by the U.S. Patent and Trade Office to classify the inventions of the students and found that what the children and adolescents invented covered all 14 major categories, including 8.7% in "clothes/accessories" (apparel, boots and shoes, buckles, jewelry, etc.), 6.6% in "amusement" (sporting goods, toys, games, etc.), 6.6% in "pets" (harnesses fluid handling, farriery, dispensing of solids, etc.). Without exaggeration, the inventions of the young inventors cover almost all aspects of our daily life, but not only the mechanical aspect.

As a result, "inventive creativity" instead of "mechanical inventiveness" is used in this study with the aim to reflect the real feature of the inventiveness of the children and adolescents. That is, inventive creativity is regarded as a synthesis of cognitive and non-cognitive traits that children and adolescents possess to express their understanding and manipulating intention of the everyday life.

1.1.5 Inventive creativity (or inventiveness) as the focus of the study

Inventive creativity among children and adolescents concerns a special kind of *real-world* technological problem solving or product design ability, which leads to a product that will have the potential to be patented by the Patent Office. To put it in a more detailed way, this special kind of creativity differentiates itself from other types of creativity in that:

(a) It is represented largely by the application of technology. In this perspective, inventive creativity is very close to "technical creativity" (Hany, 1995) or "industrial creativity" (Rossman, 1964). But due to the relatively lower level of cognition and technological acquaintance of the children and adolescents, inventive creativity of children and adolescents is not restricted to technical sphere. It also comprises design and covers almost all aspects of one's daily life.

(b) Differentiated from the inventive creativity of adult inventors, this special form of creativity of children and adolescents is rooted in the real-world context of children and adolescents which includes their home, family, school and classroom environments. In this sense, inventive creativity is very similar to the so-called "everyday creativity" (Piirto, 2004; Richards, 1999), which is distinguished from eminent and exceptional creativity, and is viewed in terms of cognitive style or orientation, rather than specific abilities.

(c) What makes inventive creativity unique and in which it is not analogous to other types of creativity is the inventor' awareness of the patent law and their attempt for a patent as a final result of invention.

In relation to the controversies discussed in the previous part, inventiveness in the current study is concerned not only with *divergent thinking* but also *convergent thinking*. Divergent thinking is helpful in the ideation phase for an inventor to break boundaries among things and try flexible combinations of components. Convergent thinking comes into play at a stage when it is necessary to narrow the number of possible solutions to a problem by applying logic and knowledge. Regarding the second controversy, inventiveness in the current study is examined at the "little-c" level. The subjects of the current study are not high-level inventors such as Thomas Edison or Alexander Bell. Instead, the focus of the current study is a group of young inventors, whose inventions are at a relatively lower level in comparison to the seminal inventions of prominent inventors. Thirdly, inventiveness differentiated itself from other types of creativity in its close relation to patent and the prescribed criteria and evaluation process. Therefore, compared to other types of creativity, inventiveness is more "effable" (Perkins & Weber, 1992), due to its reliance on concrete products. Lastly, inventiveness in the current study neither belongs to pure problem-solving nor pure self-expression. Instead, it comprises both. It is conceptualized as a technological problem solving situated in real-world contexts which is guided by design processes (Hill, 1998).

1.2 Empirical review of inventiveness studies in the field of psychology

Sternberg and Lubart (1999) noticed the existence of small number of empirical studies about creativity in the field of psychology, and called creativity one of the psychology's "orphans" (p.4). A closer examination of these "orphans" revealed that most of the studies were about scientists, writers, architects, and musicians (e.g., Gruber, 1981; Gardner, 1993; Csikszentmihalyi, 1997) and only a handful have chosen inventors and inventiveness as their research focus (e.g., Henderson, 2004a, 2004b; Rossman, 1964; Weisberg, 1993). A literature research with the key word "young inventors" in ERIC, PsycInfo, SocIndex, and L-I-Sciences & Tech Abstracts in early 2007 issued only 12 entries, leaving these young inventively gifted the "*foundlings*" of the field. Among this body of literature, it seems only Colangelo and his colleagues have done psychological research about the young inventors (e.g., Colangelo et al., 1993, 2003). Other researchers seem to have unanimously focused their research on the evaluation of the effectiveness of fostering inventiveness among children and adolescents (e.g., Plucker & Gorman, 1999; Saxon, Treffinger, Young, & Wittig, 2003; Westberg, 1996). Due to insufficient research about inventors, the relevant literature will be examined one after another.

1.2.1 Research about inventors and inventiveness

1.2.1.1 Colangelo et al.: studies about mechanical inventiveness and young inventors

In one of their studies, Colangelo and colleagues (2003) drew samples from the students of grades 3-8, who qualified for the Iowa State Invention Convention, and examined the perceptions of young inventors about the inventiveness process and their attitudes toward school and toward students. In addition, they also did a systematic analysis of the invention products of the young inventors. Invent Iowa is a comprehensive, statewide program developed to assist Iowa's educators in promoting the invention process as part of their regular curriculum from kindergarten through to high school. Students who participate in the program have the opportunity to display their inventions at their local, regional, and state invention conventions. At each level, inventions are evaluated and students are recognized for their achievements. Each year, among about 30,000 students in grades K-12 participating in the Invent Iowa Program, only 300 (1%) excel and are invited to the State Invention Convention. The participants of the study were called "young inventors" because they met the criterion for "inventor" in that they had to compete against a large number of students in order for their inventions to qualify for the competition at the State level. The major findings of this pioneering study can be summarized as follows:

(1) Gender issues. Except for some minor differences in specific inventiveness processes, not many significant gender differences were found. With 57% females and 43% males participating in the event, girls were a bit over-represented in this highly inventive sample. In response to an item about attitude to school, boys and girls replied almost equally positive. When ranking the sort of "cool" student in their eyes, girls ranked "inventors" higher than did boys. This result suggested that girls valued inventiveness

more than boys. In terms of the quality and quantity of the inventions that they had made, no significant gender differences were found. On all 22 items about inventiveness process, boys and girls were similar with an exception of five of them. Wherein boys outscored girls on three of the items and girls outscored boys on the rest two items. Given the fact that the higher the mean on each item, the more the response is consistent with the responses of adult inventors with patents, the hypothesized lead held by boy in inventiveness was almost counter-balanced by the similar good performance of their female counterparts. To summarize, this study about young inventors did not provide evidence for a clear stereotyped view of seeing boys as more inventive than girls.

(2) Comparison with adult inventors. Boys were more like adult inventors in enjoying observing or taking on hands-on activities to make, fix or take things apart. Girls were more like adult inventors in making longer incubation and keeping notes about their inventions. In contrast to the well-established adult inventors, who held a negative view against school, the young inventors', regardless of gender, held overwhelmingly positive attitude toward school.

(3) Inventions of the young inventors. The inventions of the participants of the study covered a wide range of the classifications of the U. S. Patent Office, with "Tools", "Kitchen/Bath", and "Organization" stuff accounting for 49% of the inventions. Categorized inventions by gender were fairly comparable except in the categories of "Kitchen/Bath" and "Organization" where the girls outnumbered boys by slightly less than 2:1. Proportionately, inventions in the category of "Tools" more often were submitted by boys.

This study about young inventors belongs to the spectrum of studies about mechanical inventiveness that Colangelo and his colleagues have been involved in since 1990s. In 1993, Colangelo and his co-workers reported their three-phase research of mechanical inventiveness studies. Phase 1 was an extensive gathering of biographical, vocational, and personality data of 34 inventors, who received between three and 82 agricultural and industrial patents. These inventors formed the original criterion group of mechanical inventors. Phase 2 was the development of an instrument which could be used to assess and identify young people who possess characteristics associated with mechanical inventiveness. For the criterion group of adult mechanical inventors, the Iowa Inventiveness Inventory (III) was developed to measure attitudes and characteristics of inventors. Subjects for Phase 3 were 90 young inventors, students in grades five to eight who won local and regional invention contests and reached the state convention of Invent Iowa. In Phase 3, Invent Iowa state finalists in grades five to eight (n=90) were administered the III and the Mechanical Reasoning test of the Differential Aptitude Tests. The results showed that adult and adolescent inventors were similar to one another and different from adult and adolescent non-inventors in terms of personality, biographical, and vocational characteristics associated with mechanical inventiveness. This result provides justification for further literature review about adult inventors as compensation for the lack of literature about young inventors.

1.2.1.2 Rossman: study about the psychology of the inventor

Among the literature about the psychology of the inventor, the classic study of Rossman (1964) on American adult inventors during the 1930s might be the most frequently cited one. What is special about this study is that data of key topics were collected from multiple sources, including 176 patent attorneys, 78 directors of research and development (R&D), and 710 inventors throughout the United States. The collected data were then ranked, compared, and discussed in a way that highlighted the most consistent results from the three sources. Topics covered in this study range from the definition, characteristics, mental processes, motives, and the internal and external obstacles/pitfalls of invention to the nature-nurture issue of inventiveness. The following is a summary of some topics that are most relevant to the current study.

(1) The characteristics of inventors. With the aim to find out the major mental characteristics of inventors, Rossman collected answers from the above-mentioned sources. Interestingly, while both patent attorneys and R&D directors saw "originality" and "analytical ability" as the most distinct characteristic of a successful inventor, inventors themselves rated both characteristics relatively lower. In their list of the most marking characteristics of a successful inventor, 71% of the inventors rated "perseverance", which was followed by "imagination" (43%) and "knowledge and memory" (26%). These results seem to imply while the significant others at the workplace tend to recognize inventors more because of their extraordinary cognitive abilities, inventors themselves value more perseverance in work and accumulation of knowledge. As one inventor in the study stated, "This is the secret of the inventor's success – never-ending application. The idea that an inventor is necessarily a genius is entirely fallacious. Genius for invention is merely the

capacity for concentration and for work" (quoted by Rossman, 1964, p. 42). A comparison of the results from these three source groups showed a very close agreement of the most conspicuous characteristics -- *perseverance, imagination,* and *originality.*

(2) Motivation for invention. One interest of Rossman was "What motivates or drives an inventor to invent?" The answers to this question were a mixture of intrinsic and extrinsic motivation, with most belonging to the former category. In descending order of frequency, the most prominent motives were *love of inventing, desire to improve, financial gain, necessity or need, desire to achieve, part of work, prestige,* and *altruistic reasons.* Among these, *love of invention, desire to improve, desire to achieve,* and *part of work* are typical intrinsic motivation. *Necessity or need* and *altruism* reflect the sympathy and social responsibilities of the inventors. Financial gain and prestige are typical extrinsic motivation. These results imply although inventors, at least the American inventors of the 1930s, are mostly intrinsically motivated for invention, their motivational profile is multi-dimensional which includes intrinsic, extrinsic, and social factors. This unique profile might be due to the fact that inventing is a relatively more costly industry than other creative endeavors. To become a creative writer or painter, what one needs to finance are the basic necessities such as paper, pencil, palette, canvas, reference books, and a place that is big enough for writing and painting. However, for inventors, the whole process of inventing involves enormous financial investment, including buying and renewing tools, materials, and apparatuses, equipping and maintaining a lab, paying patent application and maintenance fees, and marketing, etc. The inventors either must spend their own money or attract businessmen to their inventions. In either case, unless there is a prospect of gain, no money would be spent in developing the invention to a practical basis. The controlling effect (Deci, 1975) of this external constraint is more salient for inventors who have to earn livelihood by inventing. This is actually, to some extent, the case of the sample that Rossman has got. Among the 710 inventors investigated, 61% replied that they earned livelihood partially or completely by inventing. Maybe due to less economic reliance on inventing and less pressure on commercializing their inventions, the contemporary corporate inventors present a somewhat different motivational profile, which is characterized by more prominent intrinsic motives. This is the result of a recent study (Henderson, 2004b) about corporate inventors, which will be introduced in detail in the following part.

(3) Obstacles and pitfalls of inventors. Obstacles in Rossman's study were concerned with both internal and external constrains and pitfalls were specifically related to the art of inventing. The inventors investigated found most of the obstacles existed in their external environmental, including the lack of capital, the prejudice of people, the dishonesty of some promoters, difficulties in marketing, anticipation by others, and lack of time or facilities. As Rossman stated, the essential difference between an inventor and other creative workers is that an inventor's invention is ultimately put to a commercial test. An invention must be socially useful, practical, durable, easy to manufacture, and it above all must make profits for the manufacturer. All this exposes an inventor to more constraints than other creative workers might meet. As already discussed above, inventing is a costly endeavor. No wonder most of the inventors rated lack of capital as the greatest obstacle. Regarding the prejudice of people, almost all innovations meet with opposition and prejudice at the beginning. This might be due to the deep-rooted resistance to change that human beings have. With regard to pitfalls of invention, impracticality, over-confidence, and lack of knowledge were listed as the three most frequently met pitfalls. Practicality means there is a real need for the invention, the invention is useful and there is a market for the invention. All this is of primary importance if an inventor wants to make meaningful inventions. As this study suggests, realistic self-confidence and a solid base of knowledge are also important for making inventions.

It is worth noting that no gender issues were addressed in Rossman's study, as all 710 participants of this study were males. Rossman did not explain whether it was his intention to only focus on the male inventors or it was the case that in 1930s there were almost no female inventors. The latter explanation seems skeptical as since 1809 when Mary Dixon Kies received the first U. S. patent issued to a woman, there were more and more female inventive persons who were aware of the existence of patents and had patented their inventions. However, as stated in the About.com:Inventors (2009) website, in the old days many women patented their inventions under their husband's or father's names because at that time women were not allowed equal rights of property ownership and patents are a form of intellectual property ("How many women inventors", n.d.). Even today, it is difficult for us to know all the women who deserve credit for their creative labor, as most of the Patent and Trademark Offices all over the world do not require gender, age, racial, or ethnic identification in patent or trademark applications, including the Patent and Trademark Office in mainland China. To identify the gender of an inventor, the researchers usually rely on their "educated guess" based on the first names that they retrieved from the website of patent office (see Frietsch, Haller, Vrohlings, & Grupp, 2008). This manual work will face tremendous difficulties with a Chinese sample, as Chinese first names are not always sex sensitive. Because of the special feature of the patenting system, no ratio of the minority inventors such as young and female inventors in the whole population of China's native inventors is available.

1.2.1.3 Henderson: qualitative and quantitative studies about contemporary corporate inventors

The foci of Sheila Henderson's studies are contemporary adult corporate inventors. With the aim to draw a profile of the 21st century corporate inventors, she took both qualitative and quantitative approaches to collect data about the major characteristics of the adult inventors and of their environment. In one study (Study 1), Henderson (2004a) gave four product inventors and two control participants personality scales to rate and conducted semi-structured interviews among them exploring questions about their creative process. During the interview Henderson found that the inventor participants spoke repeatedly and consistently about how much they enjoyed their innovative work and personality alone was not sufficient to explain this high level of happiness. So the interview scripts were analyzed by using the Russ (1993, 1999) model of affect and creativity. The results of this study not only confirmed each dimension of the Russ model but also extended the Russ' model to include more affective pleasure categories. The relationship between emotion/affect and creativity has become a popular topic in the field of psychology in recent years (see Amabile et al., 2005; Forgas, 2001; Isen, 1999a, 1999b; Shaw & Runco, 1994). Henderson's study adds to the literature about the positive emotional structure of a specific creative group – inventors.

In another study (Study 2), Henderson (2004b) did an online survey among 247 corporate inventors most of whom were employed by multinational companies dedicated to research, design, and creation of new scientific processes and products. Questions asked in this survey included motivation, role identity, inventing skills, and early formative experiences. The major findings of these two studies are as follows:

(1) Gender issues. Henderson's studies provide a *male-dominant* profile for the field of invention. In Study 2, of those participants willing to disclose their gender (n=238),

approximately 81% were men and 19% women. In this study, Henderson also asked the inventors to rate how central being an inventor was to how they perceived themselves. Somewhat contradictory results were found. While male inventors were almost three times more likely to report that being an inventor was very or completely central to their role identity than did female inventors, they were also two times more likely than women to disclaim their inventor identity by reporting that being an inventor was not at all or not very central to their role identity. Role identity is believed to have a strong influence on motivation (Petkus, 1996). The contradictory results about male and female inventors' role identity do not provide useful information to explain why there are so few female inventors in the corporate world. It seems to suggest that the big differences lie in some external barriers rather than the internal ones.

(2) Motivation for invention. Though mostly similar, the contemporary corporate inventors in Henderson's studies presented a somewhat different motivational profile from that revealed in Rossman's study. Compared to Rossman's sample, the participants of Henderson's study were more predominantly intrinsically motivated to pursue a career as inventors. Of the top ten main reasons given by the inventors for inventing work, seven belonged to the category of intrinsic motivation, including *mastery, entertainment, exploration, happiness, resource provision,* and *intellectual creativity*, etc. Although two extrinsic goals, superiority and material gain, did rank in the top ten goals, they were ranked lower. While the old generation inventors in Rossman's study ranked "financial gain" as the 3rd most important reason for inventing, the contemporary corporate inventors in this study mentioned "material gain" as the 10^{th} reason. The less pronounced dependence on economic returns of inventions of the contemporary inventors might be due to the fact that most of Henderson's participants were from multinational companies that attach great importance to creativity and innovation. Such companies allocate annual budget for the research and development of their products and take care of manufacturing and marketing of the inventions. So the financial pressure of the individual inventors is eased. Yet, it is interesting to see that, though less prominent, both old generation and contemporary inventors expressed their desire for emotional returns such as superiority and prestige. Nevertheless, it is worth noting that inventors as a whole are primarily intrinsically motivated for their inventing career. It is love, passion, aspiration to master/achieve, desire to explore, and joy of inventing, etc that are the most prominent components of motivational profile of the inventors. It is these strong intrinsic motives that

enable them to withstand the emotional and intellectual stress involved in the work of inventing and bring changes to our life.

(3) Supportive environments for invention. In Study 2, Henderson adopted a *retrospective* design in the form of open-ended survey to collect data about the inventors' experiences in and outside of school that might have contributed to their ability to invent. The majority of the participants provided evidence for strong environmental influences on their inventiveness. In family settings, they reported to have access to toys, tools, materials, resources, and appliances to play with or to take apart. And some of them also had garage space, tool benches or tool shops in which to try out their inventive ideas. They also appreciated the participation of their parents, members of extended family, neighbors or peers in their inventive pursuit. At school, they remembered having the opportunities to participate in active, problem-based discovery learning. They took product-design and science courses and were active participants of inventive extracurricular activities such as science fairs or invention competitions. They recalled the freedom they were given to explore their surrounding environment and the tolerance that their parents and educators showed if they made a mess, broke things, or shorted out the electrical circuits. They also mentioned the power of inventive role models in inspiring them to invent and emphasized that they learned the value and importance of failure in discovery work.

1.2.1.4 Weisberg: ordinary view of creative achievement

A cognitive psychologist, Robert Weisberg's research interest is in the cognitive processes involved in the intentional production of novelty. In order to gain understanding of the mechanisms underlying leaps of insight and "Aha" experiences, Weisberg and colleagues not only carry out laboratory studies about the problem solving process of undergraduates, but also examine real-world creative thinking at the highest level, through case studies of prominent scientists, artists, and inventors. The invention cases that Weisberg included in his study are the invention processes of Edison's kinetoscope, Calder's mobile, Watt's steam engine, Whitney's cotton gin, and the Wright brother's flying machine. One common theme among these inventions is that they are mostly based on what is already known. These are the so-called *inventions with antecedents*, such as Watt's steam engine was built on Newcomen's, Whitney's cotton gin on an already existing gin, and Edison's kinetoscope on his phonograph. Weisberg (1993) admitted that there were inventions that were so novel and original that the majority of the people were liable to attribute the source of the invention to certain magic power, but such inventions without existing antecedents in human artifacts usually can find their sources in the Mother Nature, such as Wrights using bird flight as the basis for wing-warping. In addition, the role of analogical thinking based on local or regional analogies as well as logical reasoning were also found to be common in all invention cases.

By drawing the data received from the laboratory studies about college students with those received from the historical case studies of highest level creative achievements, Weisberg (1986, 1993, 2006) challenged the conventional *"genius" view* about creativity with his *"ordinary" view* theory. The "genius" view casts a heroic and romantic glamour over the origins of creative achievement and views creativity as a mysterious quality presented in a few selected individuals. Weisberg (1993) pointed out, though the "genius" view is pervasive in society, there is no persuasive empirical evidence to support it. In contrast, his data show that there are no such things as sudden spontaneous cognitive leaps, unconscious illuminations, or bolts of lighting from the blue with the "great" minds. When examined scientifically, the prominent creative individuals think exactly the same way as ordinary people. Ordinary thinking begins with continuity with the past. That is, while creating new processes, solutions, or products, we usually use what we already know to generate the new. Ordinary thinking also goes beyond the past, through reasoning and the accumulation of new pieces of information. And such thinking processes are ordinary or common to all individuals. Meanwhile, Weisberg noted that though we all possess these thinking skills, high-level creative persons differ from the lower-level ones in the level of the skills and in some motivational characteristics such as achievement motivation, commitment and productivity. In particular, he emphasized the positive relation between knowledge and creativity and echoed the "ten years rule" that has been proved by many other researchers (e.g., Bloom, 1985; Gardner, 1993; Hayes, 1989).

This ordinary view of creative achievement is particularly important for educational psychologists, as it lends the complex and somewhat mystical phenomenon of creativity to the scientific study by treating it as a normal thinking process. Furthermore, the "ordinary" nature of creativity as evidenced by Weisberg makes it theoretically sound and meaningful to study "little c" of minority groups such as children and adolescents.

1.2.2 Studies about the effectiveness of inventiveness training among students

For the past decades, numerous investigations have been carried out to evaluate the effectiveness of creativity training (e.g., Feldhusen, 1988, 1990; Feldhusen & Clinkenbeard, 1986; Feldhusen & Treffinger, 1985; Parnes, 1987; Torrance, 1972, 1984, 1987a; Stein, 1974, 1975; Van Gundy, 1987). Torrance (1984) analyzed the effectivefness of 142 experiments designed to facilitate creative growth and found that "rarely have any of the methods tested failed to produce measurable, statistically significant creative growth…the greatest growth occurs when creative problem solving is taught" (p. 67). In another large study, Cohn (1984) conducted a meta-analysis to investigate the effectiveness of creativity training programs as measured by performance on creativity tests. After examining a total of 106 published studies and dissertations on creativity training programs which yielded 177 independent samples of subjects, Cohn's analysis of effect sizes indicated that the effectiveness of creativity training programs can be increased when measured by subjects' performance on creativity tests. Recently, Scott, Leritz and Mumford (2004) did an intensive meta-analysis of program evaluation efforts of 70 prior studies. It was found that well-designed creativity training programs produced positive training effects regardless of the different criteria, settings, and target populations of the training programs. A further examination revealed that more successful programs were likely to focus on development of cognitive skills and the heuristics involved in skill application, using realistic exercises appropriate to the domain at hand.

Concerning inventiveness, in contrast to the desolation of the studies about the characteristics of the young inventors, there exists sizable literature focusing on the effectiveness of training students to become inventive. As expected, the results of these evaluation studies are overwhelmingly positive. The following is a summary of some of the studies.

Believing that all children have some inborn creative potential and it is the environmental influences that will either induce or repress creativity, McCormack (1981, 1984) created "Invention Workshops" as part of science programs for elementary and middle schools. There are three components of this model, including (a) children reinventing the invention by finding solutions to a problem faced by an early inventor; (b) children reinventing the inventor by studying the personality and lifestyle of early inventors, and (c) children becoming inventors by using readily available junk materials to create their own inventions. In evaluating this program, McCormack (1984) compared the Invention Workshop group with randomly selected control classes in the same school district and found that the experimental groups demonstrated significantly greater improvement in *flexibility* and *originality* as measured by the Torrance Tests of Creative Thinking (Verbal Forms A and B) (Torrance, 1966). He also found that the students in the experimental group reported positive attitudes towards science and school and an increased confidence about their problem-solving ability.

Shlesinger (1982, 1987a, 1987b), an inventor and patent attorney, also developed a model for teaching inventing. This model was developed based on his experiences as an inventor and was applied to train participants of a variety of types, including students in regular elementary schools, those in the gifted and talented programs as well as juvenile delinquent facilities. Evaluations from teachers who adopted his model indicated that students' interests in science and history increased after participation in the inventing program (Shlesinger, 1982).

Westberg (1996) designed an experimental study among 707 students in 26 intact classrooms from four through eight grades. The students were randomly assigned to the treatment group, which received eight lessons on the invention process and inventing materials, and control group, which received only an introductory, exposure lesson on inventing. Students in both groups were encouraged to develop inventions that were evaluated by the criteria of *originality, technical goodness,* and *aesthetic appeal*. It was found that the treatment group outperformed their counterparts in the control group in the *quantity* of the inventions. It was also found that the majority (83%) of the teachers of the control group commented on the students' excitement and enthusiasm for the development of inventions after the introductory lesson was taught. However the *quality* of the inventions of both groups did not differ significantly. The author attributed this result to the fact that the control group was not a rigorous control group as they also got an introductory lesson about the history and process of invention. This explanation is reasonable, as it actually indicated the positive effect of the introduction part of the training in an indirect way: one introductory course, not necessarily long and complex, once it has covered the core concepts of inventing process, can already enable the students to invent at the same level as those who take additional courses. Of course, to better understand this result, we also need to take the time issue into consideration. As Weber (2006) noted that significant inventions usually take place on a time scale that ranges across months, years, lifetimes, and even generations. Such a large time scale is less likely to be simulated in a laboratory experimentation that usually takes place on a much shorter time scale which lasts for hours, days, or weeks. With a longer time-interval design, the accumulative effect of the training is more likely to appear.

Plucker and Gorman (1999) might have noticed the "slot" that Westberg's study had and included the time effect into their evaluation design. They chose a case-based invention and design program for secondary school students as their focus of study and interviewed 32 participants of the program one year later after they had finished the training. Of particular interest in this follow-up evaluation were the participants' school year benefits, conceptions of invention and design, valuable course experiences, and the impact of the program on their career preferences. The participants reported some aspects of personal growth through this training, including increased knowledge about invent and design, improved group interaction skills, a better recognition of strengths and weaknesses, and an improved understanding of career preferences, etc. Though it was also found the training had only a minor impact on student use of reflection in inventing and designing, the overall gains of the students through this training were more salient.

Among others, the independent evaluation of the Camp Invention program (Saxon et al., 2003) might be one of the most extensive. The Camp Invention is a hands-on creativity and scientific day camp run in partnership with more than 400 schools across the USA. This program is composed of three major components, including (a) "Planet Zak", a mysterious planet, where the participants find their spacecraft has crash-landed on and where they are supposed to apply creative problem solving skills to find solutions for a series of problems; (b) "I Can Invent", in which they are supposed to give free rein to their imagination and use recycled materials/parts from a broken appliance to make an invention; and (c) "Spills and Chills", in which the children function as design engineers who are supposed to use creativity to design and build devices for safety reasons. In all the design activities they employ Newton's Three Laws of Motion to explain movement. A total of 17,526 participants, including program participants, parents, and staff were involved in the evaluation. The results revealed an extremely high level of satisfaction (greater than 90%) among all key groups. There was also extensive evidence to support the positive impact of Camp Invention on children's' attitudes towards creativity, active learning, and exploration.

From the perspectives of the parents, counselors and staff members, the Camp Invention was commented as fun, exciting, worthwhile, and engaging. The authors attributed the effect of Camp Invent to its capability of blending many important aspects of science and invention to overcome the challenge of stimulating children's creativity and imagination.

In summary, existing literature of the evaluation studies about the effectiveness of inventiveness training programs revealed positive and encouraging results. Common themes of the effects on participants that can be drawn from these studies include increased interest in science and technology, higher motivation for invention, and improved knowledge about inventing process. Some additional effects were increased confidence, increased collaborative skills, and gaining understanding of career preferences. These results provide evidence to support the belief of many psychologists that creativity can, at least to some degree, be developed or nurtured (Amabile, 1983a/b; Sternberg, 2006; Weisberg, 1993, 2006).

1.2.3 Rationale for not taking an evaluation design for the current study

Though evaluation studies have their merits in informing us about the components and procedures of program, they explain only a little about the interaction between the creators /inventors as subjects of the creation behavior and the objective environment. It is from this perspective that Treffinger and colleagues (1993) asserted that no more Masters theses or doctoral dissertations on the simple question of "Can we, through some deliberate instructional or training program, enhance performance on some specified measure of creativity?" are needed in the field of giftedness. The reason is that if we design and conduct reasonable treatments and choose variables carefully to represent a realistic operational definition of creativity, very likely the results of the evaluation will be positive. In research practice, it happens quite often that the effectiveness of a training program can be independent from the quality of the training itself. Instead, the existence of a variety of effects might lead to the subjects' higher rating of the effect of training, including a) the *Hawthorne effect* (Landsberger, 1958), which describes a temporary change to behavior or performance in response to a change in the environmental conditions; b) the *novelty effect* (Oskamp & Scalpone, 1975), which implies the tendency for improved performance simply because new technology/treatment is instituted that result in more interest or longer attention span, but not because of any actual improvement in learning or achievement; c) the *Pygmalion effect* (Babad, 1993), which refers to situations in which students perform better than other students simply because they are expected to do so; and d) the *demand effect* or *social desirability bias* (Kasl & Cooper, 1995), which reveals the existence of the tendency of respondents to reply in a manner that will be viewed favorably by others.

1.2.4 Summary

This part reviewed the literature about inventiveness studies in the field of psychology. It was found that there exist only a very small number of empirical studies about inventiveness, among which even less choose the children and adolescents as the research subjects. Of the few studies that focus on this young group, most of them are results of evaluation studies. Except Colangelo and his colleagues (Colangelo et al., 1992, 2003), there seems to be no more scientific research attempting to delineate the psychological profile of the young inventors to us. So far our understanding of the young inventors is rather limited and more well-designed empirical studies are still needed.

1.3. Different approaches to creativity

After explaining the concept of creativity and inventiveness, it is necessary to discuss the different approaches that psychologists use to study creativity. Sternberg and Lubart (1999, pp. 3-15) categorized the different approaches to creativity into six major diagrams, including *mystical, pragmatic, psychodynamic, psychometric, cognitive,* and *social-personality.* According to the authors, the mystical approach views creativity as pure spiritual and the pragmatic approach is too commercialized and less scientific. Both approaches are damaging to the scientific study of creativity. Psychodynamic has a certain contribution to the field of creativity study, but it stays outside of the mainstream of scientific psychology. Psychometric, cognitive, and social-personality approaches are the most common approaches to creativity in psychology. Each of these approaches conceptualizes creativity in different ways, has different research foci, has made certain contributions to the field, but each presents certain defects or flaws. In order to help you get an overview of the different approaches, I have developed Table 1.1 on some major themes that I extracted from the chapter. Interested readers are encouraged to read the book chapter. The approaches that I am going to review in the following part are the mainstream approaches including the psychometric approach, the cognitive approach, and the personality approach. As these approaches have an almost exclusive focus on the creative individual, I will review them together under a sub-title "individual-focused approach".

Table 1.1 Different approaches of creativity study (adapted from Sternberg & Lubart, 1999, pp.4-12)

Approach	Perspective	Research foci	Contributions	Defects/flaws	Representative authors
Mystical	Creativity as a spiritual process; mystical	Does not believe that creativity can be scientifically studied.	-	Not scientific	Rothenberg & Hausman, 1976; Ghiselin, 1985
Pragmatic	Creativity can be easily fostered through certain intervention	Concerned primarily with developing creativity without serious empirical attempts to validate the theories/models	-	Lack any basis in serious psychological theory; some false beliefs about creativity.	De Bono (e.g., lateral thinking, six thinking hats, 1971); Osborn (e.g., brainstorming, 1953); Gordon (synectics, 1961)
Psycho-dynamic	Creativity arises from the tension between conscious reality and unconscious drives	Rely almost exclusively on case studies of eminent creators.	The concepts of adaptive regression, elaboration , primary and secondary process	Difficulty of measuring proposed theoretical constructs and the amount of selection and interpretation	Freund, 1908/1959; Kris, 1952; Kubie, 1958; Noy, 1969; Suler, 1980
Psycho-metric	Creativity is composed of mental traits or measurable human characteristics	Studies on everyday subjects; focus on divergent thinking, creative problem solving, etc.	Creativity tests facilitate creativity research and make it possible to study non-eminent sample	Paper-and-pencil tests are trivial and inadequate; the major criteria failed to capture the concept of creativity	Guilford, 1950, 1967; Torrance, 1974; Plucker & Renzulli, 1999
Cognitive	Creativity as mental representations and processes	Creative mental processes and computer simulations of creative thoughts	Concepts of Geneploare model, retrieval, association, synthesis, analogical transfer, etc.	Tends to ignore or downplay the personality and social system	Finke, Ward, & Smith, 1992; Smith, Ward, Finke, 1995; Sternberg & Davidson, 1995; Weisberg, 1986, 1993; Boden, 1992, 1994; Langley, Simon, Bradshaw, and Zytkow, 1987
Social-personality	Looks at creativity from a personality and sociocultural perspective.	Creative personality, motivation and sociocultural environment as sources of creativity.	Creative personality traits; importance of intrinsic motivation; environment of eminent creators	Tends to have little or nothing to say about the mental representations and process underlying creativity	Barron, 1968, 1969; Crutschfield, 1962; Eysenck, 1993; Golann, 1962; Gough, 1979; Hennessey & Amabile, 1988; Lubart, 1990; MacKinnon, 1965; Simonton, 1984, 1988, 1994a/b
Confluence	Multiple components must converge for creativity to occur	Confluence of a variety of creativity theories and methods	Multidisciplinary views	Seems hard to apply, as researches taking such an approach are very rare	Amabile, 1983a/b, 1996; Csikzentmihalyi, 1988; Gardner, 1993; Gruber, 1989; Sternberg & Lubart, 1991, 1992, 1995, 1996

In particular, I will introduce some systems models that belong to what Sternberg and Lubart (1999) called the "confluence approach".

1.3.1 Individual-focused approach: the conventional approach to creativity

There has been a long history in the field of creativity research to perceive creativity as a primary function of an individual's personal traits or cognitive process. Based on this perception, psychometric approach, cognitive approach, and personality approach have been mostly used by psychologists to study creativity.

Psychometric approach conceptualizes creativity as being composed of mental traits or measurable human characteristics. This approach was formally advocated by Guilford (1950) as a possible way to study creativity among everyday people. Prior to this, there was a long history of perceiving creativity as divine and mysterious characteristics of some rare genius (see Becker, 1995). Guilford noted that the rarity of the eminent creators had limited research on creativity and proposed that creativity could be studied among non-eminent people with a psychometric approach, using paper-and-pencil tasks. Many researchers adopted Guilford's suggestion and different creativity tests were developed in 1960s and 1970s, among which the Torrance Tests of Creative Thinking (TTCT; 1966, 1974) was and still is one of the most frequently used paper-and-pencil creativity test (see Torrance & Presbury, 1984). TTCT is composed of both verbal and figural tests that involve divergent thinking and problem solving skills. Since its development, TTCT has been undergone consistent improvement until the latest version which consists of five verbal tests and three figural tests. For scoring, there are five norm-referenced scores and 13 criterion-referenced measures (Cramond et al., 2005). According to Sternberg and Lubart (1999), the psychometric approach had its revolutionary merit in the history, as it facilitated the creativity study by providing a brief and easy-to-administer assessment device. Moreover, it enabled the researches to examine creativity among normal people. In spite of this, they pointed out three major limitations of this approach. Firstly, the brief paper-and-pencil tests were insufficient to reveal the complex nature of creativity. Secondly, the scoring criteria of the tests failed to capture the social-contextual value of creativity such as usefulness or appropriateness. Thirdly, this approach was susceptible to the attack of some researchers who rejected the assumption that non-eminent samples could shed light on eminent levels creativity.

Cognitive approach conceptualizes creativity as being largely influenced by underlying cognitive processes or mechanisms (Baer & Kaufman, 2006; Sternberg & Lubart, 1999). Of the various cognitive models of creativity, Wallas' (1926) four-stage model and Finke and colleagues' Geneplore model might be the most influential (Finke, Ward, & Smith, 1992; Smith, Ward, & Finke, 1995; Ward, Smith, & Finke, 1999). The four stages of Wallas' model are *preparation, incubation, illumination,* and *verification.* Preparation involves a preliminary analysis of a problem, defining and setting up the problem. It involves conscious work and draws on one's education, analytical skills, and problem-relevant knowledge. During incubation, there is no conscious mental work on the problem but the mind continues to work on the problem, forming a variety of associations. The third phase is called illumination, which occurs when the promising idea breaks through to conscious awareness. Following the illumination, begins a phase of conscious work called verification, which involves evaluating, refining, and developing one's idea. Wallas (1926) noted that during creative problem solving a person could return to earlier phases in the process for another aspect of the problem. The Geneplore model consists of two phases of cognitive processes: a generative phase and an exploratory phase. In the generative phase, an individual constructs different kinds of mental representations related to the problem. A variety of cognitive processes are involved in this phase, including retrieval (Perkins, 1981; Smith, 1995; Ward, 1994; 1995), association (Mednick, 1962), combination (Baughman & Mumford, 1995; Hampton, 1987; Murphy, 1988), synthesis (Thompson & Klatzky, 1978), transformation (Shepard & Feng, 1972), analogical transfer (Gentner, 1989; Holyoak & Thagard, 1995; Novick, 1988), and categorical reduction (Finke et al, 1992). In the exploratory phase, an individual employs different processes to come up with creative ideas. Mental processes involved in this phase include the search for novel or desired attributes in the mental structures (Finke & Slayton, 1988), the search for metaphorical implications of the structures (Ortony, 1979), the search for potential functions of the structures (Finke, 1990), the evaluation of structures from different perspectives or within different contexts (Smith, 1979), the interpretation of structures as representing possible solutions to problems (Shepard, 1978), and the search for various practical or conceptual limitations that are suggested by the structures (Finke et al, 1992). According to the authors, creative thinking can be characterized in terms of how these various processes are employed or combined.

Personality approach views creativity as a combination of creative personality traits – either cognitive or non-cognitive. Due to the influence of Guilford and Torrance, creative cognitive personality traits have close associations with divergent thinking and creative problems solving. Among others, imagination (Barron, 1972; Barton & Cattel, 1972; Csikszentmihalyi & Getzels, 1973; Getzels & Csikszentmihalyi 1976; MacKinnon, 1962; Rossman & Horn, 1972) and flexibility of thought (Garwood, 1964; Helson, 1971; Helson & Crutschfield, 1970; Roco, 1993; Rossman & Horn, 1972) are the most frequently recognized cognitive personality traits of creative individuals across domains. From the non-cognitive perspective, personality psychologists try to understand the *affective* and *motivational* traits which influence the creative process. Meta-analyses show that the most conspicuous traits of creative individuals are tolerance of ambiguity, risk taking, preference for disorder, delay of gratification (Dacey, 1989); aesthetic sensitivity, broad interests, attraction to complexity, independence of judgment, self-confidence, creative self-concept (Barron & Harrington, 1981); autonomous, introverted, open to new experience, norm-doubting, self-confident, self-accepting, driven, ambitious, dominant, hostile, and impulsive (Feist, 1998). In Feist's study, he found that openness, conscientiousness, self-acceptance, hostility, and impulsivity had the largest effect size in explaining creativity. Apart from concern about the personality structure of the creative individuals, personality psychologists are also interested in the question of to which extent creative personality traits are consistent over time, and how they change over time. To answer this question, longitudinal studies were conducted. Though research is relatively inadequate on the topic, the existing literature suggests that the personality traits that distinguish creative children and adolescents tend to be the ones that distinguish creative adults and that the creative traits of creative people are rather stable (see Helson, 1999a; Feist & Barron, 2003). Though personality approaches have touched the cognitive aspect of creativity, they more often than not just label certain cognitive characteristics without going deep to reveal the underlying processes. That is the reasons why Sternberg and Lubart (1999) commented these approaches tend to have little or nothing to say about the mental representations and process underlying creativity.

1.3.2 Systems approach: a new trend in creativity study

In the field of creativity study, more and more scholars agree that multiple components must converge for creativity to occur (Amabile, 1983a/b, 1996; Csikszentmihalyi, 1988; Gardner, 1993; Gruber, 1989; Heller, 1993, 2007; Perkins, 1981; Sternberg, 1985a, 1996; Simonton, 1988; Weisberg, 1993). As already discussed in the "Introduction" part, different scholars prefer calling this approach in different ways, but the agreement is that creativity will be optimally examined only if both individual and environmental factors are taken into consideration. This new approach, which I prefer calling in the way how Csikszentmihalyi called it as "systems approach", has become the new trend in creativity study. In this part I will review some representative models of the systems approach in creativity study.

Social Psychology of Creativity. A social psychologist, Amabile (1983a/b, 1996) gives prominence to social variables that affect creative behavior. As early as the beginning of 1980s, Amabile noticed that the field of creativity research had been dominated with a narrow focus on internal personal determinants of creativity, such as personality and talent, and the external determinants, such as "creative situations", had been simply neglected. She argued that the trait approach is incomplete and creativity should be best conceptualized as a behavior resulting from particular "constellations" of *personal characteristics, cognitive abilities,* and *social environments*. Applying a consensual definition of creativity (Amabile, 1982a), she postulated a Componential Theory of Creativity (Amabile, 1983a/b) and conceptualized creativity as the confluence of *domain-relevant skills, creativity-relevant skills*, and task motivation. The consensual definition of creativity refers to the production of responses or works that are reliably assessed as *novel* and *useful* by appropriate judges. These three components are presented as factors essential for the production of such creative responses and works. Domain-relevant skills form the basis from which any performance must proceed. They include factual knowledge, technical skills and domain-specific talents. Creativity-relevant skills include cognitive style, application of heuristics for the exploration of new cognitive pathways, and working style. Task motivation accounts for motivational variables that determine an individual's approach to a given task. According to Amabile, the three components are operating at different levels of specificity. Creativity-relevant skills operate at the most general level in a way that they may influence an individual's response in any content domain. This component is similar to the concept of "g factor of creativity" that Kabanoff and Rossiter (1994) proposed in their description of the concept of applied creativity. Domain-relevant skills operate at an intermediate level of specificity. This component includes all skills relevant to a general domain. It is assumed that within a particular domain, skills relevant to any given specific task overlap with skills relevant to any other task. Task motivation operates at the most specific level. Motivation may be very specific to particular tasks within domains and may even vary over time for a particular task. The most important contribution of this model is that it integrates the social-psychological conceptualizations with the insights of cognitive and personality psychology, thus leading us to a more holistic view of creativity. In their laboratory, Amabile and colleagues (Amabile, 1996; Amabile & Conti, 1997; Hennessey & Amabile, 1988) found a positive relationship between a person's intrinsic motivation and their creativity. To apply the results to the real world, Amabile (1996) suggested that the educational system, classroom climate, college and work environment, and family could be important resources to facilitate or inhibit a person's creativity. According to her, all of these environmental factors have accumulative effects, which eventually decides a person's motivational orientation (either intrinsic or extrinsic), and subsequently partially determines the person's creativity.

The Systems Model of Creativity from the West. Like most of the researchers of creativity, Csikszentmihalyi entered the field with an interest in the personality traits and cognitive processes of creative people (Csikszentmihalyi & Getzels, 1970, 1973; Getzels & Csikszentmihalyi, 1966, 1967, 1975). Through almost three decades' research on this topic, however, he became more and more convinced that creativity cannot be studied by isolating individuals and their works from the social and historical milieu in which their actions are carried. In his own words, "I came to the conclusion that in order to understand creativity one must enlarge the conception of what the process is, moving from an exclusive focus on the individual to a systemic perspective that includes the social and cultural context in which the 'creative' person operates" (Csikszentmihalyi, 1994, p. 135). In 1988, Csikszentmihalyi proposed a dynamic model of the creative process, in which creativity is understood as a phenomenon that results from the interaction between three main systems: (1) A domain, which is a culturally defined symbol system that preserves and transmits creative products to other individuals and future generations. (2) A field, which is consisted of people who control or influence a domain, evaluates and selects new ideas. (3) A person, who draws upon information in a domain and transforms or extends it via cognitive processes, personality traits, and motivation. In the years after, Csikszentmihalyi revisited the systems view of creativity several times (see Csikszentmihalyi, 1994, 1996; Csikszentmihalyi & Wolfe, 2000) till he constructed The Systems Model of Creativity, whose shape and logic are drawn from the model of evolution (see Campbell, 1976; Mayr, 1982). The biological evolution concept postulates that when an individual organism produces a genetic variation that is selected by the environment and transmitted to the next generation. Borrowing this concept to the systems view of creativity, Csikszentmihalyi and Wolfe (2000) affirmed that creativity occurs at the interface of these three subsystems in the way that an individual absorbs information from the culture and changes it in a way that will be selected by the relevant field of "gatekeepers" who will decide if the creative product will be transmitted to the domain and the next generations or not.

The System Model of Creativity from the East. A Chinese developmental psychologist, Shi (1995, 2004) defined creativity as a manifestation of one's intellectual activities which are influenced by the environment and culture in which one grows up. In order to clarify that creativity is a system, Shi (1995) constructed a theoretical model called "A System Model of Creativity". Nine components are identified in this model which can be further divided into two subsets, namely *inner world components* and *outer world components*. The inner world components include *natural intelligence level or potential, knowledge and experience, non-intellectual personality traits, attitudes about creative tasks,* and *creative behavior*. Outer world components include *social environment, education or education opportunities, family or work environment,* as well as *creative products*. In this model, creative behavior is conceptualized as the interaction of *creative thinking, creative habit,* and *creative action*. In order to explain the mechanism of this system, Shi introduced the concept of "active intelligence" or "intelligence current (IC)", which is defined as the part of the intelligence that is involved in or directed towards creative activities. Comparing the function of IC to the function of electric circuit, Shi compared the intelligence potential to a power station and one's attitude towards the tasks to a "power switch" which either connects the IC to what he or she thinks worthwhile or disconnects the IC to what is not perceived as worthwhile. Based on this model, Shi and colleagues (2007) developed an operational model for creativity training, which is called "Iceberg-like structure of creativity cultivation". The whole model is evolved on the basis of "originality" and "value/appropriateness", which have been widely agreed as the most essential criteria of creativity. To test both models, a preliminary educational experiment was conducted in a high school in Beijing between an intellectually average and an intellectually gifted group (Qu & Shi, 2003). Results show that the significant increments of creative thinking test scores were found only in the experimental group with average intelligence but not in the intellectual gifted group. The authors argued this result might be due to the limited effect of the conventional thinking tests and proposed applying the models to the real world context and helping the school children to develop their real world problem solving abilities through training.

Systems view on creative eminents. In the field of psychology, a school of scholars have chosen creative eminents as their research focus. No matter if they adopt a qualitative (e.g., Gruber and colleagues; Gardner) or a quantitative approach (e.g., Simonton), their researches cover both individual and environmental contributes of creativity. Gruber and colleagues (Gruber, 1981, 1988; Gruber & Davis, 1988), based on case studies about creative eminents such as Charles Darwin, proposed a developmental Evolving-Systems Model for understanding unique creative people at work. According to this model, a person's purpose, knowledge, and affect grow over time, amplify deviations that an individual encounters, and lead to creative products. Developmental changes in the knowledge system have been documented in cases such as Charles Darwin's thoughts on evolution. Purpose refers to a set of interrelated goals, which also develop and guide an individual's behavior. Finally, the affect or mood system encompasses the influence of joy or frustration on the projects undertaken. Similar to Gruber, Simonton (see Simonton, 1997, 1999a) also studied the creativity of eminent people. He has analyzed many geniuses in different areas, time periods and cultures, and has concluded that social environment can have nurturing or inhibitory effects on the development of creativity. Unlike Amabile, Simonton has focused on broader environmental factors, such as those created by economic, political, social, and cultural conditions. Also unlike Amabile, Simonton has proposed that the effects of environment on the creativity of eminent people could vary across different social situations. In other words, different environments can shape eminent people's creativity in different ways. Applying Csikszentmihalyi's model to his study about creative eminents from seven different disciplines, Gardner (1993) examined the highest level of creativity through interaction among individual, domain, and field. At the individual level, cognitive ability, personality and motivation, social-psychological issues and life patterns were examined. At the domain level, nature of symbol systems, kind of activity, and status of paradigm were focused. And at the field level, an individual's relation to mentors, rivals, and followers, level of political controversy, and hierarchical organization were concentrated.

1.3.3 Summary

This part reviews different approaches that psychologists use to study creativity. Literature review was based on Sternberg and Lubart's (1999, pp. 3-15) classification of six major diagrams, with detailed review of the psychometric, cognitive, and personality approaches. These approaches each has its own advantages in exploring certain aspects of creativity, but one approach alone seems inadequate to touch such a complex phenomenon as creativity. Therefore, some prominent systems models of creativity were reviewed, including Amabile's (1983a/b, 1996) componential model of creativity, Csikszentmihalyi's (1988, 1994, 1996) systems model of creativity and Shi's (1995, 2004) system model of creativity. In addition, empirical studies that applied the systems models to the investigation of the creative eminents, including the studies of Gruber (e.g., 1981, 1986), Simonton (e.g., 1984, 1991), and Gardner (1993) have also been reviewed. The following part reviews another influential systems model of creativity, which lays the theoretical framework for the current study.

1.4 Theoretical framework of the study

Another influential systems model of creativity is Sternberg and Lubart's (1991, 1992, 1995, 1996) Investment Theory of Creativity (ITC). Though by name it seems not synthetic or confluence at all, this model is synthetic in nature in that it postulates a combination of six major components as the resources of creativity, including *intelligence, personality, motivation, thinking styles, knowledge,* and *environment*. The six resources were drawn from a number of high-ranking theories in the literature of creativity (see Sternberg & Lubart, 1999 for a review). "Investment" was borrowed from economics as a metaphor to denote the fact that creative people invest themselves in their projects to yield the "value added" on their initial idea. The rule of "buy low and sell high" which functions in economic investment is also applicable to the investment in the endeavor of creativity. Buying low means pursuing ideas that are unknown or out of favor but that have growth potential. Selling high means creative individual persists in the creative idea against the resistance from the crowd. When the creative product is finally accepted by society, usually the value of the creative product increases. This model has been chosen to guide the current study mainly because of two reasons. Firstly, as Niu (2007) stated the ITC model and the Simonton model differ themselves from other systems models in their primary emphasis on the *proactive* role of the creative individual. Though recognizing that both the individual and environment play a mutually interactive role, these approaches acknowledge the individual has a more active and stronger influence on the environment than vice versa. The proactive role of the individual is particularly important for invention, as invention does not take place in isolation. Rather, it is a social process that is full of conflicts and inventors must "negotiate" with the contexts in various ways to advance their work (Bjiker, Hughes, & Pinch, 1987; Latour, 1987; Lemelson-MIT Program, 2003). Secondly, unlike Simonton's model, ITC focused on examining a more general population instead of creative eminents. The focuses of the current study are children and adolescents, so the ITC is more appropriate. The following part will review each component of the ITC model and their relation to inventive creativity.

1.4.1 Intelligence

Both intelligence and creativity have a long history of scientific study. However even today, neither construct is quite agreed-upon by researchers in terms of the exact nature of each. Among the unresolved questions, one of the most controversial might be the relation between both. Intelligence is most often defined by experts as one's capacity, skill, or talent with three mental functions, namely *information processing, problem-solving,* and *abstract reasoning* (Snyderman & Rothman, 1987). Sternberg and O'Hara (1999) summarizes five possible relations of intelligence and creativity: (1) Creativity is one subset of intelligence (Guilford, 1950; Gardner, 1983). (2) Intelligence is one subset of creativity (Sternberg & Lubart, 1991). (3) Creativity and intelligence are overlapping sets (Getzels & Jackson, 1962; Renzulli, 1986; Smith & Neisworth, 1966;

Weinstein & Bobko, 1980). (4) Intelligence and creativity are coincident sets, as creativity is regarded as an ordinary problem solving process (Weisberg, 1986, 1993; also see the previous part of 2.2). (5) Intelligence and creativity are disjoint sets (Ericsson & Charness, 1994). Though Sternberg admitted that the most conventional view is probably the overlapping view -- that is, intelligence and creativity overlap in some respects but not in others -- he left the question open rather than expressing any confirmative view about relation between these two constructs.

Empirically, one of the more robust findings in the intelligence-creativity literature is that the two are moderately positively related (r of approximately +.20 to +.30) up to about one standard deviation above the mean in IQ (approximately 115-120) and then the relation becomes essentially zero (Albert & Runco, 1989; Barron, 1957; Barron & Harrington, 1981; Eysenck, 1995; Getzels, 1987; Gough, 1976; Helson & Pals, 2000; Jensen, 1996; MacKinnon, 1978; Simonton, 1999a; Sternberg & O'Hara, 1999; Torrance, 1980; Wallach & Kogan, 1972). Taking the results of different research together, however, one of the most recent meta-analysis studies about the correlation of creativity test and IQ test did not provide support to this moderate relation. Kim (2005) reviewed 447 correlation coefficients from 21 studies of 45,880 participants and found that the relationship between creativity test scores and IQ scores is negligible (r =.174; 95% CI = .165 -.183). Nevertheless, the study about the relation between intelligence and creativity among children and adolescents is still rare. It would be interesting to find out if this moderate to weak correlation between the two constructs also hold true for the young inventor sample.

In the education field, the relation between intelligence and creativity is quite often studied by correlating each to the scholastic achievement of the students. Getzels and Jackson (1962) compared adolescent pupils who had scored well on intelligence tests with those who scored well on creativity tests and found that highly creative children were superior in scholastic achievement compared to pupils with high IQ. This indicates a positive relationship between creativity and academic ability. The high creative people, although having an average IQ five points lower than their school population taken as a whole, performed better in school achievement. Several research studies replicated the study on other samples. Torrance (1962), for example, undertook eight replications of this famous study. Five of these studies were on elementary school students, one at high-school level and two at graduate level. It was found that six of these studies supported the findings of Getzels and Jackson that creativity is positively related to academic achievement. Yamamoto (1964) replicated Getzels and Jackson's (1962) study on 272 ninth through twelfth grade students of the University of Minnesota High School. The students in each grade were grouped into three groups based on their level of creativity and intelligence scores, including high-intelligence group, the high-creative group, and the high-intelligent-high-creative group. On analyzing the academic achievement scores of these groups, Yamamoto found no differences in academic achievement between the high creative and the high IQ groups. The high-creative students seem to be able to "compensate" for what they lack in intelligence by their creative ability to attain similar level of academic achievement. Other researchers like Jacobson (1966), Lucht (1963), Feldhusen, Treffinger and Elias (1970) have also come out in support of the Getzels and Jackson phenomenon.

Concerning inventiveness and intelligence (in terms of schoolhouse giftedness, Renzulli & Reis, 2002) discrepant results were found. Colangelo et al. (1993) studied 34 inventors who received between three and 82 agricultural and industrial patents and found that none of the inventors considered themselves as strong academic students. Over 50% considered themselves as "low achievers" and over 60% failed at least one subject in school. Even more surprising is that, three of the inventors under investigation had not attended high school and only 50% had some type of post-high school training. In contrast, Henderson (2004b) found in her study of 247 corporate inventors that 31% of them had PhDs, 31% had Master's degrees, 29% had college degrees, 6% had professional school training, and only 2% had high school degrees. The contradictory results might be due to the different domains that the two studies were focused on. Though both were about inventors, Colangelo and colleagues' study was specifically about mechanical inventiveness. Compared with inventors from other field, mechanical inventors are characterized with a notable facility with tools. This means they must not necessarily excel in traditional intelligence which has a heavy stress on mental processes. Instead, mechanically creative individuals must be very adept with tools and hands-on activities. Participants of Henderson's study were employed inventors of multinational companies in Silicon Valley, California, whose areas covered science, high technology, household, electronics, and mechanism, etc. Education plays an important role in one's making a career in a multicultural company. That is why most of the participants of Henderson's study had a degree of college or above.

Regarding the specific aspects of intelligence that might be related to mechanical inventiveness, Colangelo et al. (1992) stated that mechanical inventiveness constitutes its own set of skills and abilities. They related their understanding of mechanical inventiveness to Gardner's (1983, 1988) theory of multiple intelligences, which include linguistic, logical-mathematical, spatial, musical, bodily-kinesthetic, interpersonal, and intrapersonal etc, and speculated that mechanical inventiveness combines spatial, logical-mechanical, and bodily-kinesthetic intelligences. For the purpose of the study, only the spatial and logical-mechanical intelligences will be concentrated.

1.4.2 Knowledge

Cognitive psychology views knowledge as the understanding of concepts and theories in different subject domains and general cognitive abilities, such as reasoning, planning, solving problems, and comprehending languages (Greeno, Collins, & Resnick, 1996). Anderson (1976) distinguished two types of knowledge, namely *declarative knowledge*, which means facts about the world, and *procedural knowledge*, which refers to knowledge about how to do something. While declarative knowledge (also called "factual knowledge"), such as factors, concepts, formulas, and rules, are often the content of formal teaching in schools, procedural knowledge are processes, procedures, and courses of action that are usually acquired through direct or indirect instruction. Our knowledge includes information we learned in formal school settings and things we learned informally from our life experience.

In order to create in a certain domain, one must know something about that domain. During the past decades, an important emphasis in psychology has been put on the importance of knowledge to expertise. Educational psychologists found that whereas motivation and interest in a subject or domain seem to be the determining factors for performance at higher or the highest levels (creative achievement) at early stages, instructional methods and teaching quality becomes more and more important as the difficulty level increases (Ericsson, Tesch-Roemer, & Krampe, 1990). Partly contrary to this finding, psychometric results confirmed that differences between individuals in scientific problem-solving competence depend at the novice level more on cognitive abilities, but at the expert level more on leaning experiences and domain-specific knowledge (Heller, 1993).

In order to gain an understanding about the relation between knowledge and inventiveness, it is necessary to have a look at the cognitive approach to inventiveness. Cognitive approach views invention as a mental or cognitive process. Bjiker and colleagues (1987) perceived invention as consistent search in a problem space, which was defined as the space of all possible solutions to an invention problem. The problem space contains all the restrictions that must be filled by the new creation. With the aim to answer the question how inventors construct their problem spaces, Carlson and Gorman (1992) proposed a cognitive framework to understand invention. They viewed invention as a set of activities in which individuals combine and manipulate the symbolic with the material, a process in which ideas and concepts are manifested in terms of physical objects. Their model is composed of three major components: *mental models, mechanical representations,* and *heuristics*. The concept of mental model is borrowed from cognitive psychologist Donald A. Norman (1988), who described mental models as "the models people have of themselves, others, the environment, and the things with which they interact" (p. 17). Carlson and Gorman (1992) defined inventors' mental models as "the ideas and concepts an inventor has about his or her invention. Mental models are often dynamic prototypes an inventor can run in the mind's eye" (p. 48). In their research about inventors, the authors found that an inventor's mental model is frequently a *dynamic* and incomplete *device-like* representation that can be manipulated in the imagination. They noted that mental models are often unstable or incomplete, thus permitting the inventors to introduce changes or improvements. The second component is mechanical representations, which is defined as "the physical devices an inventor uses to build inventions" (p. 48). It is noted that one key feature of mechanical representations is that many inventors have a repertoire of preferred devices that they use repeatedly to secure a specific action. According to them, mechanical representations are central because they link an inventor's thoughts with the physical devices the inventor creates. The third component is heuristics, which is defined as "the procedures or strategies by which inventors generate and manipulate mental and mechanical representations" (p. 55). On each aspect of this model, the importance of knowledge is obvious. In order to get a big enough problem space for the effective search of solutions to happen, an individual needs to have a big enough repertoire of different mental models, which relies primarily on an individual's accumulation of different ideas/concepts or combinations of the ideas/concepts. Likewise, in order to get a good base of mechanical reorientations, an individual needs to gain knowledge and experiences about different devices. In addition, rich knowledge about some basic inventive heuristic such as segmentation, removal, asymmetry, merge, universality, nesting, anti-weight, invert, and dynamics, etc. (Altshuller, 1973, 1984) will undoubtedly enhance one's inventive ability.

On the other hand, there has been a strong shift in cognitive psychology from general mechanisms toward *domain-specific* descriptions of information processing (Ceci, 1989; Sternberg, 1989). Scott (1999) described the structure (hierarchical organization), volume (amount of information and relations) and content (items of information) of our domain-specific knowledge as important characteristics that influence how we access relevant information when performing cognitive tasks such as problems solving and creative thinking. Theories of creativity differ in the degree how they take on the centrality of domain-specific knowledge and the effect of such knowledge will have on the probability of creative production. Scott (1999) reviewed the theories of creativity in terms of their positions to the centrality of knowledge and classified the theories into two groups. One group is called "knowledge as necessary, essential, or required". This school of theories hold that knowledge is essential to the process and central to the true value in the creative product (cf., Albert, 1980; Chi, 1992; Simonton, 1984; Wallas, 1926; Weisberg, 1993). The other group is called "knowledge as important or useful, but not necessary". This school of theories suggests that a high level of knowledge may be helpful in some aspect of the creative process, but it is certainly not required (cf., Amabile, 1983a/b; Campbell, 1960; Gruber, 1989; Mednick, 1962; Mednick & Mednick, 1965). In spite, the second group does tend to recognize the value of product-specific knowledge for the creative thinking process.

Focusing on the inventive creativity of children and adolescents, which is cognitively and motivationally demanding, the current study takes the first perspective. It is assumed that knowledge is an essential prerequisite for invention. Declarative knowledge about invention and patent, such as stories of famous inventors, the major types of patents, and the differences between patentable and un-patentable products, is an important pre-requisite for invention. Procedural knowledge of inventing and patenting process, such as methods of invention, procedures of patent index searching, and process of patent application are of vital importance for children and adolescents to make meaningful inventions. Absence of mastery of this knowledge, might lead to substantial differences to the quantity and quality of the inventions of the young inventors.

1.4.3 Thinking style

Since the 1970s, thinking styles have drawn more and more attention to the field of psychology and education (e.g., Riding, 2001; Sternberg, 1988, 1997; Zhang, 2001). A style is not ability, but a preferred way of using one's abilities to approach a task or situation (Sternberg & Lubart, 1991). This definition implies that a style is neither ability nor personality; rather it is something in between or behind each. In research practice, however, it has been long discussed whether intellectual styles should be studied separately from personality or not. One group of scholars (e.g., Furnham, Jackson & Miller, 1999; Jackson & Lawty-Jones, 1996) claimed that since cognitive/learning style is a sub-set of personality, there is no need to measure intellectual styles independently, unless intellectual style is of interest in its own right. In contrast, other scholars (e.g., Busato, Prins, Elshout & Hamaker, 1999; Riding & Wigley, 1997) argued that although there was some systematic overlap between intellectual styles and personality, it certainly makes sense to mention intellectual styles and personality separately in educational settings.

In an attempt to explore this controversy, Zhang and colleague (Zhang, 2001, 2002a/b; Zhang & Huang, 2001; Zhang, 2006) investigated the relationships between thinking styles and the big five personality traits (Costa & McCrae, 1992) in both academic and non-academic settings. These studies led to consistent results which show although significant relationships are identified between thinking styles and personality traits, it is meaningful to investigate intellectual styles in addition to examining personality. In addition, results supported Sternberg's (1988, 1997) assertion that the thinking style construct is a broad intellectual style construct and the theory of mental self-government applies to both academic and non-academic settings. Based on the literature reviewed above, thinking styles and personality traits will be examined independently in this study. This and the following parts will introduce a theoretical model, based on which different thinking style types were theoretically and empirically conceptualized.

Borrowing the function of society, Sternberg (1988, 1997) put forward a Theory of Mental Self-government. The basic assumption of this theory is that the forms of government we have in the world are not arbitrary or coincidental. Rather, they are external reflections of what goes on in people's minds. In Sternberg's own words, the forms of government are "mirrors" of our mind (Sternberg, 1997, p. 19). Approaching the self-government styles from different aspects, Sternberg (1997) proposed 13 different types of thinking styles which fall into five categories, namely *functions, forms, levels, orientations and leanings*. According to Sternberg, governments serve three functions (legislative, executive, and judicial), present four forms (monarchic, hierarchic, oligarchic, anarchic), exists at two levels (global, local), demonstrate two orientations (external, internal) and two leaning aspects (liberal, conservative).

Based on a most recent empirical study, these 13 styles have been re-conceptualized into three types (Zhang & Sternberg, 2005): Type I thinking styles are the ones that tend to be more *creativity-generating* and that denote higher levels of cognitive complexity, including the legislative (being creative), judicial (evaluative of other people or products), hierarchical (prioritizing one's tasks), global (focusing on the holistic picture), and liberal (taking a new approach to tasks) styles. Type II thinking styles are styles that suggest a *norm-favoring* tendency and that denote lower levels of cognitive complexity, including the executive (implementing tasks with given orders), local (focusing on details), monarchic (working on one task at a time), and conservative (using traditional approaches to tasks) styles. The anarchic (working on whatever tasks that come along), oligarchic (working on multiple tasks with no priority), internal (working on one's own), and external (working with others) styles are Type III styles. They may manifest the characteristics of the styles from both Type I and Type II groups, depending on the stylistic demands of a specific task. For example, one could use the anarchic style in a sophisticated way (characteristic of Type I styles)—such as dealing with different tasks as they arise, but without losing one's sight of the whole picture of the central issue. By contrast, one also could use the anarchic style in a more simple-minded way (characteristic of Type II styles)—such as dealing with tasks as they come along without knowing how each task contributes to his/her ultimate goal. The foci of the current study are the so-called "creativity-generating thinking styles" as mentioned above. Due to scope restriction, this study can only focus on three of the Type I thinking styles, namely legislative, judicial, and liberal styles of thinking. The executive style will also be examined as a possible negative indicator of inventiveness.

According to the Theory of Mental Self-government, a *legislative* person likes to create their own rules and prefers problems that are not pre-structured. While doing things, such people are more likely to come up with their own ways of doing things and prefer to decide for themselves what they will do and how they will do. Sternberg (1988, 1997) stressed that a legislative style is particularly important for creativity. An *executive* person, in contrast, likes rules and regulations. He or she prefers problems that are pre-structured. Such people prefer to fit into existing structures rather than to create the structures themselves. While doing things, they like tasks that are well-defined with clearly predicable outcomes and don't like problems that are ill-defined which lead to no clear outcomes. They are interested in solving given mathematical problems, applying rules to existing problems, giving talks or lessons based on clear structure, and enforcing rules. Because of their rigidness about rules and procedures, such people are not very flexible in thinking and are therefore not very creative. A *judicial* person likes to evaluate rules and procedures, and prefers problems which entail analysis and evaluation. This type of person is interested in making critiques, giving opinions, judging people and their work, and evaluating programs. Because of their critical and analytical nature, a judicial stylist is also more likely to come up with creative ideas or products. Individuals with a *liberal* style like to go beyond existing rules and procedures and seek to maximize changes. They also like ambiguous situations, and prefer sort of unfamiliarity in life and work. These characteristics parallel, in great degree, to the characteristics of a creative individual.

Students of different giftedness levels seem to vary in the styles of thinking. Park, Park, and Choe (2005) investigated 179 students from two science high schools and 176 students from general high schools in Korea and examined whether *thinking styles* based on the theory of mental self-government could predict scientific giftedness. Results indicated that Korean gifted students preferred the legislative, judicial, anarchic, global, external, and liberal styles, whereas the non-gifted students preferred the executive, oligarchic, and conservative styles. Studies about the relationships between thinking styles and the big five personality dimensions have also been carried out. For example, the Thinking Styles Inventory and the NEO Five-Factor Inventory have been conducted to 408 university students aged 17-30 years from Shanghai, mainland China (Zhang & Huang, 2001). The hypotheses that the more creativity-*ge*nerating and more complex *thinking styles* were related to the extraversion and openness personality dimensions, and the more norm conforming and simplistic thinking styles were related to neuroticism were supported. No specific pattern was identified in the relationships of thinking styles to the agreeableness and conscientiousness dimensions. So far, there seems to be non-existence of literature that relates thinking style to inventiveness. The current study will serve to fill in this gap.

1.4.4 Personality

Personality can be defined as the pattern of characteristic thoughts, feelings, and behaviors, that distinguishes one person from another and that persists over time and situations (Phares, 1986). Among others, personality is probably the most widely investigated area in the field of creativity study. For instance, an average approximately 3500-4500 creativity references were added to the literature each decade from the 1970s to the 1990s (cf. Feist & Runco, 1993; Sternberg & Lubart, 1999).

So far, there have been quite a few extensive reviews of the studies about the relation between personality and creativity. In the early 1980s, Barron and Harrington (1981) reviewed a series of personality studies in relation to creativity and concluded that the strongest correlates of creative achievement were aesthetic sensitivity, broad interests, attraction to complexity, independence of judgment, intuition high energy level, self-confidence, and creative self-concept. In the late 1990s, Feist (1998) reported the results of a meta-analysis study on the topic of creativity and personality. The major results of this study were that creative people in general are more autonomous, introverted, open to new experience, norm-doubting, self-confident, self-accepting, driven, ambitious, dominant, hostile, and impulsive. Of these, the largest effect sizes were on openness, conscientiousness, self-acceptance, hostility, and impulsivity. It was also found that creative people from different domains demonstrated different personality profiles. For example, artists are distinguished more by their emotional instability, coldness, and the rejection of group norms than are scientists. Creative scientists, in contrast, exhibited very small effects on these socialization scales. From the perspective of developmental psychology, it is extremely important to know which psychological variables early in life consistently and clearly predict an individual's creative achievement later in life. With this research focus, Feist and Barron (2003) reported the results of a 44-year longitudinal study about 80 male graduates, exploring the relation of students' intellect, potential and personality to creativity. They found the traits of self-confident, openness, tolerance, and psychological mindedness served as a relatively more direct link to creative behavior. To be more exact, tolerance and psychological mindedness resulted in a significant increase in variance explained 20% over and above potential and intellect. That is the more tolerant and psychologically minded the student was, the more likely he/she was to make creative achievements over his lifetime.

Because of the existence of thousands of studies exploring the relationship of personality and creativity, personality will not be examined in detail in this study. Instead, three types of personalities that have been repeatedly proved to be predictive for creative behavior (Feist, 1998; Feist & Barron, 2003), namely *openness, risk-taking,* and *tolerance of ambiguity* will be examined in this study. The choice of these three personality traits is made primarily on the basis of Carlson and Gorman's (1992) cognitive framework of invention, which has been introduced in the "knowledge" part. As they noted, the "mental models" that an inventor has are often unstable or incomplete so that the inventors can have enough space to make changes or improvements. This unstable or incomplete situation causes considerable cognitive and emotional stress and an inventor must stay open to different possible solutions, be tolerant to the ambiguity that the unstable and incomplete situation causes and sometimes, take some risks to try absolutely new materials or solutions. Furthermore, the process of invention involves massive "exhaustive research" (Lemelson-MIT Program, 2003) and is characterized as "recursive" (Wolf & Mieg, 2008). Only those highly open individuals who have more tolerance of ambiguity and are willing to take risks at a certain time can cope well with the unpredictable situation and thus survive and thrive.

It is worth noting that due to the dearth of literature about children adolescents' personality and their inventiveness, literature about adult creative individuals will be reviewed. This approach is methodologically acceptable because as literature review suggested that the creative personality tends to be rather stable and that the traits that distinguish creative children and adolescents tend to be the ones that distinguish creative adults (Feist, 1999).

Openness to experiences. Of all the available personality models, the Big Five Model (Costa & McCrae, 1992; McCrae & Costa, 1999) is certainly one of the most widely studied and respected. The five personality traits of this model are *neuroticism, extraversion, openness, agreeableness,* and *conscientiousness*. McCrae and Costa (1997) remarked that Openness to Experience (in the literature it is often used in the abbreviation form: Openness) should be regarded as a broad constellation of traits with cognitive, affective, and behavioral manifestations. From the cognitive perspective, Openness resembles some form of *intellect*, which is defined as "the ability to learn and reason…(and the) capacity for knowledge and understanding" (Morris, 1976, p. 682). Of the five constructs of the Big Five, Openness is the only one that is positively related to psychometric measures of intelligence and other cognitive abilities, such as divergent thinking (with Pearson's r around .40) (McCrae, 1987). Some cognitive manifestations for Openness are imaginative, knowledgeable, original, and artistic. However, cognition alone is not sufficient to cover the meaning of Openness. Openness also encompass some motivational or affective manifestations, including high curiosity, broad interest, need for variety, and preference for complexity, etc. Examined at the behavioral level, open people are adventurous, bored by familiar sights, and stifled by routines. Therefore, they seek sensations, take risks, and actively try new things. In questionnaire form, Openness involves sensitivity to fantasy, feelings, aesthetics, ideas, actions, and values (McCrae & Costa, 1987). Many studies have shown that the Openness dimension is most closely related to creativity. Helson (1999b) even labeled Openness a "cardinal characteristic" of creativity. In his early studies at the Institute of Personality Assessment and Research (IPAR) at the University of California about persons whom have been nominated by experts for their outstanding qualities of originality and creativity, MacKinnon (1992) concluded that openness to experience turned to be one of the most striking characteristics of the creative talents. McCrae (1987) examined the relations among divergent thinking, as assessed by six different sub-tests, Gough's (1979) Creative Personality Scale and the measures of the Five-Factor Model (FFM). He found that openness to experiences was positively related to all sub-measures of divergent thinking except one, whereas none of the other dimensions of personality showed any consistent relation to divergent thinking. Amabile and colleagues (1993) administered the NEO Five Factor Inventory to a small group of professional artists and found a strong tendency toward Openness. They also found that Openness was related to a preference toward intrinsic motivation, which was measured by the Work Preference Inventory (WPI; Amabile, Hil, Hennessey, & Tighe, 1994). Dollinger and colleagues (2004) conducted a research about personality and creativity by using the Test of Creative Thinking-Drawing Production (TCT-DP; Urban and Jellen, 1996), a Thematic Apperception Test (TAT), Adjective Check List-based personality measures and scales for creative personality among a group of 151 college students. The results of the study suggested that the Openness dimension of the "Big 5" related to most creativity measures. The first meta-analysis on the topic of creativity and personality was published in 1998 (Feist, 1998) and the main conclusions from this study were that creative people in general are more autonomous, open to new experiences, norm-doubting, self-doubting, self-confident, self-accepting, driven, ambitious, etc and among these, the largest effect size was Openness. To be more exact, Openness was found to be positively related to creative behavior through the interaction with a supportive environment when the situation allows for the manifestation of the influence of openness, when feedback valence are positive and when they are confronted with a heuristic task that allows them to be creative (George & Zhou, 2001).

Risk-taking, also called willingness to take risks (see Glover & Sautter, 1977; McClelland, 1956), is another important personality trait of creative individuals. Higher risk-taking individuals are usually higher sensation seekers, who have higher needs for varied, novel, and complex experiences and would therefore be more willing to take physical and psychological risks for the sake of those experiences (Zuckerman, 1979). Barron and Harrington (1981) suggested that sensation seeking is among the traits that should be investigated as correlates of creativity, and a series of studies (Zuckerman, 1979) have demonstrated significant positive correlations between early forms of Zuckerman's Sensation Seeking Scale (SSS-V) and a variety of measures of creativity and creative behavior. Barron (1963) associated creativity with personal impulsivity and daring, and also referred to the risks as inherent in the desire to create. In the realm of scientific creativity, Kaplan (1963) stated the role of self-confidence and risk-taking in fostering creativity of research scientists in an organizational setting, and McClelland (1963) proposed that strong achievement motivation in the creative scientist promotes the taking of "calculated risks" essential to scientific discovery. Relations between creativity and risk-taking in children and adolescents have also been suggested. Getzels and Jackson (1962) referred to the willingness of creative adolescents to free themselves from customary modes of thought in order to pursue new directions, that is, to risk the uncertainty of the unknown. Bruner (1960) described the children's need to free themselves from the fear of risking error in order to make the occasional "intuitive leap" during the course of thinking. Both of the foregoing perspectives imply that risk-taking focused on tolerance of error is part of the fabric of creative thought. Within such a perspective, creativity can indeed be equated with cognitive risk-taking. Glover (1977) discovered in his study that when the level of risk-taking in groups of students increased, the students' performance on the Torrance Test of Creative Thinking also increased in flexibility and originality, decreased in elaboration, and there was no change in fluency of responses.

Tolerance of ambiguity. Ambiguity is the term we apply to perceived insufficiency of information regarding a particular stimulus or context (McLain, 1993). Budner (1962) defined perceived ambiguity as a source of threat and identified three types of ambiguous stimuli: *novel, complex,* and *insoluble* (subject to multiple incompatible interpretations). Ellsberg (1961) equated ambiguity with second order probability, that is, the degree of certainty with which an individual could estimate the probability associated with each branch of a decision represented in the extensive form. Frenkel-Brunswik (1949) associated ambiguity with authoritarianism and prejudice and described intolerance of ambiguity as intolerance of diversity among people. Taken the previous definitions together, Norton (1975) elicited eight categories of ambiguity and defined the intolerance of ambiguity as "a tendency to perceive or interpret information marked by vague, incomplete, fragmented, multiple, probable, unstructured, uncertain, inconsistent, contrary, contradictory, or unclear meanings as actual or potential sources of psychological discomfort or threat" (p. 608). A relation between tolerance of ambiguity and creativity has often been proposed. People who are tolerant of ambiguity like ambiguous situations, or at least can live with them for some time (MacDonald, 1970). In contrast, individuals who are intolerant of ambiguity quite often feel constrained, anxious or tense in ambiguous situations. Vernon (1970) seemed to think that this is the most important trait for creative work (cf. Golann, 1962; Stoycheva, 1998, 2003). Other authors have suggested that the more individuals tolerate ambiguity, the more creative they are (Barron & Harrington, 1981; Golann, 1963; Sternberg & Lubart, 1995; Urban, 2003). This hypothesis is based on the idea that situations requiring creative thinking often involve ambiguity. The more a person can tolerate ambiguous objects, the more likely the person can deal with them. For Stoycheva (1998, 2003), tolerance of ambiguity is linked to creativity because ambiguity-tolerant individuals are able to accept the feelings of anxiety and psychological discomfort naturally provoked by ambiguity associated with new, difficult situations. Based on Urban's (2003) components model of creativity, tolerance of ambiguity is believed to contribute to the creative process because it empowers the intrinsically motivated exploration of novel, unusual or complex stimuli. In spite of these theoretical proposals, empirical research has rarely tested the relations between tolerance for ambiguity and creativity. In 1990, Tegano, using the Tolerance of

Ambiguity Scale (AT-20; MacDonald, 1970), observed a positive correlation (r = .31, p<.05) between early educators' tolerance of ambiguity and their MBTI creative style score, thus offering evidence that the tolerance of ambiguity scale was positively correlated to a creativity style index. Furnham and Avison (1997) observed a significant link between tolerance of ambiguity and preference for surrealistic paintings, which is a partial aspect of creative style. Comadena (1984) examined creative performance of 76 undergraduates in brainstorming groups and observed that tolerance of ambiguity was positively linked to the number of produced ideas. However, studies about the relation of tolerance of ambiguity and inventive potential of children and adolescents seem non-existent. So it would be helpful to include this factor in this study.

1.4.5 Motivation

Also relatively well-researched field of creativity study is motivation. Psychologists assume that behavior does not occur at random. It is caused. The behavior of organism is assumed to be largely caused by motives. Psychologists define motivation as an internal process that activates, guides, and maintains behavior over time (Baron, 1992; Schunk, 1990); or the influence of needs and desires on the intensity and direction of behavior (Slavin, 1994); or the study of why people think and behave as they do (Graham & Weiner, 1996). Depending on the sources of drive and the direction of goal orientation, motivation is generally dichotomized into two opposite types, namely *intrinsic* and *extrinsic motivation.* White (1959) and Harter (1978) defined intrinsic motivation in terms of individuals' innate needs to be effective in their interactions with the environment. DeCharms (1968) proposed that intrinsic motivation results from the individual's desire to be the primary control of causality of his or her own behavior. Deci and Ryan (1985) characterized an intrinsically motivated state as oriented toward seeking and conquering optimal challenges. In their conceptualization, intrinsic motivation results from both the need for competence and the need for self-determination. In its simplest form, what social psychologists commonly refer to as intrinsic motivation is what Aristotle described as "which we desire for its own sake". In contrast, *extrinsic motivation* is the drive to engage in an activity as a means to an end. Individuals who are extrinsically motivated work on tasks with the expectation that the participation will result in desirable outcomes such as reward, praise, money, material gains, or avoidance of failure or punishment. What role the intrinsic and extrinsic motivation plays in driving an individual to be creative has long been an interesting topic for the researchers.

Due to its strong impact, intrinsic motivation has been identified as one major component of many creativity theories. For example, "intrinsic motivation" is one of the component of Amabile's (1983a/b) componential model of creativity. In Woodman and Schoenfeld's (1989, 1990) interactionist model of creative behavior, intrinsic motivation is also acknowledged as a component that is conducive to an individual's creative accomplishment. In the interactive approach, which focuses on the development of an individual's creativity within society, Csikszentmihalyi (1990a) and Gardner (1993) both included intrinsic motivation as a personal characteristic that contributes to creativity.

A growing body of empirical studies about motivation and creativity come to the same conclusion that intrinsic motivation is conducive to creativity. Studies of personalities of highly creative people have described them as being totally absorbed in and devoted to their work (Barron, 1963; MacKinnon, 1962). In a set of longitudinal studies following people from elementary school through adulthood, Torrance (1981, 1983, 1987b) found that people who were doing what they loved were more creative in their pursuits. A study of talented youth in math and science reported that these creative teens displayed higher levels of intrinsic motivation than their peers (Heinzen, Mills, & Cameron, 1993). Utilizing a case-study approach, Gruber (1986; Gruber & Davis, 1988) also observed that highly creative people possess an intense commitment to their work, manifested as a fascination with a set of problems that sustains their work over a period of years. Research has also found that creative people are energized by challenging tasks, a sign of high intrinsic motivation (Albert, 1990; Perkins, 1988). In his well-known research about 91 exceptional individuals of USA, including 14 Nobel Prize winners and celebrities in various fields such as writers, artists, musicians, philosophers, physicians, chemists, biologists, and economists, etc., Csikszentmilhalyi (1997) described the highly creative persons as highly intrinsically motivated people who even reached a state of "flow" wherein there are heightened feelings of enjoyment and a centering of concentration, such that even the passage of time may seem to slow. Earlier, Csikszentmilhalyi (1990b) argued that people involved in creative pursuits actively seek flow experiences and that creativity is more likely to result from such states.

While intrinsic motivation seems undoubtedly favorable for creativity, the opposite – extrinsic motivation undermines creativity – seems to be not always true. As a matter of fact, the relation between extrinsic motivation and creativity has become the focus of even more research, which leads to greater controversy. In a series of experimental studies about the comparison of the creative behavior of groups of female students that were either exposed to external evaluation or not, Amabile (1983a) found the creativity of the group who were exposed to external evaluation were significantly lower than the "non-evaluation" group. These results were consistent for different experiments with different creativity activities, including algorithmic vs. heuristic tasks, artistic tasks, and verbal tasks. Further studies have confirmed the detrimental effect of expected performance evaluation (an extrinsic motivator) and have also provided evidence to the fact that the receipt of positive evaluation prior to performance produces negative effects on creativity (Amabile, Goldfarb, & Brackfield, 1990; Bartis, Szymanski, & Harkins, 1988; Hennessey, 1989; Szymanski & Harkins, 1992). Similarly, people are less creative when simply being watched by others (Ambile et al., 1990). In addition, competing for prizes to be offered to makers of the "best" products also has been shown to undermine creativity (Amabile, 1982b, 1987). Contracting for a reward, to be received contingent on task engagement, also leads to lower levels of creativity (Hennessey, 1989; Kruglanski, Friedman, & Zeevi, 1971; McGraw & McCullers, 1979). In spite of this, a number of studies designed in the behavior modification tradition have shown positive effects of *reward* on various aspects of creative performance (e.g., Campbell & Willis, 1978; Eisenberger & Selbst, 1994; Glover, 1980; Halpin & Halpin, 1973; Locurto & Walsh, 1976; Milgram & Feingold, 1977). In most of the studies, participants were told to "be creative" on a particular type of task and were rewarded for increasing this behavior.

Their responses were assessed by the criteria of fluency, flexibility, originality and elaboration. It was found that the benefits of reward were most apparent on the behaviors that could be easily modified using an algorithmic, or step-by-step approach. When reward was found to enhance originality, subjects had been explicitly instructed to try to generate unusual responses. In another study, interesting results were found with children (Ambile, Hennessey, & Grossman, 1986). When children made a deal with the researcher to tell a story in return for playing with a Polaroid camera as a reward, the typical undermining effect of reward was found. Surprisingly, however, children who told a story after playing with the camera as a "non-contracted-for" reward actually told more creative stories than a control group. It was explained that the children may have perceived the *noncontingent* reward as a bonus, which put them in a good mood and intensified their involvement in the storytelling activity.

Actually, the controversial role which extrinsic motivators play in creative behavior has raised Amabile's attention and has led her to a revised view of extrinsic motivation and creativity (Amabile, 1993, 1996). She referred to Deci's (1975; Deci & Ryan, 1985) theory about the double effects of a reward (including feedback), namely a *controlling* effect which makes an individual feel challenged and controlled versus an *informational* effect which provides the recipient with information about his competence and self-determination. Building upon this distinction, Amabile (1993) differentiated two types of extrinsic motivators: *synergistic* extrinsic motivators, which provide information or enable the person to better complete the task and which can act in concert with intrinsic motives; and *nonsynergistic* extrinsic motivators, which lead the person to feel controlled and are incompatible with intrinsic motives. Due to its informative nature, the synergistic extrinsic motivators can be beneficial for creativity. This revised view of extrinsic motivation and creativity is described by Amabile explicitly as "Intrinsic motivation is conducive to creativity; controlling extrinsic motivation is detrimental to creativity; but informational or enabling extrinsic motivation can be conducive, particularly if initial levels of intrinsic motivation are high" (Amabile, 1996, p. 119).

In Rossman's (1964) study about successful professional inventors, he also addressed the issue of motivation. While analyzing the responses of the inventors to the question "What motives or incentives cause you to invent?", he found that over half of the inventors mentioned "love" or "desire to improve", which fall into the intrinsic motivation category. The love of work has also been talked about as indicative of inventive individuals by the 34 inventors with 3 to 82 patents in the study of Colangelo et al. (1993). Likewise, in her study about 247 corporate inventors, Henderson (2004b) asked each inventor to provide three reasons for why they pursued the inventing work. The results showed a salient *internally-motivated* image of the inventors: seven out of the top ten most frequently mentioned goals were related to intrinsic motivation with mastery as the No. 1 reason. Although among the top 10 listed goals, two extrinsic goals, namely superiority and material gain, were also mentioned, their positions in the list were located near the bottom (ranked number 8 and 10 respectively). Unexpectedly, however, in Rossman's (1964) study, right after the two intrinsic motives, "financial gain" which is a typical extrinsic motivation, followed as the third most frequently mentioned incentive. He admitted that inventing is a business undertaken with a hope of profit. Before any invention is perfected and marketed, a great deal of money must be spent in developing and perfecting the original mental conception. Amabile's (1996) Intrinsic Motivation Principle mentioned above can be used to explain this seemingly paradoxical result. When "financial gain" becomes a necessity of living and is essential for implementation of inventive products, its enabling effect outweighs the controlling effect. Then it becomes one motivator of invention. Mansfield and Busse's (1981) theory of different motives acting on different parts of the creative process can also lend an explanation to this phenomenon. It seems that for inventors, the pure love of invention and the internal desire to improve drives them to pursue a career as an inventor. But in order to bring the inventions at hand to successful completion and pursue the career as an inventor with ease, the dynamic spur of profit is essential.

With regard to the gifted children and adolescents, writers and researchers on gifted education acknowledged the merits of both intrinsic and extrinsic motivation

(Clinkenbeard, 1994; Feldhusen, 1998; Hay, 1993; Lens & Rand, 2000). Many researches have found that rewards, praise, and recognition from teachers and parents, which were all extrinsic, were effective motivators for gifted children to pursue their creative potential. In the school setting, Philips and Lindsay (2006) found that the support systems of the schools were appreciated by the young gifted as an important motivator for them to translate their giftedness into high performance. In particular, they appreciated the praise from their teachers for trying alternative and creativity approaches in their work. Bloom (1985) found that in the early years of talent development it was the motivational support and encouragement by home and teachers, as well as other rewards and recognition that helped the gifted children to grow.

To summarize, previous studies about intrinsic vs. extrinsic motivation of creative individuals, particularly those of the inventors and children, seem to depict a mixed image: there is evidence of the importance of both intrinsic and extrinsic motivation for adult inventors; there is also evidence of appreciation of rewards and recognition of achievements among the gifted children. As a result, it seems reasonable to assume that a combination of both intrinsic and extrinsic motivation should have an effect on the young participants' act of invention. This is the reason why both intrinsic and extrinsic motivation is considered in the current study.

1.4.6 Environment

Systems approach attaches great importance to the environmental perspective of creativity. Csikszentmihalyi (1994) pointed out that it would be impossible to approach creativity without taking into account the social/environmental parameters around a person, as creativity is not an attribute of individuals but is of social systems making judgments about individuals. The core concept of his "Systems Model of Creativity" (refer to 1.3.2) is that the nature of creativity is context-dependent, and that the interaction among domain, field, and individual is essential in motivating creative individuals to achieve higher goals. Simonton (1984, 1992a, 1994a) studied historically eminent people across different times and societies and found that societies can have a tremendous impact on people's creativity. He concluded that it is the historic time and social environment, rather than individual factors, which are crucial for the generation of creative contributions.

Contemporary approaches to understanding the impact of the social environment on creativity propose that external factors influence creativity by the effect that they have on the individual's motivational state (Conti & Amabile, 1999). Amabile (1983a/b, 1996) by applying this approach in her research practice, established the componential model of creativity (refer to 1.3.2). Though environment was not proposed as a component in this model, through about three decades' empirical investigations, Amabile and her colleagues found consistent influence of the environment on motivation. That is, when a person's intrinsic motivation was supported by the environment, he/she is more likely to be highly creative, while when he or she was pressured or constrained by extrinsic motivators, such as deadlines, surveillance, and competition (Amabile, 1982b; Amabile et al., 1990), his or her creativity would be impeded.

For children and adolescents, family and school are two most important environments for their development and socialization. In the family setting, many researchers note the importance of parental support and encouragement in the progress and achievement of gifted young people. Feldman and Goldsmith (1986) studied the development of child prodigies and found that their parents played an important role in their development in providing support and encouragement. Gogel, McCumsey, and Hewett (1985) asked over 1,000 families about the successful ways of raising their gifted children and consistent encouragement and praise came out to be one of the most cited parenting ways. Other studies indicated that parents assisted the development of their gifted children by supporting their interests (Bloom & Sosniak, 1981); by encouraging curiosity and active exploration (Kulieke & Olszewski-Kubilius, 1989); by encouraging autonomy and perseverance and focusing their resources on their gifted children (Robinson & Noble, 1991). Csiksentmihalyi, Rathunde, & Whalen (1997) persisted that recognition, praise and support from parents, teachers and peers should be included as part of immediate external rewards. The environmental stimulant seems even more effective for the Chinese students to behave creatively. In a cross-cultural study about the American and Chinese adolescents' creativity in accomplishing a collage design task, the Chinese students' creativity was increased when given direct instruction (which can be interpreted as a verbal encouragement) to be creative (Niu & Sternberg, 2003).

Like families, schools play an important role in communicating cultural values to their students and to socialize them. Previous studies about the role of school in fostering inventiveness are contradictory. In one study, researchers (Colangelo et al., 1993) interviewed a group of mechanical inventors and asked about their view of schooling. Most of the inventors examined found school pleasant but mentioned that school was not the primary source for their knowledge of mechanics. They reported that they learned most of what they needed to know on their own by reading on areas of interest. For the most part, they learned by "doing and observing". When asked whether schools could do something to help inventive students, the inventors were not sure how schools could help young inventors. Some maintained that schools over-emphasized conformist thinking and did not encourage or recognize creative or inventive students. The vast majority thought that schools needed to do more to recognize and encourage inventive students. A survey among young inventors, in contrast, voiced another opinion. They were overwhelmingly positive about the role of school (Colangelo et al., 2003). A more recent study about entrepreneur inventors (Henderson, 2004b) found that the inventor participants mentioned with notable frequency that they had materials and resources for invention, access to tools, appliances and equipment, and sometimes independent places in which to try out their inventive ideas. They also remembered having opportunities to participate in activities based on active problem-based discovery learning in early school years up through to graduate education. These activities included science affairs, invention grants/competitions, and product-design courses, etc. The inventors regarded these activities as affording freedom for their unique ideas to blossom and providing them inspiration to express their creativity in terms of tangible discoveries, creations, and inventions. In other words, the encouragement and resources that schools provided to them during their school years were recognized by the inventors as stimulating factors for the development of their inventive talent. It is worth noting that the above-mentioned studies were all carried out in the West, literature about the part that contemporary schools play in inhibiting or fostering creativity is still rare. The current study will help us explore this issue with a large sample drawn from over 100 schools in mainland China.

In sum, stimulating environments where students can get enough support and encouragement have been repeatedly proven to be important for creativity to occur. In the current study, such stimulating factors in both family and school settings will be focused. It is worth noting, that support can be both *emotional/mental* and *material*. In their model of Perceptions of the Work Environment for Creativity, Amabile and colleagues (1996) identified three enabling elements ("stimulants"), including encouragement, autonomy, and resources. In their study, they defined encouragement at an organizational level, which included encouragement of risk-taking, idea generation, innovation, supportive evaluation of new ideas, reward and recognition to creativity, etc. For the current study, encouragement is defined in particular relation to inventive behavior, which includes encouragement of being inventive, participation and persistence in inventive activities as well as reward and recognition to inventiveness. Most literature addresses the resources in terms of *time* and *money* and has provided evidence that resources available to projects are directly related to the projects' creative levels (Cohen & Levinthal, 1990; Damanpour, 1991; Farr & Ford, 1990; Tushman & Nelson, 1990). In the current study, resources at home refer to financial support from parents for children to take inventive activities and availability of materials that children need for making inventions. In the school setting, resources refer to existence of an "inventing place" for the students and availability of the needed materials for making inventions.

1.4.7 A hypothetical model of the study

The previous part reviewed the literature about the systems approach of creativity with a special emphasis on the Investment Theory of Creativity (ITC). ITC is emphasized because it is established on the basis of the most relevant findings in the field. Due to its highly pertinent nature, the ITC lays the basis for the selection of the variables of the study. In spite of this, the components identified by ITC are criticized as "loosely connected" (Csikszentmihalyi, 1991). To remedy this, the Munich Model of Giftedness (MMG; Heller, 1992; Heller et al., 2005) is borrowed to provide the *structure* mode for the variables. The decision for MMG was made because of three reasons. Firstly, inventiveness in the current study is perceived as one specific giftedness (refer to the Introduction part for a review). MMG is characterized as a *multi-dimensional* and *typological* constructs model of giftedness which also incorporates creativity. Such a model is more appropriate than other cognitive or motivational models for current study. Secondly, MMG is developed on the basis of a causal model of performance behavior in the gifted and talented (Heller & Hany, 1986), which emphasizes the interplay of cognitive, personal characteristics and environmental factors. This means, though not labeled as so, MMG is also a systems model. Such a model fits the systems approach of the current study. Thirdly, MMG is a nationally and internationally validated model (Heller & Perleth, 2004; Heller et al., 2005; Scheblanova, Averina, Heller, & Perleth, 1996), including validation studies with Asian samples (e.g., Korean samples). This gives MMG advantages over other models to be applied to a Chinese sample.

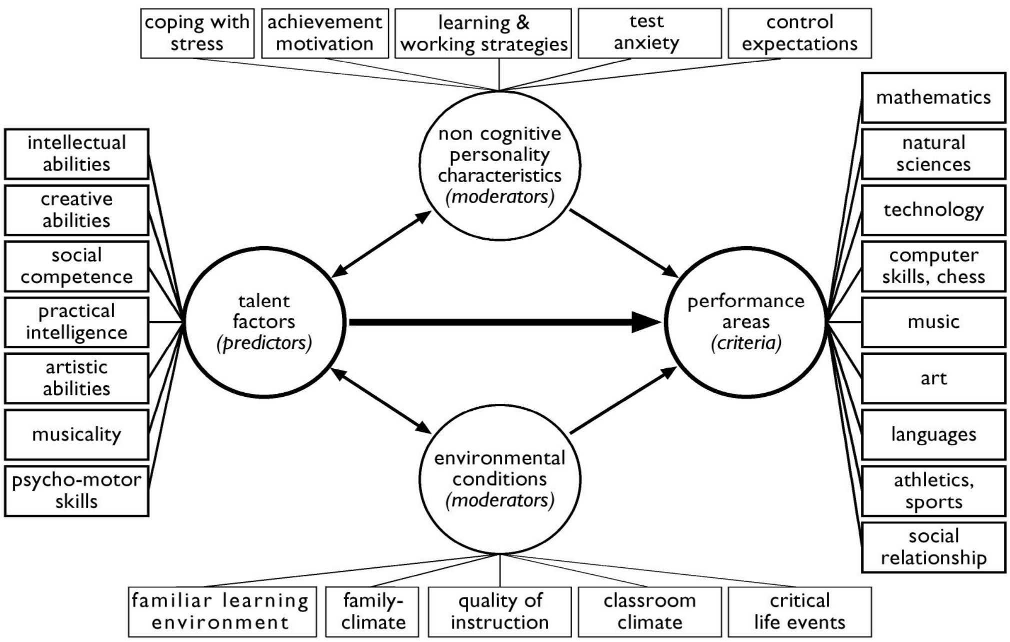


Figure 1.1 The Munich Model of Giftedness (MMG) (according to Heller, 1992; Heller et al., 2005)

As Figure 1.1 shows, MMG consists of seven types of relatively independent ability factors, including creative abilities. These talent or cognitive factors serve as predictors of relevant performance domain, which in the current study is invention. Non-cognitive personality characteristics (e.g., motivation, interest, self-concept) and environmental factors (e.g., family and school climate) serve as moderators. It is worth noting that the differentiation between predictors and mediators in this model is for diagnostic purposes (Heller, 1992; Heller et al., 2005). According to Heller (1987, 1989), diagnoses of giftedness can serve an important function in personality nurturance such as individual counseling or intervention. As the main purpose of the current study is to provide parents and school teachers with a psychological profile of the young inventors, the results can provide useful information for diagnostic purposes. So it is appropriate to also differentiate possible predictors and mediators. Based on the variables of ITC and the framework of MMG, a systems model of inventiveness is hypothesized, which is presented in Figure 1.2.

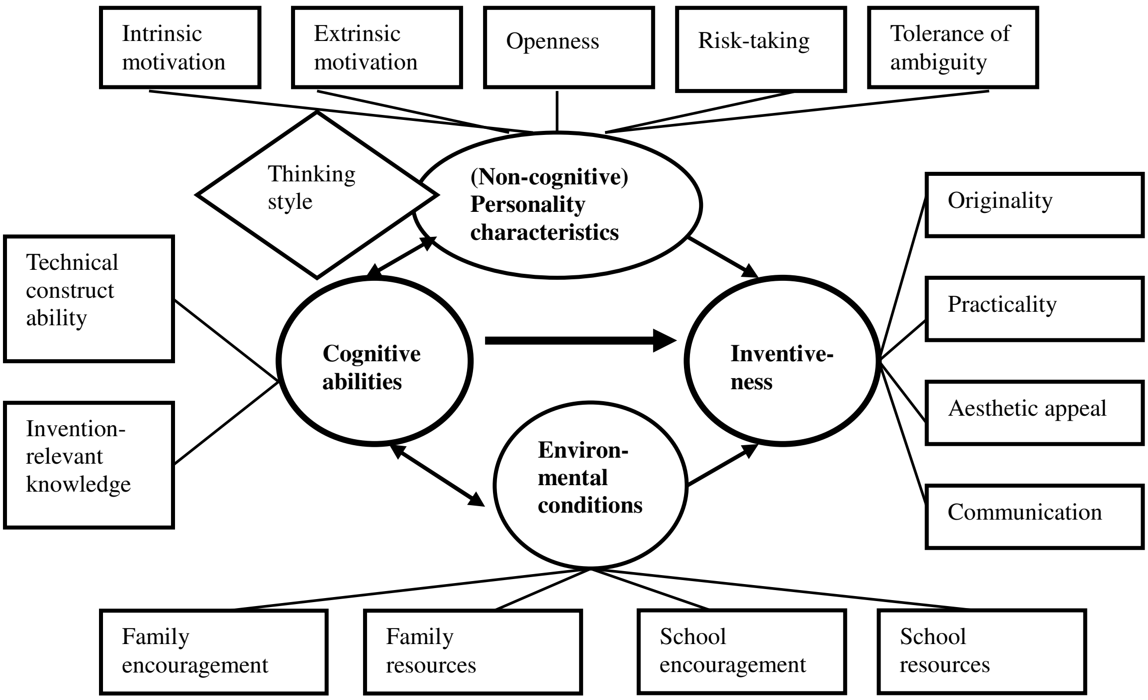


Figure 1.2 A hypothesized Systems Model of Inventiveness: adapted from the Investment Theory of Creativity (Sternberg & Lubart, 1991, 1992) and the Munich Model of Giftedness (Heller, 1992; Heller et al., 2005)

In this model, cognitive factors, including technical-constructive abilities and invention-relevant knowledge (factorial knowledge of the history of invention; declarative knowledge of the patent law; and procedural knowledge of the method and process of invention) are hypothetical predictors of inventiveness. Non-cognitive personality factors, including intrinsic motivation, extrinsic motivation, openness to experiences, risk-taking, and tolerance to ambiguity as well as environmental factors (encouragement and resources at home and school) are moderators. It is worth noting, while constructing the model I find it difficult to find a proper position for thinking style. According to Sternberg and Lubart (1991) style is not ability, but rather a preferred way of using one's abilities to approach a task or situation. Later, Sternberg and Grigorenko (1997) perceived intellectual style as a "bridge" between cognition and personality. Based on these, thinking style is put somewhere between the cognitive factors and the non-cognitive personality factors. Given the fact that there is actually a controversy in the field about whether intellectual styles should be studied separately from personality, the current study can serve to explore if the thinking style variables are loaded on the same factor as personality factors. At the right end of the model is outcome domain – inventive creativity or inventiveness (for definition please refers to 1.1.5). This construct is treated as the criterion of the study.

1.5 Research questions and hypotheses

The current study is designed to serve five major research purposes: Firstly, to examine how the individual and environmental factors are related to one another in predicting the inventiveness of young inventors. Secondly, to explore in which individual and environmental aspects the higher- and lower-level young inventors differ. Thirdly, to explore gender differences among the participants in each cognitive, non-cognitive, and environmental domain. Fourth, to explore age-related differences among the participants in each cognitive, non-cognitive, and environmental domain In addition, due to the scanty empirical studies about young inventors, our knowledge about this special group is rather limited. So the current study also serves an extra purpose of providing basic information about who the young inventors are and what they invent.

To serve these purposes, five main research questions are of special interest:

1. How the individual and environmental factors are related to one another in predicting the inventiveness of young inventors?
2. In which individual and environmental aspects do the higher- and lower-level young inventors differ?
3. In which individual and environmental aspects do male and female young inventors differ?
4. In which individual and environmental aspects do young inventors of various age groups differ?
5. Who are the young inventors and what do they invent?

Altogether three hypotheses are made for the 1st research question:

H1a: *Intrinsic motivation, creative personality (openness, risk-taking, tolerance ambiguity) and creative thinking style (legislative, judicial, and liberal) are positively related to one another, while negatively related to extrinsic motivation and executive thinking style.*

This hypothesis is derived from Runco's (2007) recommendation of a dichotomy of *indicative* and *contra-indicative* traits to creativity. Indicative traits are those personality traits that are positively related to creativity and contra-indicative traits are those negatively related to creativity. Personality traits here are used in a broader sense, which include motivational, cognitive, and affective components of personality. This perception is in line with Helson's (1999b) definition of personality as "the relatively enduring organization of motivations and cognitive and affective resources (traits) that any person manifests or that distinguishes one individual from another" (p. 361).

H1b: *Examined in categories, both individual and environmental factors account for a significant amount of influence on student inventiveness, yet neither individual nor environmental factors alone can sufficiently explain one's inventiveness.*

This hypothesis is made based on the assumptions of most of the systems models of creativity. As already discussed in the previous part (refer to pp. 45-50 for a review), systems approaches view creativity as an interaction of multiple factors within and outside of an individual. This means neither individual nor environmental factors alone can sufficiently account for inventiveness. Rather, factors from both domains have an effect on the criterion variable. Some previous studies have provided evidence to this hypothesis (e.g., Niu, 2007; Sternberg & Lubart, 1991, 1996).

***H1c**: Examined separately, invention-relevant knowledge is the best predictor for the inventiveness of young inventors.*

Weisberg (1986, 1993, 2006), through his comparison of the creative eminents and normal people, found that the creative eminents are extraordinary because of their products, but not because of the processes by which these products are brought about. Creative eminents use the same thinking process as do the normal people. The great difference between these two groups is their level of skills (refer to pp. 34-35 for a review). He emphasized the positive relation between knowledge and creativity, as when domain-specific knowledge increases, one's domain relevant skills are also likely to increase. His ordinary view about creativity has been supported by a series of evaluation studies, which found students can be trained to make inventions. It is based on this stream of literature that the above hypothesis is made.

Regarding the 2nd research question, the following hypotheses were made:

***H2a**: Compared to less successful inventors, more successful young inventors have more knowledge about the patent law and invention.*

The reasoning for this hypothesis is the same as that for H1d (see above). Weisberg's (1986, 1993, 2006) ordinary view about creativity and the existence of empirical evidence for the effectiveness of inventiveness training lay the basis for this hypothesis. It is hypothesized that because of the lack of a control group, the within group intellectual difference will be minimal. Rather, the variation in invention-relevant knowledge will make the difference between the higher- and lower-level groups.

***H2b**: Compared to less successful inventors, more successful young inventors are more intrinsically motivated for taking inventive endeavors.*

There is evidence that young inventors are similar to adult inventors and different from adult and young non-inventors in terms of personality, biographical, and behavioral characteristics associated with inventiveness (Colangelo et al., 1993). Researches about adult inventors have delineated a highly intrinsically motivated profile for adult inventors (see Henderson, 2004b; Lemelson-MIT Program, 2003; Rossman, 1964). This personal trait can be regarded as an important motivational prerequisite for making inventions, as psychologists agree that invention is both intellectually and emotionally demanding (Henderson, 2004a, 2004b; Lemelson-MIT Program, 2003). The more intrinsically motivated an inventor is the more likely that he or she will be able to withstand the challenges and advance his or her inventions. So it is reasonable to hypothesize that higher-level young inventors are also more intrinsically motivated for taking inventive endeavors than their lower-level counterparts.

***H2c**: Compared to less successful inventors, more successful young inventors are more open to new experience, willing to take risks and more tolerant with ambiguity.*

This hypothesis is derived primarily from the cognitive features of the invention process, particularly the cognitive framework of invention developed by Carlson and Gorman (1992) (refer to pp. 55-56 for a detailed review). They maintained that the "mental models" that an inventor has are often unstable or incomplete so that the inventors can have enough space to make changes or improvements. An inventor who is more open to different possible solutions, more tolerant to the ambiguity cased by unstable/incomplete situation, and more willing to take risks is more likely to come about with new inventions. Moreover, the process of invention involves massive "exhaustive research" (Lemelson-MIT Program, 2003) and is characterized as "recursive" (Wolf &

Mieg, 2008). A more open mind, higher tolerance of ambiguous situations, and willingness to take risks will enable an inventor to persevere and progress in the inventive endeavor.

***H2d**: Compared to less successful inventors, more successful young inventors score higher in the scales of legislative, judicial and liberal thinking styles but lower in executive thinking style.*

This hypothesis is derived from the existing theory about the relationship between styles of thinking and creativity. Zhang & Sternberg (2005) identified three major types of thinking styles, including Type I thinking styles that tend to be more creativity-generating, Type II thinking styles that tend to be more norm-favoring, and Type III thinking styles that is a combination of the first two types depending on the task and situation. In their model, legislative, judicial, and liberal styles are typical creativity-generating thinking styles, while the executive style is typical norm-favoring. Inventiveness is perceived as a special form of creativity in the current study. It is, therefore, hypothesized that the higher-level young inventors score higher in the creativity-generating thinking styles, including legislative, judicial and liberal styles, and lower in the norm-favoring thing style such as executive style.

***H2e**: Compared to less successful inventors, more successful young inventors are from families or schools where more learning resources and experiences are available and where inventiveness, trial, and persistence are more encouraged.*

Researches about adult inventors revealed that they appreciated encouragement from parents and teachers to engage in inventive activities and the availability of resources (tools, materials, devices, and private lab, etc.) at both home and school was conducive to their development of inventiveness (Henderson, 2004b). On the other hand, lack of financial support and prejudice of people are the two greatest obstacles to being inventive (Rossman, 1964). Compared to adults, children and adolescents are more susceptible to the influence of the outer environment, so it is hypothesized that higher-level young inventors are from a family or school where more learning resources and experiences are available and where inventiveness, trial, and persistence are more encouraged.

Concerning the 3rd research question which is concerned with gender issues, no specific hypotheses can be made because of the contradictory results existing in the literature about gender differences in creativity. Baer (in press) examined 80 different studies on gender and creativity and found that half of them found no differences. And among the rest half which did find differences, the results were split. While about 2/3 of the studies found higher creativity in women, 1/3 found men to be more creative. Even so, Baer and Kaufman (2006) reminded that because investigations that fail to find statistically significant differences are less likely to be submitted to publication, it is possible that the proportion of published studies showing gender differences of any kind can be somewhat artificially inflated. Also in the field of invention, which is typically male-dominant, the existing literature does not suggest clear gender differences in either adult or young samples. Henderson (2003) found no gender differences in self-reported creative achievement of 247 corporate inventors. In their study about American young inventors, Colangelo and colleagues (1993) also did not provide evidence for a clear stereotyped view of seeing boys as more inventive than girls. Based these literatures, it seems more proper to make a general hypothesis as follows:

H3a: *In general, there will not be many gender differences in inventiveness and inventiveness-related cognitive and non-cognitive factors.*

Although no significant gender differences can be hypothesized for person-related factors, differences in the environment might be expected. Eagly (1987) maintained that adoption of gender roles determine appropriate conduct for men and women and can lead to gender differences. China has a long history of Confucius tradition, which attaches primary importance to the harmony of society. To keep the harmony, it is emphasized that everybody finds his or her proper position in the hierarchy of human relations and act accordingly. As invention is generally perceived as a non-domestic and typical male thing, it is thought to be not proper for girls. This gender role perception might lead parents or teachers to consciously or unconsciously provide less encouragement and resources to develop inventiveness in girls. Therefore, it is hypothesized that

***H3b**: Boys perceive more encouragement and resources than girls from parents and teachers for engaging in inventive activities.*

The 4th research question is about age-related differences on the variables under investigation. There is a surprising dearth of research involving direct comparisons of creativity among different age groups, maybe because of the distinct discontinuous character of the development of creativity (Torrance, 1975). Despite this, results from a fine-grained cross-cultural study about technical creativity among children and adolescents in China and Germany can provide useful insights for making hypotheses (Shi, Zha, Zhou, & Heller, 1998). In this study, German and Chinese researchers adopted longitudinal and cross-sectional designs to follow 207 Chinese and 143 German 5th to 7th-grade students for three years. Seven tests were given to the students, including five for assessing technical creativity (product improvement, problem solving in physics and technology, uses test, mental folding test, and analogy test) and two for assessing intrinsic motivation (in terms of interest and thirst for knowledge). Results from both countries suggested a developmental trend in both cognitive and motivational domains of technical creativity. Based on this result it is hypothesized:

***H4a**: There will be an increase in intrinsic motivation, inventiveness, technical construct ability, and knowledge about invention with age.*

As no literature is available about age-related differences in thinking style and perceptions of the creative environments, no hypotheses are made for these two domains.

The last research question is an exploratory one which will be answered by descriptive analyses of the relevant demographic and biographical data. So no hypotheses are made for this question.

CHPATER 2 – METHOD

2.1 Participants

The focus of the current study is a special group of children and adolescents who were identified for their extraordinary inventive creativity. The sample was drawn from the participants of the "1st Inventive Ideation Contest for Children and Adolescents in China" that was held in Beijing in July 2007. Each of these participants had to receive merit recognition at the local and regional level in order to be selected for the final contest. Of this group (N=1223), a sample of 621 were drawn from the 4th to 12th grades by adopting a stratified sampling principle that maximizes the representativeness of the sample in terms of gender, school types, and regions.

The participants were from 112 schools that are scattered all over China. Over half of the schools (52.7%, n=59) belong to the developed area of China which covers seven provinces and three municipalities. From each province and municipality of this area a total of 350 students (167 boys and 183 girls, accounting for 56.6% of the total number of participants) took part in the current study. One quarter of the schools (n=28) belong to the developing area of China that covers nine provinces and one Ethnic Autonomous Region (EAR). From six provinces and the EAR of this area a number of 129 students (78 boys and 51 girls, accounting for 20.9% of the total number of participants) took part in the current study. The rest 25 schools (accounting for 22.3%) were from the underdeveloped area of China that is composed of six provinces, one municipality and four EARs. In this area 139 students (56 boys and 83 girls, accounting for 22.5% of the participants) that came from one province, one municipality and two EARs participated in the current study. In summary, the developmental level of the areas where the participants came from in terms of high- middle- and low-level roughly equals 3:1:1.

The geographical scatter of the participating schools of the study is presented in Table 2.1 and Figure 2.1.

Table 2.1 Geographical scatter of the participating schools

Areas [a]	Regions (Number of schools)			Total (%)
	Provinces	Municipalities	EAR	
Developed	Guangdong (20) Jiangsu (4) Zhejiang (4) Shandong (6) Liaoning (3) Fujian (12) Hebei (1)	Beijing (7) Shanghai (1) Tianjin (1)	-	7 provinces (100%) 3 municipalities (100%) 350 students (56.6%) **59** schools (52.7%)
Developing	Henan (2) Heilongjiang (2) Shanxi (8) Hubei (6) Sichun (5) Jilin (1) *Hunan (0)* [b] *Anhui (0)* *Jiangxi (0)*	-	Inner Mongolia (4)	6 provinces (66.7%) 1 EAR (100%) 129 students (20.9%) **28** schools (25%)
Under-developed	Shaanxi (5) *Hainan (0)* *Qinghai (0)* *Yunnan (0)* *Gansu (0)* *Guizhou (0)*	Chongqing (7)	Ningxia (6) Guangxi (7) *Xinjiang (0)* *Tibet (0)*	1 province (16.7%) 1 municipality (100%) 2 EARs (50%) 139 students (22.5%) **25** schools (22.3%)
Total	14 provinces (79)	4 municipalities (16)	3 EARs (17)	14 provinces (63.6%) 4 municipalities (100%) 3 EARs (60.0%) 618 students [c] **112** schools (100%)

a: The division of the three developmental areas is based on a research done by the Chinese Academy of Social Sciences. The results were published in Li, Li & Gao (2008);
b: Provinces or EARs where no participants came from.;
c: 3 participants did not provide information about their schools.

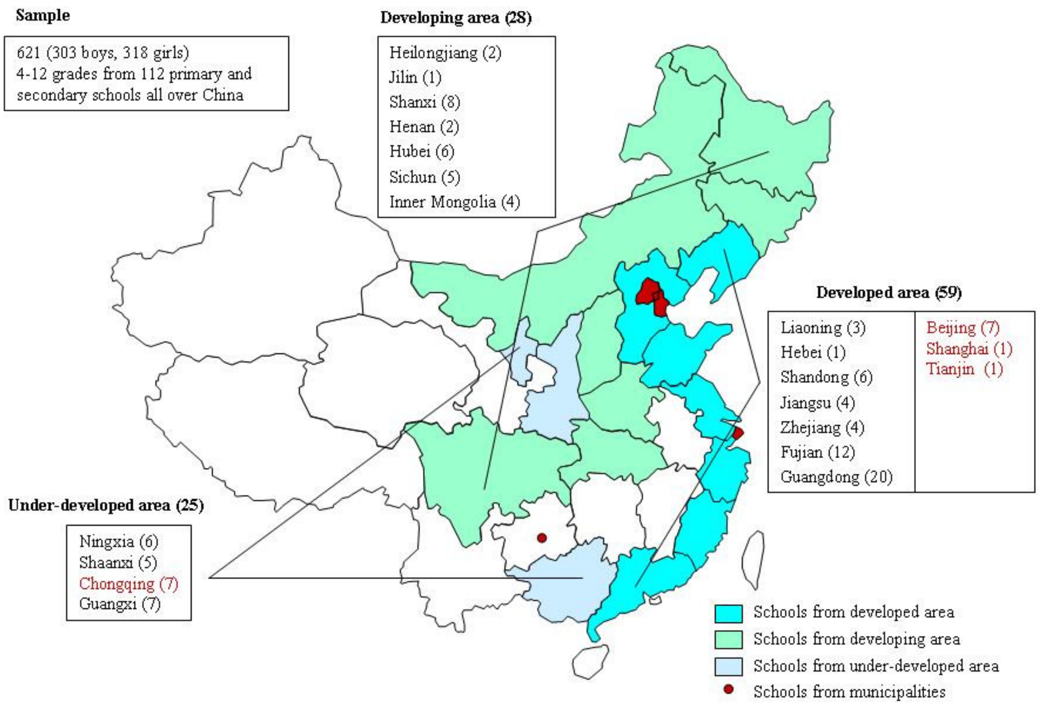


Figure 1: Geographical Scatter of the Participating Schools

In China, the secondary education[4] is divided into two stages, namely the junior secondary and senior secondary stages. The majority (98%) of the junior secondary school is for three years, with only very few lasting four years. The senior secondary education has 3-year duration. With the aim to minimize the differences among the schools, only the 3-year junior high and 3-year senior high schools were examined. Among the 621 participants of the study, 259 (126 boys and 133 girls) were from the primary schools, 188 (85 boys and 103 girls) were from the junior high schools and 174 (92 boys and 82 girls) were from the senior high schools. The average age of the participants from primary schools were 11.7 (SD=1.1), from the junior high schools were 14.0 (SD=.98) and from the senior high schools were 17.2 (SD=1.1). Table 2.2 presents the mean age and gender of the young inventors by age group. As this table shows, girls were slightly over-represented in the current study. Of the 621 participants, 318 were girls, accounting for 51.2% of the total and 303 were boys, accounting for 48.8%. The average age of the young inventors were 13.9 years old (SD=2.5). In terms of the age group, 41.7% (n=259) were from the 4-6 grades, about 1/3 (n=188, 30.3%) were from 7-9 grades, and less than 1/3 (n=174, 28%) were from 10-12 grades.

[4] Description of the Ministry of Education, P. R. China, retrieved on 14th June 2008 from http://www.moe.edu.cn/edoas/website18/en/basic_b.htm

Table 2.2 Mean age and gender of the young inventors by age group

Age Group	Grade	M	SD	Male	Female	Total	%
	4	10.5	.63	34	25	59	9.5
Primary	5	11.4	.67	38	44	82	13.2
	6	12.6	.65	54	64	118	19.0
	Total	**11.7**	**1.1**	**126**	**133**	**259**	**41.7**
	7	13.5	.92	34	49	83	13.4
Junior high	8	14.4	.78	45	47	92	14.8
	9	15.0	.82	6	7	13	2.1
	Total	**14.0**	**.98**	**85**	**103**	**188**	**30.3**
	10	16.8	.75	54	56	110	17.7
Senior high	11	17.7	1.1	29	21	50	8.1
	12	18.9	1.0	9	5	14	2.3
	Total	**17.2**	**1.1**	**92**	**82**	**174**	**28.1**
Total		**13.9**	**2.5**	**303**	**318**	**621**	**100%**

Of the 621 participants, 619 (response rate of 99.7%) have provided information about the educational level of their parents. Over half of them (n=319, 51.5%) reported their fathers as having got a college degree or above and about half of them (n=265, 42.8%) reported their mothers as having got a college degree or above. Among the 621 participants, 38 held at least one patent, accounting for 6.1% of the whole sample. Among them, 20 were boys, accounting for 52.6% of the total and 18 were girls, accounting for 47.4% of the total. Almost half of them (n=17, 44.7%) were from the 10^{th} -12^{th} grades, thirteen (34.2%) were from the 4-6 grades, and eight (21.1%) were from the 7^{th} -9^{th} grades. The mean age of this young patentee group was 14.9 with a standard deviation of 3.4. Table 2.3 is a summary of the gender, age, and grade group of the young patentees.

Table 2.3 Gender, age, and grade group of the young patentees

	Group 1	Group 2	Group 3	
Gender	4-6 grades	7-9 grades	10-12 grades	Total
Male	4	4	12	20(52.6%)
Female	9	4	5	18(47.4%)
Total	13(34.2%)	8(21.1%)	17(44.7%)	38(100%)

Notes: Mean age =14.9, SD=3.4

2.2 Instrumentation (research variables and their operationalization)

Instruments used in this study can be divided into two types: (1) cognitive ability and inventiveness tests, which were taken in paper-and-pencil form; (2) self-report questionnaires, where the subjects rated different items according to their own situation on 5- or 7-point Likert scales. The instructions of the cognitive ability test that were originally in German were translated into Chinese by the author. The translated version was discussed with two science teachers from mainland China to make sure that the instructions can be correctly understood by the students. Back translation was not entailed for this test, because the cognitive ability test chosen for the current study was von-verbal in nature. The questionnaires that were originally written in English were translated into Chinese by the author. Back translation was applied by two English teachers of mainland China in order to minimize misunderstanding or mistranslation of the original items. After back translation, discussion was held among the translators with regard to the discrepancies in the translation process, in order to ensure consistency of the used and definition of the constructs.

2.2.1 Biographical measures

Students' entry characteristics were measured by a self-developed biographical inventory, which asked about students' age, gender, school, grade, the region where they come from, parents' educational level, and if they had a patented invention or not. The items of this inventory were based on previous studies.

2.2.2 Technical construct ability

For measuring the cognitive abilities of the students, the *non-verbal* tests of the KFT-HB 4-12 sub-scale of the Munich High Ability Test Battery (in German: Münchner Hochbegabungstestbatterie, MHBT, Heller and Perleth, 2007a/b) were used. The KFT-HB (Cognitive Abilities Test for Highly Gifted Students) is a German version of Thorndike and Hagen's Cognitive Abilities Test (CogAT; Thorndike & Hagen, 1971, 1993) adapted particularly for highly gifted students. Like CogAT, KFT-HB also has three types of subtests: verbal, quantitative, and non-verbal. For the purpose of this study, only the *non-verbal* tests were used. This decision was based on Colangelo and colleagues' (1992) conceptualization of mechanical inventiveness which emphasizes spatial and logical-mechanical intelligence. Non-verbal Test 1, comprising 25 items, is a figure classification test. In this test, students were given two columns of geometrical figures. In the left column are three geometrical figures that are put together according to a certain rule (e.g., shape solid, hollow, symmetric, overlap, etc.). In the right column are five geometrical figures that are very similar to the figures in the left column, but among them only one belongs to the same category of the given figures. The task of the students was to choose one figure from the five figures given in the right column that they think matches the example figures. Students were given 10 minutes (excluding the time for instruction) to finish the test. Non-verbal Test 2, also comprising 25 items, is a figure analogy test. In this test, students were given two columns of geometrical figures. Different from N-Test 1, the example figures in this test are presented in a form of unsolved equation (A:B=C:?), indicating "the relation between Figure A and B equals to the relation between Figure C and Figure ?". The task of the students was to choose one from the five figures given in the right column that they think would solve the equation. The solution of this problem involves the *inductive extraction* of the features of the individual figures and then the *deductive reasoning* from solution principles. Students were given 8 minutes (excluding the time for instruction) to finish this test. For both N-Test 1 and N-Test 2, two parallel versions (Version A and Version B) are developed. According to the MHBT Manual (Heller & Perleth, 2007a/b), both of these tests are to measure the nonverbal *technical constructive abilities* of the students.

2.2.3 Knowledge of patent law and invention

The Evaluation Board of the competition (refer to p.102 for a description about this board) developed a 71-item instrument to examine the students' knowledge about patent law and invention. Among them 26 items were designed in the "fill in the blank" form (e.g., Patent right is the right granted to the patentees through legal procedures by the state-accredited intellectual authorities. It is a kind of ________ asset); 15 were multiple choices (e.g., Which of the following is eligible to be registered as "trademark"? A. the "red cross"; B. a wolf; C. the five-ring logo of Olympics; D. "IPR"); 15 were "true or false" questions (e.g., While applying for a patent, the applicant must open as much as possible the secret of his/her invention to the patent office. After getting the patent, they must pay annual fee to maintain their patent. Is this statement True or False?); and 15 were open-ended questions (e.g., "How does an inventor think?"). These items examine two types of knowledge of the participants: declarative and procedural knowledge. Declarative knowledge was measured by the items such as the major types of patents, the differences between patentable and unpatentable products, and history of famous inventions, etc. Procedural knowledge was measured by the items including methods of invention, procedures of patent index searching, and process of patent application, etc. The total score of this test is 100. Students were asked to write down their answers in the examination paper, which was then submitted to the Evaluation Board for scoring.

2.2.4 Inventiveness

For testing the inventiveness level of the students, the Organizing Committee of the competition developed an inventiveness test based on their conceptualization of inventiveness. In this test, the participants were asked to read carefully the requirements of the tasks before they move on to accomplish the tasks. The work sheets of the test are in similar form to a document that a patent agent always uses to help their clients to apply for a patent. In these two pages, the participants were asked to name their invention, draw a model of the invention, mark each part of the product, and indicate their functions. Very importantly, the participants were asked to describe in detail the most notable *unobvious* characteristics of the invention and the most remarkable advantages of the invention in comparison to the existing objects or solutions.

This test, by large part, is similar but not identical to the widely used Torrance's Product Improvement Tasks (Torrance, 1962). It differs from the traditional improvement tasks in three ways. Firstly, this test was described in a way that stimulated the participants to think and behave in the way inventors do. The organizers called this test "Invention Scheme Test" instead of "Improvement Test". Also in describing the requirements and evaluation criteria, the organizers chose to use the words such as "invent" and "invention" instead of "make", "improve" or "produce". This wording style transmits a strong role expectation to the students. Role identity is found to have strong influence on motivation (Perkus, 1996). In her study about adult product inventors, Henderson (2004b) found that being an inventor occupied a major part of the self perception of the inventors. It can be expected that this subtle labeling endeavor can motivate the students to do their utmost in this test.

Secondly, instead of using the traditional assessment criteria of fluency, flexibility, originality, and elaboration, which highlight the divergent thinking skill, the Evaluation Board adopted the criteria of the Patent Office which were *novelty, practicality, aesthetic appeal,* and *communicational effectiveness. Novelty* answers the question "Is the invention a fresh and unexpected idea?" In other words, a novel invention must cause "surprise"

(Brunner, 1962) and must strike beholders as unexpected. *Practicality* answers the question "Is the invention appropriate for the stated need or idea?" This criterion emphasizes relevance and effectiveness (Bruner, 1962) and more recent writers such as Amabile and Tighe (1993) have stated that products must be appropriate, correct, useful, or valuable. *Aesthetic appeal* refers to the question "Does the invention have strong aesthetic appeal to intended audience?" *Aesthetic* in this instrument has a narrow meaning which stresses the "pure aesthetic" qualities or "external elegance" (Cropley & Cropley, 2008) of the invention. "External elegance" is characterized by Cropley and Cropley as r*ecognition* (the beholder sees at once that the product has a certain something), c*onvincingness* (the beholder is convinced by the product), and *pleasingness* (the beholder finds the product "beautiful"). In addition, the organizers added *communicational effectiveness* as the fourth dimension of evaluation. The underlying interest of this criterion is "Are the structure, elements, and functions of each component communicated to intended audience effectively?" By character, this sub-scale belongs to the category of verbal test. But in contrast to the traditional verbal form of creativity test which focuses on divergent thinking, the test used in this study emphasizes the effectiveness of the verbal texts that a participant provides to describe his or her inventive product. Without exaggeration, this sub-test is a normal verbal test without much creativity flavor. But it addresses one important aspect of practical creativity which is "communication". Taking a process perspective, Heller and Facaoaru (1987) and Cropley (1994) identified communication in their models of invention and gifted achievement. However, communication as a separate dimension of creativity assessment is not yet usual. So this study can serve as a new attempt to accommodate this perspective.

Thirdly, the most distinct aspect of this instrument is that it was developed and used by a group of experts who are either patent examiners of the State Intellectual Property Office of China, university professors or professional researches whose research focus is intellectual property right and the related issues. Because these experts are well-acquainted and trained professionals in the field of invention, their ratings can be trusted as reliable and authoritative. Actually, Torrance, at the early stage of his practice of creativity assessment, attempted to adopt the US Patent Office criteria for rating new inventions as a scoring scheme for the TTCT (Torrance, 1959). He was also able to prove the strong predictive validity of this approach. However, due to enormous difficulty in training the novice raters and implementing the complex assessment process, Torrance had to "eschew" this method (Cramond et al., 2005). The current study distinguishes itself from most of the creativity studies in its access to this professional group as raters of inventiveness.

2.2.5 Thinking styles

The styles of thinking of the students were measured with the Thinking Style Inventory developed by Sternberg and Wagner (1992). The complete version this inventory is composed of 104 items measuring 13 types of thinking styles. For the interest of this study, four types (32 items) of thinking styles that are closely related to creativity were measured: (1) Legislative thinking style is the tendency to create or generate one's own rules and ways of doing things (e.g., I like situations where I can use my own ideas and ways of doing things). (2) Executive thinking style is the inclination to follow suite and the preference of well-structured problems (e.g., I like projects that have a clear structure and a set plan and goal). (3) Judicial thinking style is the propensity to evaluate things and make comments (e.g., I enjoy work that involves analyzing, grading, or comparing things). (4) Liberal thinking style is the tendency to go beyond existing rules and preference of ambiguous and unfamiliar situations (e.g., I like to challenge old ideas or ways of doing things and to seek better ones). Each of these types of these thinking styles was measured with eight items which were put on a 7-point Likert scale (1=not at all true of me; 7=completely true of me) for the participants to give their ratings.

2.2.6 Motivation

The motivation of the students in making inventions was measured with the Work Preference Inventory (WPI) (Amabile et al., 1994). WPI is composed of 30 items falling into two primary categories: intrinsic motivation, measuring *self-determination* (e.g., I prefer to figure things out for myself), *competence* (e.g., I want to find out how good I really can be in making inventions), *task involvement* (e.g., I am so absorbed that I forget about everything else), *curiosity* (e.g., Curiosity is the driving force behind much of what I do), *enjoyment* (e.g., What matters most to me is enjoying what I do), and *interest* (e.g., The more difficult the problem, the more I enjoy trying to solve it); extrinsic motivation, measuring *competition* (e.g., To me, success means doing better than other people), *recognition* (e.g., I am strongly motivated by the recognition I can earn from other people), *money or other tangible incentives* (e.g., I am strongly motivated by the rewards I can get), and *constraint* by others (e.g., I am concerned about how other people think of my work.). Though confirmatory factor analysis indicated that a 4-factor model, which further divided intrinsic motivation into Enjoyment and Challeng and extrinsic motivation into Outward and Compensation, showed better model fit, the authors stated that because the distinction between intrinsic and extrinsic motivation was so frequently relied on, they could be maintained as primary scales. In this study, the primary distinction of intrinsic and extrinsic motivation is used. WPI has been applied to a student sample with meaningful factor structures, adequate internal consistency (.79 for Intrinsic and .78 for Extrinsic Motivation), good short-term test-retest reliability (.84 for Intrinsic and .94 for Extrinsic Motivation), and good longer term stability (.67-.85 for Intrinsic and .73-.84 for Extrinsic Motivation). These items were adapted in a way that suit the situation of invention by putting them after one sentence "When doing invention,…". Then, participants were asked to indicate on a 5-point Likert scale, ranging from 1=not at all true of me to 5=very true of me.

2.2.7 Personality

Based on literature review (see the previous chapter), three types of personalities were examined in this study, namely *openness to experience, risk-taking,* and *tolerance of ambiguity.*

Openness to experience was measured with the relevant items, 10 in number, from the Big Five Inventory (BFI; Benet-Martínez & John, 1998; John, Donahue, & Kentle, 1991). A questionnaire instead of Adjective-Checklist was chosen to assess this personality, because questionnaire measures of Openness give higher validity coefficients than do adjective-factor measures (McCrae & Costa, 1987). Although the NEO-PI-R (Costa & McCrae, 1992) is perhaps the most elaborate and widely used instrument for measuring the personality traits related to the Big Five, it is only one of a growing family of instruments intended to measure the five broadest dimensions of personality. BFI, with its high reliability and briefness (composed of 44 items), was chosen as a measure of personality for the International Sexuality Description Project (ISDP), which represents one of the largest cross-cultural studies that involves 17,837 individuals from 56 nations. Through this large-scale cross-cultural study, BFI was found to possess high levels of internal reliability (a mean Cronbach's itemized alpha coefficient of .76 for all five scales and .76 for the sub-scale of Openness) across all cultures (Schmidt et al., 2007). Although the BFI scales show substantial convergent validity with Costa and McCrae's (1992) factor definitions, there are some subtle but important differences for Openness. Items measuring the *value* and *action* facets failed to make it onto the BFI Openness scale when applied cross-culturally (Benet-Martínez & John, 1998). So the ten items measure four perspectives of Openness, including *fantasy* (e.g., I have an active imagination), *aesthetics* (e.g., I am sophisticated in art, music, or literature), *feelings* (e.g., I am curious about many different things), and *ideas* (e.g., I am original, have new ideas). Participants were asked to reply on a 5-point Likert scale, ranging from 1=not at all true of me to 5=very true of me.

Risk-taking was measured by a shortened version of the Attitudes towards Risks Questionnaire (ATRQ; Franken, Gibson, & Rowland, 1992). This inventory was developed by initially constructing 34 items pertaining risk-taking beliefs and behaviors about "disregard of social approval" (e.g., While I don't deliberately seek out situations or activities that society disapproves of, I find that I often end up doing things that society disapproves of) or "disregard of danger" (e.g., The greater the risk and more fun the activity). On the basis of factor analysis, the authors developed a shortened version of ATRQ with 10 items (α = .84). This shortened version was taken for the present study. Because ATRQ was developed among university students in Canada, re-adaptations were necessary while applying it for younger sample in China. With the help of one English teacher and one science teacher in China, I re-phrased two items and constructed one new item of this inventory in a way that suits the situation of children and adolescents in China better. The comparison of the original and the re-adapted items as well as the reasons for re-adaptation are displayed in Table 2.4.

Table 2.4 Comparison of the original items of ATRQ and the re-adapted ones

Original item	Re-adapted item	Reasons
31. I often think about doing things that are illegal.	II-7. I often think about breaking some set rules.	Chinese adolescents are educated to become legal citizens. Rephrasing "illegal" to "breaking some set rules" is more acceptable to the Chinese way of thinking.
23. I do not let the fact that something is considered immoral stop me from doing it.	II-12. I do not let the fact that the majority is opposing me stop me from doing things.	Morality is highly stressed in Chinese culture. This item is rephrased in a way that is more compatible with the Chinese mindset.
20. I like to do things that almost paralyze me with fear.	II-15. I often think about doing things that I know my teachers would disapprove of.	As the only child of the family, the youngsters of China are usually not encouraged to take physical risks. This item is replaced by a new one that is more relevant to the students' school life.

Tolerance of ambiguity in the present study is defined as "a tendency to perceive or interpret information marked by vague, incomplete, fragmented, multiple, probable, unstructured, uncertain, inconsistent, contrary, contradictory, or unclear meanings as actual or potential sources of psychological discomfort or threat" (Norton 1975, p. 608). This variable was measured with eight items of the Measure of Ambiguity Tolerance (MAT-50; Norton, 1975). The complete version of MAT-50 contains 61 items that measure eight dimensions of tolerance of ambiguity. For the current study, eight items were drawn from four dimensions of this instrument, including *philosophy* (e.g., I prefer the certainty of always being in control of myself), *public image* (e.g., It would bother me if different close friends of mine had conflicting opinions of me), *problem solving* (e.g., A problem has little attraction for me if I don't think it has a solution), and *art forms* (e.g., I like movies or stories with definite endings). These items were put on a 5-point Likert scale (1=not at all true of me; 5=completely true of me) for the participants to give their ratings.

2.2.8 Family and school environments

The family and school environments of the students were assessed by a self-developed questionnaire composed of 18 items. The content of the questionnaire was based on the existing literature about the stimulating factors of supportive environments for creativity both at home and school (Bloom, 1985; Csiksentmihalyi et al., 1997; Feldman & Goldsmith, 1986; Gogel et al., 1985; Philips and Lindsay, 2006; Robinson & Noble, 1991; for a detailed description please refer to 1.4.6; pp.72-75). The factors were put on Likert scale for the participants to rate. The underlying assumption is that it is the psychological meaning of environment events that largely influences creative behavior (Amabile, 1988; Woodman, Sawyer, & Driffin, 1993). Two environmental factors, namely *encouragement* and *resources*, in both family and school settings were examined. Home encouragement included parents' encouragement for (1) *openness* (assessed by 2 items; e.g., My parents encourage me to try new things); (2) *being inventive* (assessed by 1 item: My parents encourage me to make inventions), and (3) for *persistence/perseverance* in taking inventive activities (assessed by 2 items; e.g., If I meet some difficulties in making inventions, my parents will encourage me to carry on). School encouragement included (1) the *creative atmosphere* at school and in the classroom (assessed by 2 items; e.g., There is an inventive atmosphere in our school); (2) encouragement for *being inventive* (assessed by 3 items; e.g., In our class inventive students will be praised and set as examples for other students to learn from), and (3) encouragement for *participation* in inventive activities (assessed by 2 items; e.g., In our school we are encouraged to participate in inventive activities). Home resources included *financial support* from parents for making inventions, *take part in inventive events* and the *availability of materials* for children to make inventions (assessed by 3 items; e.g., Whatever I need for making inventions, my parents will try their best to get it for me). Resources at school included the existence of an "*inventing place*" for the students and *availability of the needed materials* for making inventions (assessed by 3 items; e.g., In our school we have a special place for making inventions). These items were rated on a 5-point Likert scale (1=not at all true of me; 5=completely true of me) for the students to rate.

2.3 Factor structure of the self-developed environmental questionnaire

These 18 items were subjected to a factor analysis with varimax rotation. While running the analysis, a cut-off point of .4 was used to suppress the lower loadings, because this cut-off point is widely accepted as appropriate for interpretative purposes (Field, 2005; Stevens, 1992). With regard to the criterion of retaining factors, the Kaiser's criterion with eigenvalues greater than 1 was used, as with large sample, it is thought to be a safe criterion (Field, 2005).

The initial principal components analysis yielded a four-factor solution as the best fit for the data, accounting for 55.9% of the variance. The first factor included seven items in relation to the school environment. These items were concerned with the inventive atmosphere (items 12 and 16), rewards and recognition for inventive work (items 13, 17, and 18), and organizational facilitation (items 14 and 15). With most of the items corresponding to KEYS' (Amabile, Taylor, & Gryskiewicz, 1995) description about the "organizational encouragement" sub-scale of the instrument, this factor was named "school encouragement". With an eigenvalue of 5.5, this factor accounted for 30.5% of the variance after rotation. The second factor included four items (items 1, 2, 3, and 4) from the family environment. With the core content of "encouragement" of parents in three different situations, namely in the action/process of making inventions, upon trying new things, and upon meeting difficulties, this factor was named "family encouragement". With an eigenvalue of 2.28, this factor accounted for 12.7% of the variance after rotation. The third factor was composed of three items (items 6, 7, and 8), which described the financial and material resources available at home for the participants to make inventions. This factor was named "family resources". The eigenvalue for this factor, which accounted for 6.8% of the variance, was 1.22. The fourth factor was composed of three items (items 9, 10, and 11), which described the financial and material resources available at school for the participants to make inventions. This factor was named "school resources". The eigenvalue for this factor was 1.07 and it accounted for 5.9% of the variance. Item 5, the only item with a reversed value, did not achieve an adequate loading on any factor to be included in the four-factor solution. So this item was deleted from the questionnaire, making the final version of the questionnaire comprising 17 items. Table 2.5 presents the results of the factor analysis of the environmental questionnaire.

Table 2.5 Results of factor analysis for self-developed environmental questionnaire

Items	Factor 1	Factor 2	Factor 3	Factor 4
12. There is an inventive atmosphere in our school.	.76			
13. Our school encourages us to be inventive students.	.76			
14. In our school we are encouraged to participate in inventive activities.	.75			
15. In our school special teachers are assigned to teach us how to make inventions.	.71			
16. There is an inventive atmosphere in our class.	.71			
17. In our school inventive students will be praised and set as examples for other students to learn from.	.68			
18. In our class inventive students will be praised and set as example students for others to learn from.	.55			
1. My parents encourage me to make inventions.		.77		
2. My parents encourage me to try new things.		.73		
3. In the process of making inventions, I can feel the encouragement of my parents.		.72		
4. If I meet some difficulties in making inventions, my parents will encourage me to carry on.		.55		
5. My parents don't encourage me to take risky activities[R].				
6. My parents finance me to participate in this contest.			.71	
7. My parents finance me to make inventions in my spare time.			.64	
8. Whatever I need for making inventions, my parents will try their best to get it for me.			.54	
9. In our school we have a special place for making inventions.				.72
10. In our invention place at school we have many materials.				.56
11. Whatever I need for making inventions, my teachers will try their best to get it for me.				.51
Eigenvalue	5.5	2.28	1.22	1.07
Variance (%)	30.5	12.7	6.8	5.9
α	.85	.76	.70	.52

It is worth noting that the screen plot was checked and it suggested a two-factor model. So factor analysis procedures were re-run to force a two-factor solution. In this two-factor model, all family items loaded on one factor and all school items on another with the exception of Item 9, which was a description about the school environment but wrongly loaded on the family factor. In terms of the accounted variance, the two-factor solution accounted for 43.2% of the variance, which was 12.7% lower than the four-factor solution. Without differentiating encouragement from resources in the family and school environments, the two-factor solution did not present the potential to reveal more information about the respective environmental conditions, so the decision was made to adopt the four-factor solution for further data analyses.

To follow the factor analysis, the reliability of each factor was computed by using the Cronbach Alpha coefficient of internal consistency. For Factor 1 (school encouragement) α was .85, for Factor 2 (family encouragement) α was.76, for Factor 3 (family resources) α was.70, and for Factor 4 (school resources) α was.52. With an average α of .71, this instrument presents an acceptable though not impressively high inter reliability. This might be due to the limited number of items in this questionnaire. For further study, extension of the current version of environmental inventory into a longer multi-dimensional form is suggested. Of course, a trade-off between breadth and depth of relevant domains in adopting a systemic approach is worth careful consideration in research design, which will be discussed in more detail in the "Limitations" part.

2.4 Procedures

2.4.1 Organization of the biographical survey and cognitive ability test – Session I

Under the request of the Organizing Committee, cognitive test was to be given among all participants (N=1223) in the same place at the same time. In order to make the best use of time, the biographical survey was taken together with the cognitive ability test. One day before the survey, the author of the study had a meeting with the organizer and a support team of 20 university students. The author introduced how the survey should be conducted and assigned tasks to each team member. The survey was taken in a seminar hall with a seating capacity of 1895. All the questionnaires were transported to the seminar hall half an hour before the survey. In order to minimize the students' chances of copying answers from their neighboring students, three steps were taken: (1) Students from the same school were arranged to sit in lines instead of in rows. Because the seats of the seminar hall had high backrests, this way of sitting was supposed to block the communication between the students with their familiar peers. (2) Different versions of the KFT-HB 4-12 were distributed to different lines of the students. KFT-HB 4-12 – Version A was distributed to the lines with the uneven numbers and Version B was distributed to the lines with even numbers. Through this step, it was guaranteed that the two students sitting side by side got different versions of the test, so even if they happen to be from the same grade, there was no chance for them to copy answers from each other. (3) The 20 members of the support team plus 20 working staff of the Organizing Committee were standing in different places in the hall to supervise the students while they were taking the tests.

It took about half an hour to arrange the seats for the students. Following this, the author explained to the whole audience through a microphone on the rostrum why the seats were arranged in that way with the aim to relieve anxiety from the students. The author informed the students that they were going to answer a short questionnaire and to take some interesting tests. We arranged the seats in this way in order to make sure that each student could concentrate on his or her work and could finish the tests independently. In order to invite enough seriousness from the students in regard to the tests and at the same time not to provoke them to be nervous, the secretary of the Organizing Committee emphasized that the results of the tests would not be counted in their final results in the competition, but their attitudes towards and behaviors in taking the test would be observed.

While the lead-in part of the survey was taking place on the presidium, the support team had already started to distribute the survey materials to the students. After all the students had got the survey materials, the author asked them to put the questionnaire part aside (the questionnaires were not bound together with the test paper) and concentrate on the test paper. The author asked the students to fill in their personal info on the first page, and very importantly, to write down which version of KFT-HB test they had received. The support team walked around to check if the students had filled in the version of tests. Despite this precaution, 134 students forgot to indicate this information in their submitted tests, which could be only treated as invalid data. After that, the author explained what the tests looked like and what the students were required to do with the concrete examples provided by the original tests. The students were encouraged to ask questions if they did not understand the tests.

The KFT-HB 4-12 N-Test 1 lasted for 10 minutes, the N-Test 2 lasted for 8 minutes. Both the secretary of the Organizing Committee and the author controlled the time of testing. When the testing time was up the support team started to collect the papers and immediately the students were asked to transfer their attention to the questionnaires part. The questionnaire part took the students 5-10 minutes to finish.

2.4.2 Organization of the questionnaire survey – Session II

The second questionnaire survey, which contained the questions about the students' motivation, personality, thinking styles, and perceptions of the family and school environments, was conducted within smaller groups (33-44 per group) on the second day of the competition. Six volunteer teachers helped the author to distribute the questionnaires to students scattered in 17 classrooms in the teaching building of one university in Beijing where the competition took place. Students were told that the questionnaire was designed in a way to collect the students' views or perceptions about themselves and about the environments. There was no right or wrong answers to each question and the participants were encouraged to choose one answer that best describes themselves or their situations. They were also told that the data would be treated confidentially and not be shown to the Organizing Committee or their teachers. There was no time limitation for the participants to answer the questions. Most of the participants took 10-20 minutes to fill out the questionnaire.

2.4.3 Organization of the inventiveness and knowledge tests – Session III

The "Invention Scheme Test" and the Knowledge Test about patent law and invention methods were developed and organized independently by the Organizing Committee of the competition. These tests, each taking one hour, took place on the second day of the competition in 32 different classrooms (30-40 students per classroom) in the teaching building of the university. For each group, there were two persons independent from the participating schools supervising the tests. Because both tests were compulsory for the competition, the response rates were 100%. After the tests, the test papers were collected and subject to evaluation by an evaluation panel assembled by the Organizing Committee.

2.4.4 Evaluation board

The Evaluation Board of the Invention Scheme Test was composed of 34 experts from the field of invention. Among them, 21 were full-time employees of the State Intellectual Property Office, P. R. China, including 20 patent examiners (16 females, 4 males, M_{age}=28.8, and average working years of 3-5) and one intellectual property researcher. The rest were professors (all males) from universities or research institutes. Among them, five were professors of intellectual property, four were professors of science and technology (including one whose research field is specialized in inventiveness), and four were from the humanities field. Table 2.6 presents the composition of the evaluation board.

Table 2.6 Members of the Evaluation Board

IPR Professionals (21)		Professors (13)		
State Intellectual Property Office, P. R. China		Research Fields		
Patent examiners	IPR researcher	IPR	Science & Technology	Humanities
20 (16 females, 4 males)	1 (male)	5 (male)	4 (male)	4 (male)

In the current study, expert assessment was used because professionals are the most appropriate raters for inventions. As already discussed in the theoretical part (refer to p.21), inventiveness differentiates itself from other forms of creativity by the unique criteria it has to satisfy and the special evaluation process it has to go through before an invention can be patented. Patent examiners are well trained professionals. Nonprofessionals of the field will find it very difficult to associate an artifact or object with the previous technology and make a right decision, no to mention their assessment might not be valued at all as they are not qualified examiners. Gardner (1993) supported the use of *relevant* judges of the community of culture. According to him, "Creativity is inherently a communal or cultural judgment" (p. 36) until a creative product has been accepted by the relevant field, it can only be referred to "potentially creative". Csikszentmihalyi and Wolfe (2000) concerned about "Who is entitled to decide what is creative?" (p. 90). With their special qualification, IPR experts and certified patent examiners are undoubtedly the most appropriate "gatekeeper" of the field of invention.

2.4.5 Scoring procedure

Based on the agreed criteria of *novelty, practicality, aesthetic appeal* and *communicational effectiveness*, members of the evaluation board rated the invention schemes of the students on a 4-point Likert scale with 4 stands for excellent, 3 for good, 2 for average, and 1 for poor. Table 2.7 presents the descriptions of each evaluation criterion of the invention scheme.

Table 2.7 Description of the evaluation criteria of the invention scheme

	Excellent (4)	Good (3)	Average (2)	Low (1)
Novelty	This invention is *completely* new and unexpected.	This invention is *mostly* new and unexpected.	This invention is *somewhat* new and unexpected.	This invention is *very similar* to the prior products
Practicality	There is *convincing* evidence that this invention will work effectively	There is *sufficient* evidence that this invention will work effectively	There is *some* evidence that this invention will work effectively	There is *little* evidence that this invention will work effectively
Aesthetic appeal	This invention has *extraordinary* aesthetic appeal to intended audiences	This invention has *sufficient* aesthetic appeal to intended audiences	This invention has *somewhat* aesthetic appeal to intended audiences	This invention has *minimal* aesthetic appeal to intended audiences
Communi-cational effectiveness	Describes the invention idea and the solution *precisely* and *thoroughly*	Describes the invention idea and the solution *thoroughly*	Describes the invention idea and the solution *pretty well*	*Briefly* describes the invention

It is worth noting that due to time restriction and the heavy workload to assess over 1000 products, the evaluation board could not execute the consensual assessment procedure (Amabile, 1982a). The inter-rater reliability was consequently unavailable for the test. This is one of the limitations of the current study and will be discussed in detail in the "Limitations" part.

2.5 Online survey as a supplementary way of data collection

Due to the busy schedule of the competition programs, only over half of the participants were organized to participate in the 2nd session of the survey. As a remedy, an online survey was designed and conducted after the competition. The questionnaire (comprising 107 items) was compiled into two separate HTML pages, with a submission button at the bottom of each page. With the new technology, it was possible to configure an automatic reminder in a small pop-up window saying "This page cannot be submitted because you have forgotten to answer X question. Please answer it before proceed to the next page". This function served to guarantee the completeness of the data collected through the Internet.

While taking the on-site survey about their entry characteristics on the first day of the competition, 381 participants provided their Email addresses voluntarily, including 162 who had already taken the on-site survey during the competition. This group was excluded from the online survey, leaving 219 to become the potential participants. Among these Email addresses, however, 57 were proved to be wrong, which reduced the number of participants to 162. An Email was sent to these students three weeks after the competition, inviting them to answer the questionnaire online. To increase the response rate, the students who did not reply were pursued up for 17 weeks till the author thought further attempts wouldn't bring any substantial changes. Eventually, sixty students submitted their questionnaire online, with a response rate of 37%. This rate is pretty low in comparison to the on-site survey, but compatible to the average response rate of 36.83% reported by a meta-analysis of 31 Email surveys (Sheehan, 2001).

To sum up, the main variables of the study are students' intelligence (measured by non-verbal cognitive abilities), knowledge, thinking style, motivation, personality, and the home and school environments. For each variable three to six sub-components were selected by observing a *parsimonious rule*, which means including those previously tested most relevant attributes while excluding those less relevant. This approach requires a careful and systematic review of the previous studies. Even though, this opens the study to the risk of a Type II error, in which some significant effect might be neglected. But as the focus of the study is not specific variable domain but the correlation and interaction of the involved domains, the risk of excluding some possible important attributes will not undermine the value of the study as an attempt to explore inventive creativity in a systemic way.

CHAPTER 3 – RESULTS

There are five major purposes of the current study: Firstly, to examine how the individual and environmental factors are related to one another in predicting the inventiveness of young inventors. Secondly, to explore in which individual and environmental aspects the higher- and lower-level young inventors differ. Thirdly, to explore gender differences among the participants in each cognitive, non-cognitive, and environmental domain. Fourthly, to explore age-related differences among the participants in each domain. Fifthly, to provide a qualitative description of the participants who had got patents as well as their patented inventions.

According to different research purposes, different data screening processes were taken before running relevant data analysis procedures, including ungrouped data screening for the whole data set with the aim to answer the first research question and grouped data screening for the sub-groups for answering the second and third research question. This part is arranged in the order of the five research questions with a preliminary analysis about the descriptive information of the participants at the beginning. In answering each research question, process and results of data screening will be first presented followed by the results of relevant data analyses.

3.1. The individual and environmental determinants

3.1.1 Data screening for ungrouped data

With all the variables identified, data screening procedures were conducted through various SPSS procedures to examine the accuracy of data entry, missing values, and fit between their distributions and the assumptions of multivariate analysis. To answer the first research question, the whole sample was taken as one and screening processes for *ungrouped* data were conducted.

Of the 621 students whom were drawn for this study, 418 of them had complete data, which counted for 67% of the whole dataset. Further examination of these values revealed that missing values were scattered through multiple cases and variables, ranging from a missing rate of 0.2% to 1.8% with some of the questionnaire items. It would be a substantial loss of data simply to exclude all participants who did not complete all responses. For different types of data different approaches were adopted to deal with missing data. To deal with the missing data for all interval data collected by questionnaire ratings, including motivation, personality, thinking styles, and environmental conditions, SPSS Missing Value Analysis (MVA) was conducted to check if the data were missing completely at random. With χ^2=16128.74, DF=14643, and $p<.001$, the Little's MCAR (missing completely at random) test reached statistical significance. Though this result did not provide statistical proof for the completely random pattern of the missing values, it did not completely deny an adoption of the Expectation Maximization (EM) method for imputing missing data. The EM method was used, because it is the simplest and most reasonable approach (Tabachnick & Fidell, 2007). However, this approach was not thought to be appropriate for standardized test such as cognitive ability test. So the 97 cases that did not have cognitive ability scores were excluded from relevant data analyses, leaving the complete dataset of 524 for the analyses in relation to cognitive ability. With regard to the knowledge and inventiveness tests, as both bests were obligatory for the participants, no missing data were detected.

Multivariate procedures require that the data set should be normally distributed. In order to check the normality of the variables, the shape of the distribution of each variable was checked instead of using formal inference tests. This is because the current study is dealing with a large sample. For large samples the null hypothesis in relation to normality is more likely to be rejected due to small standard errors for both skewness and kurtosis (Field, 2005; Tabachnick & Fidell, 2007). SPSS Frequency revealed that most of the variables displayed normal distributions, while some of them presented more or less negative skewness, including slight negative skewness for legislative thinking style, liberal thinking style, communication subscale of inventiveness and family encouragement. Alongside, moderate negative skewness was found for cognitive, knowledge and family resources.

In the presence of a ceiling effect (acute negative skewness), the probability of the inflation of Type I error (false significance) is higher (Austin & Brunner, 2003). So in the forthcoming steps of data analyses, a variety of methods were applied to lower the rate of Type I error.

3.1.2 Strategy of data analysis

There is controversy about whether non-normally distributed data should be transformed before parametric analyses are conducted. One group of authors recommended data transformation as a remedy for violation of parametric assumptions such as normality (Field, 2005; Tabachnick & Fidell, 2007), while another group argue that in most practical cases the parametric approaches for inferences about means are so robust that it can be recommended in nearly all applications (Kubinger, Rasch, & Moder, 2009; Rasch & Guiard, 2004). Acknowledging the frequent existence of screwed distributions with significant samples on psychometric instruments, Simonton (1999b) suggested that data be resorted to various types of nonparametric and robust statistical methods and the results of different methods be compared. In order to get less biased results, parametric analysis on both original and rank transformed data, as suggested by Conover and Iman (1981), were conducted.

Rank transformation (RT) procedure replaces the observations with their ranks. Then apply the standard distribution-specific, parametric methods, such as t-test and F test, to the ranked data (Conover & Iman, 1981). It's now well-known that various nonparametric methods are equivalent to the application of parametric methods to the *ranked* data, including the Spearman's rho (Spearman, 1910) as the nonparametric version of the Pearson's r, Wilcoxon-Mann-Whitney (Mann & Whitney, 1947; Wilcoxon, 1945) test as the nonparametric equivalent of the independent t-test, and Kruskal-Wallis test (Kruskal & Wallis, 1952) as the nonparametric counterpart of the one-way ANOVA. Due to its ease of implementation and robustness, RT has been widely applied in medicine (e.g., O'Gorman & Woolson, 1993) and ecology (e.g., Angermeier & Winston, 1998; Kramer & Schmidhammer, 1992; Potvin & Roth, 1993). Through wide application, favorable results were presented to support the versatility of RT also in multiple regression (Angermeier & Winston, 1998; Conover, 1999), two-way ANOVA (Regeth & Stine, 1998), factorial ANOVA (Augner, Provenza, & Villalba, 1998; Choi, 1998), as well as logistic regression and discriminant analysis (O'Gorman & Woolson, 1993). Because of its robustness and versatility, RT over other transformation procedures was used in this study.

For the purposes of the current study, data analysis procedures including bivariate correlation, multiple regression, exploratory factor analysis, t-test, logistic regression, and MANOVA were used. For each analysis, the same procedures were run for both original and RT data with the aim to check if the results were the same. Comparison of the two methods showed that except for t-test and MANOVA, which produced marginal discrepant results, consistent results were found for the rest of the data analyses with both original and RT data. Due to restricted scope of the dissertation, only the results of the parametric analyses on original data will be reported in detail. The results of the non-parametric analyses on RT data will be presented in Appendix 6 (pp. 265-274) for interested readers.

3.1.3 Reliabilities

For the variables under investigation the inter-reliability of the items were calculated using Cronbach's coefficient alpha. The overall reliabilities of the scales were moderate to high, ranging from .52 to .85, with an average of .71. Reliabilities of the scales are presented in Table 3.1 together with the sample items and the sources of the scales.

3.1.4 Correlations

The first research question of the current study is concentrated on how individual and environmental factors are related to one another in predicting inventiveness. To answer this question, an exploratory analysis was undertaken to examine the correlations among all the predicting variables and the inventiveness scores using Pearson's correlation coefficients. As Table 3.2 shows intrinsic motivation was positively related to creative personality, including Openness ($r=.54$, $p<.01$), risk-taking ($r=.28$, $p<.01$), and tolerance of ambiguity ($r=.28$, $p<.01$). It was also positively related with creative thinking styles, including legislative ($r=.43$ $p<.01$), judicial ($r=.33$, $p<.01$) and liberal ($r=.62$, $p<.01$) thinking styles as well as creative environment, including family encouragement ($r=.27$, $p<.01$), family resources ($r=.26$, $p<.01$), school encouragement ($r=.24$, $p<.01$) and school resources ($r=.37$, $p<.01$). No significant relation was found between intrinsic motivation and technical construct ability, but a positive relation was found between intrinsic motivation and knowledge ($r=.10$, $p<.05$). In contrast, extrinsic motivation was negatively related to the tolerance of ambiguity ($r=-.40$, $p<.01$), liberal thinking style ($r=-.11$, $p<.01$), school resources ($r=-.13$, $p<.01$) and technical construct ability ($r=-.11$, $p<.01$). As expected, extrinsic

Table 3.1 List of reliabilities, sample items, instruments, and the authors for relevant variables (N=612)

Variables	α	Sample item	Instrument	Author(s),year
Motivation				
Intrinsic motivation	.73	I enjoy trying to solve complex problems.	Work Preference Inventory (shortened)	Amabile et al. (1994)
Extrinsic motivation	.61	To me, success means doing better than other people.		
Personality				
Openness	.73	I like to reflect and play with ideas.	Openness subscale of Big Five Inventory	John et al. (1991)
Risk-taking	.71	The greater the risk, the more fun the activity.	Attitudes Towards Risks Questionnaire	Franken et al. (1992)
Tolerance of ambiguity	.64	A problem has little attraction to me if I don't think it has a solution.	Problem-solving subscale of Measure of Ambiguity Tolerance (MAT-50)	Norton (1975)
Thinking style				
Legislative	.72	I like to play with my ideas and see how far they go.	Thinking Style Inventory	Sternberg & Wagner (1992)
Executive	.69	I am careful to use the proper method to solve any problem.		
Judicial	.69	I like projects where I can study and rate different views.		
Liberal	.84	I like situations where I can try new was of doing things.		
Environment				
Family encourage	.76	My parents encourage me to make inventions.	*Self-developed*	
Family resources	.70	My parents finance me to make inventions in my spare time.		
School encourage	.85	Our school encourages us to be inventive students.		
School resources	.52	In our school we have a special room/place for making inventions		
Technical construct ability	.75	Figure classification / figure analogy (non-verbal) items	KFT-HB 4-12: N-Test1+N-Test2	Heller & Perleth (2007a/b)
Inventiveness	.76	Improvement test with the criteria of the Patent Office	Invention Scheme Test	Organizing Committee of the competition

Table 3.2 Correlations among the independent and dependent variables

		1	2	3	4	5	6	7	8	9
1	Intrinsic motivation	1								
2	Extrinsic motivation	-.08	1							
3	Openness	.54 **	-.07	1						
4	Risk-taking	.28 **	-.06	.37 **	1					
5	Tolerance of ambiguity	.28 **	-.40 **	.25 **	-.03	1				
6	Legislative thinking	.43 **	.05	.47 **	.36 **	-.02	1			
7	Judicial thinking	.33 **	.13 **	.36 **	.20 **	-.05	.47 **	1		
8	Executive thinking	.01	.34 **	-.11 **	-.19 **	-.32 **	.14 **	.32 **	1	
9	Liberal thinking	.62 **	-.11 **	.56 **	.36 **	.25 **	.62 **	.47 **	-.01	1
10	Family encouragement	.27 **	-.06	.25 **	-.04	.12 **	.25 **	.30 **	.18 **	.33 **
11	Family resources	.26 **	-.03	.25 **	.01	.12 **	.28 **	.26 **	.10 *	.37 **
12	School encouragement	.24 **	-.04	.26 **	-.02	.13 **	.19 **	.19 **	.09 *	.30 **
13	School resources	.37 **	-.13 **	.38 **	.15 **	.18 **	.23 **	.24 **	.01	.40 **
14	Tech. construct ability	.04	-.11 **	.12 **	.09 *	.04	.08	-.01	-.07	.11 **
15	Knowledge	.10 *	-.04	.17 **	.02	.07	.19 **	.05	-.06	.16 **
16	Originality	.05	.03	.04	-.04	.04	.03	.06	.07	.04
17	Practicality	.03	.05	.07	.01	.01	.05	.02	.02	.03
18	Aesthetic appeal	.04	.00	.08	-.03	.00	-.01	.01	.02	.01
19	Communication	.05	.06	.05	-.02	.04	-.07	.04	.01	-.00

*p<.05, **p<.01, (2-tailed test)

Table 3.2 (Continued)

		10	11	12	13	14	15	16	17	18	19
10	Family encouragement	1	1								
11	Family resources	.58 **									
12	School encouragement	.34 **	.38 **	1							
13	School resources	.28 **	.35 **	.44 **	1						
14	Tech. construct ability	.04	.02	.04	.07	1					
15	Knowledge	.10 *	.09 *	-.02	.05	.24 **	1				
16	Originality	.10 *	.05	.10 *	.08	.12 **	.15 **	1			
17	Practicality	.03	.00	-.05	-.04	.12 **	.19 **	.38 **	1		
18	Aesthetic appeal	.04	.03	.02	.01	.17 **	.24 **	.49 **	.59 **	1	
19	Communication	.04	.04	-.05	-.01	.05	.19 **	.33 **	.44 **	.41 **	1

*p<0.05; **p<0.01 (2-tailed test)

motivation was positively related to executive thinking style (r=.34, p<.01). Out of expectation, extrinsic motivation, like intrinsic motivation, was positively related to judicial thinking style (r=.13, p<.01).

Openness was positively related to risk-taking (r=.37, p<.01) and tolerance of ambiguity (r=.25, p<.01) with moderate correlation coefficients. While positively related to legislative (r=.47, p<.01), judicial (r=.36, p<.01), and liberal (r=.56, p<.01) thinking styles, Openness was negatively related to executive (r=-.11, p<.01) thinking style. Like intrinsic motivation, Openness was positively related to all creative environmental variables, with moderate correlation coefficients ranging from .25 to .38.

While positively related to intrinsic motivation and Openness (see above), risk-taking was also positively related to legislative (r=.36, p<.01), judicial (r=.20, p<.01), and liberal (r=.36, p<.01) thinking styles. Meanwhile, it was negatively related to executive thinking style (r=-.19, p<.01). With regard to the correlation with the cognitive variables, a positive relation was found between risk-taking and technical construct ability (r=.09, p<.05). While positively correlated to intrinsic motivation, Openness, and risk-taking (see above), the legislative thinking style was also positively related to other three styles of thinking, with correlation coefficients ranging from .14 to .62. Positive relations were also found between judicial and executive (r=.32, p<.01) and liberal (r=.47, p<.01) thinking styles. But no significant correlation was found between executive and liberal thinking styles. Legislative (r=.19, p<.01) and liberal (r=.16, p<.01) thinking styles were positively related to knowledge, while liberal thinking style was also positively related to technical construct ability (r=.11, p<.01).

All environmental variables were positively related to one another with a Pearson's r ranging from .28 to .58. These relations were all significant at the .01 level. Besides positively related to intrinsic motivation and creative personalities, these environmental variables were also positively related to the creative thinking styles at the .01 level, with a Pearson's r ranging from .19 to .40. Positive relations were also found between the family environmental variables and the executive thinking style. However, overall, the valences of the correlation coefficients were smaller in comparison to the rest of those thinking styles. No significant relation was found between the school resources and the executive thinking style.

Compared to the correlations among the motivation, personality, thinking style and environmental variables, only limited correlations were found between the non-cognitive variables and the cognitive (e.g., technical construct ability and knowledge) variables. While technical construct ability was positively related to Openness and liberal thinking style and negatively related to extrinsic motivation, no significant relations were found between technical construct ability and the environmental variables. A bit more pronounced relations were found between knowledge and the non-cognitive variables and between knowledge and the two family environmental variables. Knowledge was positively related to intrinsic motivation, Openness, legislative and liberal thinking styles (see above). It was also positively related to family encouragement (r=.10, p<.05) and family resources (r=.09, p<.05). Technical construct ability and knowledge were positively related to each other with a moderate correlation coefficient of .24, p<.01.

In terms of the correlations between inventiveness and the independent variables, even less significant correlations were found. Among the predicting variables, only the environmental variables of encouragement and the two cognitive variables were found positively related to inventiveness. Encouragements from the family and school both were positively related to the originality sub-scale of inventiveness with a marginal Pearson's r of .10, p<.05. Technical construct ability was positively related to all sub-scales of inventiveness except communication with a Pearson's r=.12 for both originality and practicality and r=.17 for aesthetic appeal, p<.01. Knowledge was positively related to all sub-scales of inventiveness with r=19 for practicality and communication, r=15 for originality, and r=.24 for aesthetic appeal. All these correlations were significant at the .01 level. The four subscales of inventiveness were moderately related to one another in a positive way with Pearson's r ranging from .33 to .59.

3.1.5 Factor structure of the variables under investigation

The current study was guided by a social cognitive model of inventiveness that integrated both individual and environmental variables. A natural question about this model was whether the major components of the model were correspondent to the factor structure that the variables suggested. With the aim to answer this question, exploratory factor analysis was conducted for all independent and dependent variables.

All 19 variables were subjected to a factor analysis with oblimin rotation. An oblimin over varimax rotation was adopted because preliminary analysis with varimax revealed high correlation between some of the factors (with r of .-.77 and .89). While running the analysis, a cut-off point of .4 and the Kaiser's criterion with eigenvalues greater than 1 were used by following suggestions of some of the statisticians (Stevens, 1992; Field, 2005). The results of this factor analysis are presented in Table 3.3.

Table 3.3 Factor analysis of all independent and dependent variables

Variables	Factors					Dimension
	1	2	3	4	5	
Risk-taking	.77					Creative individual traits
Liberal thinking	.73					Creative individual traits
Openness	.72					Creative individual traits
Legislative thinking	.72					Creative individual traits
Intrinsic motivation	.65					Creative individual traits
Judicial thinking	.57					Creative individual traits
Practicality		.79				Inventiveness
Aesthetic appeal		.79				Inventiveness
Communication		.74				Inventiveness
Originality		.67				Inventiveness
Tolerance of ambiguity			-.73			Non-creative individual traits
Executive thinking			.72			Non-creative individual traits
Extrinsic motivation			.69			Non-creative individual traits
Family encouragement				.75		Inventive environment
Family resources				.73		Inventive environment
School encouragement				.71		Inventive environment
School resources				.52		Inventive environment
Tech. construct ability					.80	Cognition
Knowledge					.69	Cognition
Eigenvalue	4.22	2.41	1.88	1.62	1.08	
Variance (%)	22.2	12.7	9.9	8.5	5.7	

Note. Only loadings larger than .04 are shown. All decimals are omitted.

The initial principal components analysis yielded a five-factor solution as the best fit for the data, accounting for 59.0% of the variance. Intrinsic motivation, Openness, risk-taking and the three creative thinking styles (legislative, judicial, and liberal) were loaded on the same factor, which can be interpreted as "creative individual traits". This factor had an eigenvalue of 4.22 and accounted for 22.2% of the variance. The four sub-scales of inventiveness (originality, practicality, aesthetic appeal, and communication) were loaded on the same factor with an eigenvalue of 2.41 and an accountable variance of 12.7%. With an eigenvalue of 1.88 and accountable variance of 9.9%, the third factor was composed of extrinsic motivation, executive thinking, and non-tolerance of ambiguity. This factor can be interpreted as "non-creative individual traits" as in contrast to Factor 1. The fourth factor included the four environmental variables. It had an eigenvalue of 1.62 and accounted for 8.5% of the variance. This factor can be labeled as "creative environment". The last factor was composed of technical construct ability and knowledge, which were ready to be labeled "cognition". The eigenvalue of this factor, which accounted for 5.7% of the variance, was 1.09.

As a post-examination step, the screen plot of the factor loadings was checked to see if the five-factor model solution was the best fit for the data. As the screen plot also suggested a clear 5-factor model, there was no need to try other solutions.

3.1.6 Multiple regression

Regression analysis was conducted in order to examine the influence of various independent variables on inventiveness. Four separate sequential regression analyses were run with all individual and environmental variables as predictors on originality, practicality, aesthetic appeal, and communication. Independent variables were put into blocks in the way the hypothesized model suggests. The first block was composed of the non-cognitive personality variables, including motivation, personality, and thinking style variables. They were entered first. The second block was the cognitive variables of technical construct ability and knowledge, followed by the environmental variables. Sequential regression was employed to determine if the later added block of variables would improve the prediction of inventiveness beyond that afforded by the previous entered ones.

Regression analysis for the criterion of *originality* revealed no significant prediction of non-cognitive personality characteristics on originality. After Step 2, with the cognitive factors entering the model, $\Delta R^2 = .03$, $F_{inc}(2,512)=7.82$, $p<.001$, indicating that the cognitive factors add significantly to the fitness of the model. Addition of the environmental factors, however, did not improve the prediction. After Step 3, with the four environmental factors in the equation, no significant R^2 and ΔR^2 (change of R^2) were found. At the end of the sequential regression, with all independent variables in the equation, $R=.24$, $F_{inc}(4,508)=1.54$, $p>.05$. In order to examine which individual variables account for the model, the correlation and coefficients tables were checked. It was found that the technical construction ability and knowledge are the two significant predictors of originality. Table 3.4 presents the results of this regression analysis.

Table 3.4 Regression analysis for the criterion of **originality**

	Originality (DV)	Tech. construct ability	Knowledge	B	SE B	β	ΔR^2
Tech. construct ability	.12			.01	.00	.10*	.03***
Knowledge	.14	.24	1	.01	.00	.12**	
Mean	2.96	35.26	76.83				
SD	.72	12.23	16.94				
						Adjusted	R^2=.03***
							R=.22***

Note. R^2= .02 for Step 1 (p>.05); ΔR^2 = .03 for Step 2 (p<.001); ΔR^2 = .01 for Step 3 (p>.05).
*p<.05; **p<.01; ***p<.001

Regression analysis for the criterion of *practicality* revealed the same results as those for the analysis for originality. While non-cognitive personality characteristics alone did not predict practicality significantly, the addition of cognitive factors added significantly to the fitness of the model, ΔR^2=.03, $F_{inc}(2,512)$=8.78, p<.001. Addition of the environmental factors did not improve the prediction. At the end of the sequential regression, with all independent variables in the equation, R=.25, $F_{inc}(4,508)$=1.65, p<.05. Post-examination of the correlation and coefficients tables revealed that knowledge was the only significant predictor of practicality. Table 3.5 presents the results of this regression analysis.

Table 3.5 Regression analysis for the criterion of **practicality**

	Practicality (DV)	Tech. construct ability	Knowledge	B	SE B	β	ΔR^2
Tech. construct ability	.12			.01	.00	.09*	.03***
Knowledge	.17	.24	1	.01	.00	.15**	
Mean	2.97	35.26	76.83				
SD	.65	12.23	16.94				
						Adjusted	R^2=.03***
							R=.22***

Note. R^2 = .02 for Step 1 (p>.05); ΔR^2 = .03 for Step 2 (p<.001); ΔR^2 = .01 for Step 3 (p>.05).
*p<.05; **p<.01; ***p<.001

Regression analysis for the criterion of *aesthetic appeal* also revealed no significant prediction of non-cognitive personality characteristics on originality. Like the previous regression analyses, the addition of the cognitive factors add significantly to the fitness of the model, $\Delta R^2 = .06$, $F_{inc}(2,512)=17.45$, $p<.001$. At the end of the sequential regression, with all independent variables in the equation, R=.30, $F_{inc}(4,508)=.38$, $p>.05$. In order to examine how each individual independent variable is related to aesthetic appeal, the correlation and coefficients tables were checked. This post-examination revealed Openness, technical construction ability, and knowledge were the three significant predictors of aesthetic appeal. Table 3.6 presented the results of this regression analysis.

Table 3.6 Regression analysis for the criterion of **aesthetic appeal**

	Aesthetic Appeal (DV)	Openness	Tech. construct ability	Knowledge	B	SE B	β	ΔR2
Openness	.11				.17	.07	.14*	
Tech. construct ability	.17	.12			.01	.00	.12**	.06***
Knowledge	.23	.17	.24		.01	.00	.20***	
Mean	2.82	3.83	35.26	76.83				
SD	.73	.61	12.23	16.94				
							Adjusted	R^2 =.07***
								R=30***

Note. R^2 = .03 for Step 1 (p>.05); ΔR^2 = .06 for Step 2 (p<.001); ΔR^2 = .00 for Step 3 (p>.05).
*p<.05; **p<.01; ***p<.001

Concentrating on the criterion of *communication,* the regression analysis revealed that the non-cognitive personality characteristics predicted communication significantly, $R^2 = .04$, $F(9,514)=2.11$, $p<.05$. The addition of cognitive factors improved the fitness of the model, $\Delta R^2 = .03$, $F_{inc}(2,512)=7.61$, $p<.001$. The addition of the environmental factors, however, did not improve the prediction. At the end of the sequential regression, with all independent variables in the equation, R=.28, $F_{inc}(4,508)=1.83$, $p>.05$. Post-examination revealed that legislative thinking style and knowledge were the two significant predictors of communication. Table 3.7 presents the results of this regression analysis.

Table 3.7 Regression analysis for the criterion of **communication**

	Communication (DV)	Legislative style	Knowledge	B	SE B	β	ΔR2
Legislative style	-.04			-.14	.05	-.18**	.03**
Knowledge	.16	.18	1	.01	.00	.17**	
Mean	3.32	3.47	76.83				
SD	.63	.97	16.94				
						Adjusted	R^2 =.04** R=.25**

Note. R^2 = .04 for Step 1 (p<.05); ΔR^2 = .03 for Step 2 (p=.001); ΔR^2 = .01 for Step 3 (p>.05).
**p<.01

3.1.7 Summary

Zero-order correlations revealed considerable correlations within and among the motivational, personality, and thinking style variables. Subsequent factor analysis suggested a solution which instead of differentiating motivation, personality, and thinking style, dichotomized the motivational, personality, and thinking style variables into "creative" (intrinsic motivation, openness, risk-taking, legislative style, judicial style, and liberal style) and "non-creative" (extrinsic motivation, executive style, and intolerance of ambiguity) sub-constructs. This result provides support for H1a (p.79).

Sequential regression analyses revealed that only the individual factors accounted for the level of inventiveness assessed by the inventiveness test designed by the Organizing Committee of the competition. However, with only 3% to 7% variance of the dependent variables accounted for by these individual factors, the predictive strengths of the variables are rather weak. So it is implausible to retain H1b (p.79). The predictive power of individual and environmental factors on inventiveness needs more investigation, preferably by using different criterion variables. This research purpose will be re-addressed in the next part by using more objective measures of inventive creativity. That is, whether the participant has got a patent or not. Nevertheless, it is worth noting that in each regression model, knowledge accounted significantly for the variance. So the importance of knowledge seems indubitable. This result provides indirect support for H1c (p.80).

3.2 Comparison of the patentee and non-patentee groups

To answer the second research question "In which individual and environmental aspects the higher- and lower-level young inventors differ", the whole sample was divided into two groups according to their status of possessing a patent or not. The higher-level inventiveness group held at least one patent upon taking part in the contest and the lower-level inventiveness group did not have any patented inventions. For the research purpose, data screening processes for grouped data were followed for the patentee and non-patentee groups respectively.

3.2.1 Data screening for grouped data

Of the 583 students who did not have patents, 393 of them had complete data, which counted for 67% of the whole dataset. Further examination of these values revealed that missing values scattered through multiple cases and variables, ranging from a missing rate of 0.2% to 1.9% with some of the questionnaire items. It would be a substantial loss of data simply to exclude all participants who did not complete all responses. For different types of data different approaches were adopted to deal with missing data. To deal with the missing data for all interval data collected by questionnaire ratings, including motivation, personality, thinking styles, and environmental conditions, SPSS Missing Value Analysis (MVA) was conducted to check if the data were missing completely at random. With $\chi 2=15496.05$, DF=14107, and $p<.001$, the Little's MCAR (missing completely at random) test reached statistical significance. Though this result did not provide statistical proof for the completely random pattern of the missing values, it did not completely deny an adoption of the Expectation Maximization (EM) method for imputing missing data. The EM method was used, because it is the simplest and most reasonable approach (Tabachnick & Fidell, 2007). However, this approach was not thought to be appropriate for standardized test such as cognitive ability test. So the 87 cases that did not have intelligence scores were excluded from relevant data analyses, leaving the complete dataset of 496 for the analyses in relation to cognitive ability.

In terms of normality, the histogram with normal curve of each variable was checked instead of computing normality check test because a sub-sample of 583 subjects is still a large sample. This process revealed very similar results as the normality check for the whole sample. Most of the variables displayed normal distributions, while some presented more or less negative skewness, including slight negative skewness for legislative thinking style, liberal thinking style, family encouragement and communication subscale of inventiveness. Alongside, moderate negative skewness was found for family resources, intelligence and knowledge. The presence of ceiling effects in some variables in this group also calls for special methods targeting to lower the rate of Type I error.

Among the 38 patentees, 28 had complete data, accounting for 74% of total. The Little's MCAR revealed $\chi2$=.000, DF=1027, and p=1.00, indicating the data were missing completely at random. With this result, it was confident to use Estimation Maximization procedures to impute the missing data. In consistence with the previous steps, EM was not applied to the cognitive ability test, leaving 28 valid cases entering the data analyses in relation to cognitive ability. SPSS descriptive statistics revealed the absolute value of the z scores of skewness were less than 2.8 and that of the kurtosis were less than 1.9, indicating the normal distribution of the variables in this group could be assumed.

3.2.2 *t*-test

In order to detect the differences between the patentee and non-patentee groups in all variables under investigation, independent sample *t*-test was conducted with the status of possessing a patent or not as the grouping criterion and all the cognitive (cognitive ability, knowledge), non-cognitive (motivation, personality, thinking styles), environmental variables and outcome variables (originality, practicality, aesthetic appeal and communication sub-scales of inventiveness) as dependent variables. One-tailed test was concentrated because the patentee group was supposed to achieve better in most of the scales than the non-patentee group. For effect size, the Hedges's g value was calculated from each *t* value following the formula

$$ES = t\sqrt{\frac{n_1 + n_2}{n_1 n_2}}$$

ES=effect size (Hedge's g)

n1=sample size of Sub-sample 1

n2=sample size of Sub-sample 2

Hedges's g is an inferential measure. It is computed by using the square root of the Mean Square Error from the analysis of variance testing for differences between the two groups. Based on the harmonic mean instead of the arithmetic mean of n1 and n2, this formula has been recommended for the calculation of the effect sizes for *unequal-sized* samples (e.g., Cohen, 2008; Howell, 2002; Westermann, 2000). For interpretation purpose, the Hedges's g values were transformed into Cohen's d by following the formula of "$d = g \surd (N/df)$" (Cohen, 1988). Due to large sample size, d roughly equals g.

One important assumption of *t*-test is the homogeneity of variance of the dependent variables. The test of homogeneity of variance for unequal sized samples is particularly important, as with samples of unequal sizes the assumption of equal variance is more likely to be violated (Field, 2005). So before interpreting the results of t-test, the Levene's tests for equality of variances were checked. Of the 19 variables under investigation, all Levene's tests were not significant at the .05 level except for legislative thinking style ($F=3.88$, $p<.05$) and school encouragement ($F=7.89$, $p<.01$). Violations of homogeneity usually can be corrected by using a more stringent α level (Tabachnick & Fidell, 2007, p86). Following the suggestion of these authors, an α level of .025 was used for legislative thinking style and .01 for school encouragement in determining the significance level of the t values.

No significant differences were found between these two groups in thinking style, cognitive ability, knowledge, and any sub-scale of inventiveness. Differences were found in intrinsic motivation, where the patentees ($M=4.10$, $SD=.42$) scored significantly higher than the non-patentees ($M=3.95$, $SD=.48$), $t(619)=-1.94$, $p<.05$, with a medium sized effect of $g=.32$. The patentee group ($M=4.00$, $SD=.61$) also scored higher than their non-patentee counterparts ($M=3.82$, $SD=.60$) in Openness, $t(619)=-1.80$, $p<.05$, also with a medium sized effect of .30. In contrast to the limited differences in the individual domain, substantial differences were found in the school environment but not in the family environment. The patentee group ($M=4.12$, $SD=.62$) reported significantly more encouragement in the school setting for being inventive than did the non-patentee group ($M=3.44$, $SD=.97$), $t(619)=-4.26$, $p<.001$. Significant differences were also found in school resources, wherein the patentee group ($M=3.57$, $SD=.81$) reported significantly more availability of resources in the school setting for making inventions than did the non-patentee group ($M=3.09$, $SD=.93$), $t(619)=-3.11$, $p<.001$. With the effect size of .71 for school encouragement and .52 for school resources, the differences in the school setting were more pronounced than the differences in motivation and personality. Results of the *t*-test were presented in Table 3.8. In order to visualize these differences, Figure 3.1 was created.

Table 3.8 *t*-test on the independent and dependent variables between the patentee and non-patentee groups

Variables	Group1 Non-patentees (n1=583)		Group 2 Patentees (n2=38)			
	M	SD	M	SD	*t*	g
Motivation						
Intrinsic motivation	3.95	.48	4.10	.42	-1.94*	.32
Extrinsic motivation	3.17	.48	3.18	.41	-.05	.01
Personality						
Openness	3.82	.60	4.00	.61	-1.80*	.30
Risk-taking	3.14	.66	3.28	.61	-1.35	.23
Tolerance of ambiguity	3.23	.69	3.17	.72	.50	.08
Thinking style						
Legislative thinking	5.67	.83	5.62	.99	.30	.05
Judicial thinking	4.85	.95	4.92	1.08	-.42	.07
Executive thinking	4.24	.96	4.44	.85	-1.24	.21
Liberal thinking	5.53	1.03	5.57	1.11	-.23	.04
Environment						
Family encouragement	3.80	.91	3.80	.95	-.04	.01
Family resources	4.00	.89	4.16	.81	-1.04	.17
School encouragement	3.44	.97	4.12	.62	-4.26***	.71
School resources	3.09	.93	3.57	.81	-3.11***	.52
Tech. construct ability [a]	35.35	12.29	33.64	11.18	.72	.12
Knowledge	76.36	16.85	72.12	20.03	1.49	.25
Inventiveness						
Originality	2.95	.72	2.95	.73	.02	.00
Practicality	2.97	.65	2.95	.70	.17	.03
Aesthetic appeal	2.80	.72	2.79	.74	.08	.01
Communication	3.25	.68	3.19	.73	.61	.10

a: n1=496, n2=28. *p<.05; ***p<.001 (1-tailed)

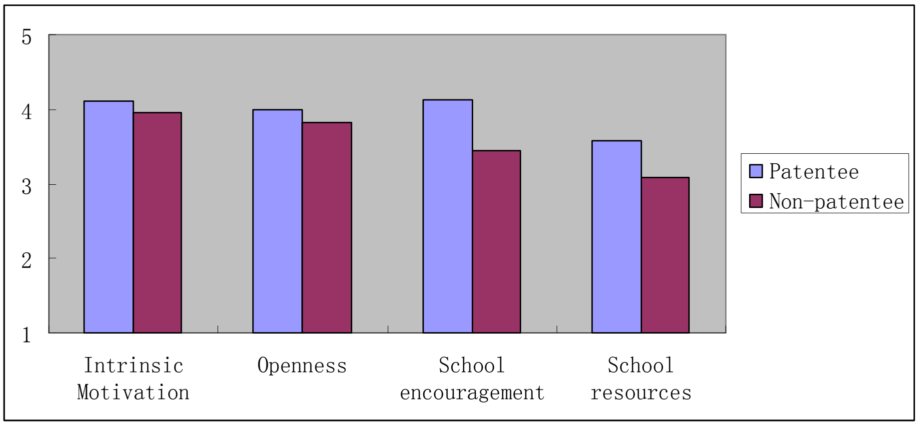


Figure 3.1. Comparison between the patentee and non-patentee groups

3.2.3 Logistic regression

Results of the t-test only showed in which variables the highly inventive and the less inventive differ and how much they differ. These results, however, did not provide further information about along which dimension/s we will be able to distinguish the two groups, nor can it help us find the classification functions to predict group members on the set of variables. In order to answer these questions, logistic regression was used. The decision was made for logistic regression and not discriminate analysis is because of the flexibility of logistic regression. In comparison to discriminate analysis, logistic regression has no assumptions about the distributions of the predictors and has more power to predict group membership when the group sizes are unequal (Tabachnick & Fidell, 2007). In the current study, some of the predictors presented certain ceiling effect and the sample sizes of the patentee and non-patentee groups were unequal, so logistic regression was regarded as more appropriate.

A sequential logistic regression analysis was performed through SPSS on the basis of the two environmental variables (school encouragement and school resources) and then after addition of the non-cognitive variables of intrinsic motivation and Openness. A sequential instead of direct procedure was conducted because of two reasons. Firstly, the previous t-test revealed more substantial differences in the environmental domain than in the individual one. This suggests that the environmental variables as a whole may have stronger prediction power than the individual factor. Secondly, the variables used as predictors were inter-correlated (refer to Table 3.5). Direct logistic regression is not regarded as optimal for correlated predictors because of the difficulties with interpretation.

In terms of the classification cutoff point, the default cutoff point of .5 was not regarded as optimal for the current study due to the fact that the patentee group is a relatively smaller group in the whole population. In such cases, adoption of prior probabilities would be recommended. However, due to the unavailability of prior research about the ratio of young inventors in the whole population, adoption of prior probability is impossible. Nevertheless, it is possible to estimate an optimal cutting score for the classification if the relative group sizes are representative of the population (Hair, Black, Babin, Anderson, & Tatham, 2006). In the current study, participants were from 112 schools that scatter all over China, covering all four municipalities, three ethnic autonomous regions (5 in total) and 14 provinces (23 in total) (refer to Table 3.2 for an overview). With such a sample, the representativeness of the relative sizes of the groups in the actual population can be assumed.

With unequal group sizes, the optimal cutting score for a discriminant function is the weighted average of the group centroids. Based on this, the following formula was suggested by Hair and colleagues (2006, p. 298):

$$Z_{CS} = \frac{N_A Z_B + N_B Z_A}{N_A + N_B}$$

Z_{CS} = optimal cutting score between groups A and B

N_A = number of observations in Group A

N_B = number of observations in Group B

Z_A = centroid for Group A

Z_B = centroid for Group A

The centroids of Group A and B were obtained by running a preliminary discriminant analysis with the same variables that will be entered into logistic regression. For the non-patent group a centroid of -.06 was obtained and for the patent group the centroid was 0.93. These two values were put into the above formula, which issued an optimal cutting score of .90. Hair and colleagues also warned that the optimal cutting score must consider the cost of misclassifying an object into the wrong group. If the misclassification costs are unequal, the optimal cutting score will be the one that minimizes the costs of misclassification. By applying the cutoff point of .90, however, the cost of classification of misclassification of the patent group is too high, as none subject was successfully classified into this group. To minimize this cost, the reversed cutoff point, that is .10, was used.

A test of the full model with the environmental predictors against a constant-only model was statistically significant, χ^2 (2, N=621) = 22.17, p<.001, indicating that the environmental predictors, as a set, reliably distinguished between the patentee and the non-patentee groups. Examined at the individual level, only school encouragement was found making specific contribution to the prediction, χ^2(1, N=621)=10.61, p=.001, Exp(B)=2.21, confidence interval 1.37 to 3.56. Classification based on the environmental variables was impressive for the non-patentee group, with 81.8% non-patentees correctly predicted, but unimpressive for the patentee group, with 34.2% of the patentees correctly predicted. The overall success rate was 78.9%.

Addition of "intrinsic motivation" and "openness" to the model did not result in significant model efficient, block χ^2(2, N=621)=.15, p>.05. In the opposite, it even lowered the "-2 Log likelihood" values slightly (from 263.78 to 263.63 after the individual variables were added).

Table 3.9 Sequential logistic regression of environmental and individual factors on the membership of patentee or non-patentee

		B	SE	χ^2	Exp(B)	95.0% C.I.for EXP(B)	
						Lower	Upper
Model 1	School encouragement	.79	.24	10.61**	2.21	1.37	3.56
	School resources	.28	.21	1.77	1.33	.88	2.01
	(Constant)	-6.69	1.01	44.29	.00		
Model 2	School encouragement	.78	.25	9.76**	2.18	1.34	3.56
	School resources	.26	.22	1.41	1.30	.84	2.01
	Intrinsic motivation	.17	.45	.14	1.18	.49	2.84
	Openness	-.04	.38	.01	.97	.46	2.02
	(Constant)	-7.12	1.63	19.03	.00		

**p<.01, ***p<.001

This result showed there was no significant improvement of the model fit when the individual variables were added to the model composed of only environmental variables. In terms of classification, the correctness of predicting both groups increased slightly, with 82.8% for the non-patentee group and 36.8% for the patentee group. Accordingly, the overall successful prediction rate for both groups was increased to 80.0%. Table 3.9 presents the results.

3.2.4 Summary

The t-test showed no significant differences between patentees and non-patentees in thinking style, cognitive ability, knowledge, or inventiveness. Thus, H2a (p.80) and H2d (p.82) are untenable. Significant differences were found in intrinsic motivation, Openness, school encouragement, and school resources, where patentees scored higher in each of the factor. These results provide full support for H2b (p.81) and H2c (p.81) and partial support for H2e (p.82). Of these variables, school encouragement showed the biggest effect size (.71), followed by school resources (.52), intrinsic motivation (.32), and Openness (.30). Logistic regression suggested that school encouragement was the only factor that made significant contribution to the prediction. This environmental model resulted in an overall successful rate of classification of 78.9%.

3.3 Comparison of gender and age groups

The third research question of the current study is to explore the gender and grade-level differences among the participants in relation to the cognitive, non-cognitive, environmental as well as the outcome variables of inventiveness. To answer this question, a 2×3 (gender × age group) multivariate analysis of variance (MANOVA) was conducted with all independent and dependent variables. MANOVA instead of separate ANOVAs was chosen for these research purposes because MANOVA can detect whether two groups differ along a combination of variables, thus having greater power to detect an effect (Huberty & Morris, 1989; Field, 2005).

Theoretically, prior to MANOVA, the whole data set should be divided into the sub-groups formed by the intersections of the relevant factors and independent data screening procedures should be done to each sub-group. For the current study, the sub-groups were 126 boys and 133 girls from the 4th to 6th grades, 85 boys and 103 girls from the 7th to 9th grades, and 92 boys and 82 girls from the 10th to 12th grades. Grouped data screening procedures were not taken because of two reasons. Firstly, in order to conduct the data screening process properly the whole data set should be divided into six independent data sets. Then after treating missing values, detecting outliers, and examining the assumptions of multivariate analysis the separate data sets should be combined again for further data analysis. The process of dividing and combining data sets can cause unexpected man-made or system-caused mistakes and once any mistakes happen the costs to pay are too high. Secondly, careful and systematic data screening has been done for the whole data set for the previous data analyses (refer to pp. 105-106). This process can suffice further sub-group comparisons in that the missing values have already been treated and the distribution of each variable checked. The outcome that moderate negative skewness was found for the two cognitive variables (cognitive ability and knowledge) as well as the family resources is important background information to bear in mind while choosing appropriate methods for data analysis.

3.3.1 2×3 MANOVA on all variables

As a preliminary check for robustness, the Box's M test for homogeneity of dispersion matrices was conducted. However, with the result significant at $p<.001$, the robustness is not guaranteed. This may be due to the unequal cell sizes of the sub-groups. According to Tabachnick and Fidell (2007), in such circumstances, the advantage of Pillai's Trace criterion is more important. Therefore, all the multivariate F values reported in the following parts are based on the Pillai's Trace. For post hoc analysis, Tukey above other methods was chosen because Tukey controls the Type I error rate very well and is more powerful when testing large numbers of means (Field, 2005), which is the case with the current study. In order to account for multiple comparisons of means and control the rate of Type I error, pairwise comparisons with adjusted significance level through Bonferroni correction were conducted.

Multivariate analysis revealed there was a significant main effect of gender, $F(19, 500)=3.40$, $p<.001$, $\eta^2=.11$ and grade group, $F(38, 1002)=4.98$, $p<.001$, $\eta^2=.16$. But the interaction of gender and grade group did not reach the significance level, indicating that gender differences within each grade group were not statistically evident.

3.3.2 Gender differences

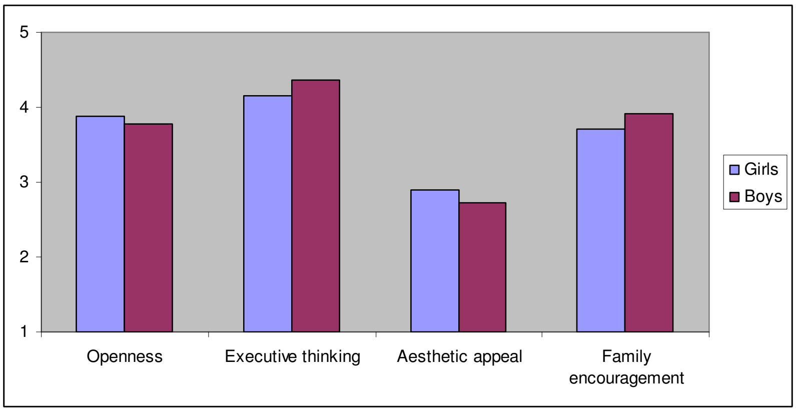
Univariate tests revealed that girls ($M=3.88$, $SD=.60$) were more open to inventive ideas than boys ($M=3.77$, $SD=.62$), $F(1, 518)=3.90$, $p<.05$, $\eta^2=.01$. They ($M=4.16$, $SD=.98$) scored lower than boys ($M=4.37$, $SD=.92$) in executive thinking style, $F(1, 518)=6.22$, $p<.05$, $\eta^2=.01$ and their inventions ($M=2.90$, $SD=.72$) were rated higher in aesthetic appeal than those invented by their male counterparts ($M=2.73$, $SD=.73$), $F(1,518)=7.67$, $p<.01$,

η^2=.02. However, girls (M=3.70, SD=.93) perceived less encouragement from their parents for being inventive than boys (M=3.91, SD=.88), F (1, 518) =7.78, p<.01, η^2=.02. No significant differences were found between boys and girls in terms of motivation, cognitive ability, knowledge, and the level of inventiveness. Results of the univariate tests for gender differences were presented in Table 3.10. To visualize the differences Figure 3.2 was given.

Table 3.10 Gender differences in all variables

	Girls n1=318		Boys n2=303			
Variables	M	SD	M	SD	F	eta^2
Motivation						
Intrinsic motivation	3.95	.49	3.94	.46	.01	.00
Extrinsic motivation	3.21	.47	3.17	.49	.66	.00
Personality						
Openness	3.88	.60	3.77	.62	3.90*	.01
Risk-taking	3.11	.67	3.17	.65	1.29	.00
Tolerance of ambiguity	3.27	.67	3.17	.72	1.90	.00
Thinking style						
Legislative	5.70	.85	5.66	.85	.46	.00
Judicial	4.86	.95	4.88	.99	.16	.00
Executive	4.16	.98	4.37	.92	6.22*	.01
Liberal	5.48	1.03	5.59	1.04	1.82	.00
Environment						
Family encouragement	3.70	.93	3.91	.88	7.78**	.02
Family resources	4.00	.87	4.00	.91	.04	.00
School encouragement	3.53	.98	3.41	.95	2.38	.01
School resources	3.07	.96	3.2	.88	3.51	.01
Tech. construct ability [a]	35.20	12.65	35.32	11.79	.00	.00
Knowledge	78.01	16.53	75.55	17.31	2.47	.01
Inventiveness						
Originality	2.97	.76	2.92	.69	1.28	.00
Practicality	2.99	.66	2.96	.64	.58	.00
Aesthetic appeal	2.90	.72	2.73	.73	7.67**	.02
Communication	3.39	.65	3.22	.67	1.55	.00

*p<.05, **p<.01 (2-tailed test); [a] n for girls is 272, n for boys is 252.



Note. For executive thinking the scale ranges from 1 to 7.

Figure 3.2. Gender differences in Openness, executive thinking style, and family encouragement

3.3.3 Age-related differences

Tukey tests revealed that the middle group (7^{th}-9^{th} graders; M=3.93, SD=.60) were the most open among the three groups and there was a significant mean difference between this group and the youngest group (4^{th}-6^{th} graders; M=3.75, SD=.61), F(2, 518)=4.30, p<.05, η^2=.02. The youngest group (4^{th}-6^{th} graders; M=3.03, SD=.71) were most reluctant to take risky activities in comparison to their elder counterparts in grades 7^{th} to 9^{th} (M=3.25, SD=.65) and 10^{th} to 12^{th} (M=3.20, SD=.56), F(2, 518)=6.14, p<.01, η^2=.02. For both comparisons, the mean differences were significant at the adjusted more stringent significance level of .025. In parallel to their Openness, the middle group (M=4.08, SD=.89) scored the lowest in executive thinking and there was a significant mean difference between this group and the younger group (M=4.35, SD=1.04), F(2, 518)=4.30, p<.05, η^2=.02.

Age-related differences were also found in technical construct ability and knowledge. The eldest group (M=31.12, SD=10.57) scored lower in the technical construct ability test than the other two younger groups (for 4^{th}-6^{th} grades, M=36.44, SD=12.57; for 7^{th}-9^{th} grades, M=36.97, SD=12.30), F(2, 518)=10.68, p<.001, η^2=.04. In the knowledge test, the middle group (M=82.54, SD=15.74) achieved higher than the younger group (M=78.74, SD=17.49), who surpassed their eldest counterparts (M=66.55, SD=12.41), F(2, 518)=40.46, p<.001, η^2=.14. Sizable differences were also found in originality and aesthetic appeal sub-scales of inventiveness. The youngest group (M=3.18, SD=.60) scored the highest in originality in comparison to the middle group (M=2.77, SD=.66) and the eldest group (M=2.81, SD=.86), F (2, 518)=20.61, p<.001, η^2=.07. The youngest group (M=2.94, SD=.65) also scored higher in aesthetic appeal than their elder counterparts at the 7th to 9th grades (M=2.79, SD=.71) and those at the 10th to 12th grades (M=2.63, SD=.84), $F(2, 518)=7.95$, $p<.01$, $\eta^2=.03$. Table 3.11 and Figure 3.3-3.5 present the results of these comparisons.

Table 3.11 Grade-level differences in all variables

Variables	Group 1 (4-6 grades) n1=228		Group 2 (7-9 grades) n2=163		Grade 3 (10-12 grades) n3=133			
	M	SD	M	SD	M	SD	F	eta^2
Motivation								
Intrinsic motivation	3.92	.49	3.96	.50	3.95	.42	.40	.00
Extrinsic motivation	3.18	.52	3.18	.45	3.19	.44	.02	.00
Personality								
Openness	3.75	.61	3.93	.60	3.84	.60	4.30*	.02
Risk-taking	3.03	.71	3.25	.65	3.20	.56	6.14**	.02
Tolerance of ambiguity	3.26	.76	3.26	.64	3.10	.63	2.55	.01
Thinking style								
Legislative	5.61	.93	5.73	.77	5.73	.80	1.38	.01
Judicial	4.87	1.01	4.78	.99	4.97	.85	1.42	.01
Executive	4.35	1.04	4.08	.89	4.34	.86	4.30*	.02
Liberal	5.56	1.06	5.46	1.02	5.35	1.00	.95	.00
Environment								
Family encouragement	3.87	.92	3.79	.95	3.71	.82	1.30	.01
Family resources	4.04	.91	4.04	.87	3.96	.81	1.02	.00
School encouragement	3.56	.94	3.35	1.03	3.46	.93	2.06	.01
School resources	3.23	.98	3.06	.92	3.04	.84	2.41	.01
Tech. construct ability	36.44	12.57	36.97	12.33	31.12	10.57	10.68***	.04
Knowledge	78.74	17.49	82.54	15.74	66.55	12.41	40.46***	.14
Inventiveness								
Originality	3.18	.60	2.77	.66	2.81	.86	20.61***	.07
Practicality	3.02	.63	2.96	.61	2.92	.73	1.13	.00
Aesthetic appeal	2.94	.65	2.79	.71	2.63	.84	7.95***	.03
Communication	3.32	.66	3.24	.55	3.18	.76	2.10	.01

*p<.05, **p<.01 (2-tailed test)

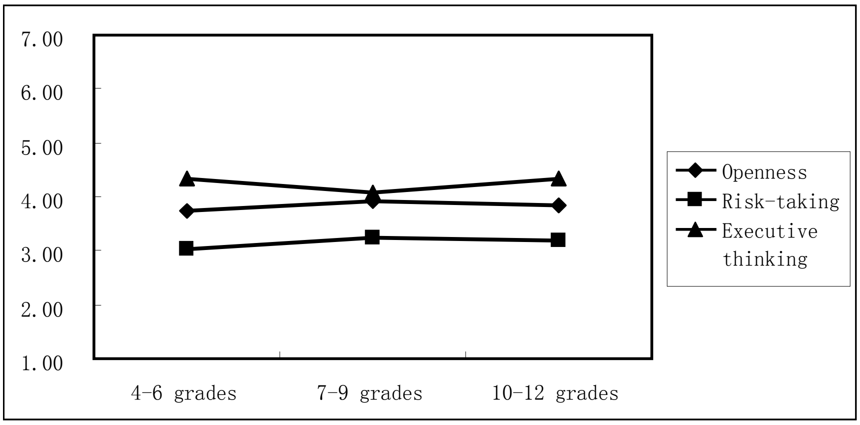


Figure 3.3. Grade-related differences in non-cognitive personality characteristics

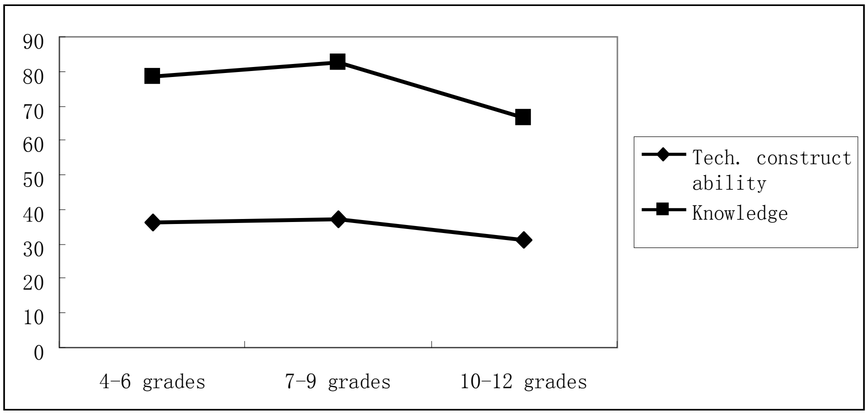


Figure 3.4. Grade-related differences in cognition

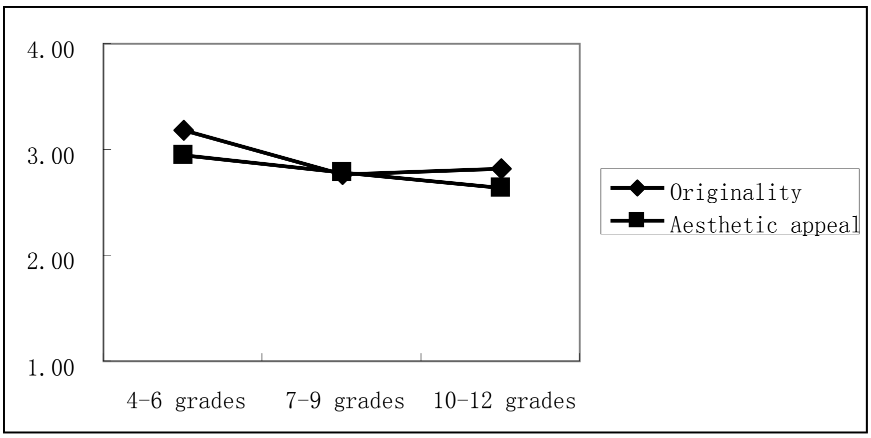


Figure 3.5. Grade-related differences in inventiveness

3.3.4 Summary

This set of data analyses target the third and fourth research questions about the gender- and age-related differences among the participants. Of the 19 variables under investigation, significant gender differences were found in only four variables, indicating that gender differences are not very pronounced. So H3a (p. 83) is supported. Post-examination of the gender-differences showed that girls actually showed more potential for inventing in that they scored higher in Openness and lower in executive thinking style. The inventions made by girls were also rated by experts as more aesthetically appealing than those made by their male counterparts. From their parents, however, girls perceived less encouragement for being inventive. This result provides support for H3b (p. 84).

Regarding age-related differences, the results did not provide support to the hypothesized development in inventiveness. In contrast, from lower to higher grades, the students' inventiveness (in terms of originality and aesthetic appeal) dropped. Concerning the development in other cognitive domain and the non-cognitive personality domain, there was a growth in some creative personality traits (Openness and risk-taking) and decrease in executive thinking style. However, this developmental trend did not continue from junior high to senior high level.

3.4 Who are the young inventors and what do they invent?

3.4.1 Biographical data of the young inventors

Of the 621 participants of the contest, 38 (6.1%) reported holding one or more patents. Among them, 20 (52.6%) are boys and 18 (47.4%) are girls. The average age of the young patentees are 14.9 (SD=3.4), with almost half of them (N=17, 44.7%) from the 10^{th} to 12^{th} grades. In terms of the social economic status of the regions where the patentees come from, almost 2/3 (N=24, 63.2%) of them are from the economically developed areas of China, eight (21.1%) are from the economically developing areas and five (13.2%) are from the under-developed areas. In terms of the educational level of the parents, 18 (47.4%) fathers and 14 (36.8%) mothers of the patentees have gained a college degree or above.

3.4.2 Categories of the inventions of the young inventors

Thirty-eight participants reported a number of 74 patents (M=1.4, SD=.89) with 68 (91.9%) containing a description. The reason why there were more patents than patentees was because some participants have reported more than one patent. With the aim to compare the categories of the inventions made by the young inventors with those reported in the previous study (Colangelo et al., 2003) in the USA, the present study used the same categories (see Appendix 5, pp. 263-264) that the previous study used to classify the inventions.

Table 3.12 presents the categories of the inventions of the China's young inventors by gender. As this table shows there were some overlaps of the most popular categories of inventions among boys and girls. For boys, the most popular inventions were tools (18.4%), followed by amusement (15.8%). Then came clothes/accessories, automotive, and electronic (13.2% for each). For girls, the most popular inventions were kitchen/bath stuff, clothes/accessories, and amusement, accounting for 16.7% each, followed by tools and safety/protection/rescue stuff (13.3% each). Despite these similarities, boys outnumbered girls in the categories of medical and electronic by over 3:1, whereas girls outnumbered boys in the category of safety/protection/rescue by 4:1.

Table 3.12 Categories of the inventions of the China's young inventors by gender

	Gender					
	Male		Female		Total	
Category	N	%	N	%	N	%
Tools	**7**	**18.4**	**4**	**13.3**	**11**	**16.2**
Kitchen/Bath	4	10.5	5	16.7	9	13.2
Organization	1	2.6	1	3.3	2	2.9
Clothes/Accessories	**5**	**13.2**	**5**	**16.7**	**10**	**14.7**
Safety/Protection/Rescue	1	2.6	4	13.3	5	7.4
Farm	0	0	0	0	0	0
Amusement	**6**	**15.8**	**5**	**16.7**	**11**	**16.2**
Pets	0	0	0	0	0	0
Automotive	5	13.2	2	6.7	7	10.3
Furniture	1	2.6	2	6.7	3	4.4
Medical	3	7.9	0	0	3	4.4
Cleaning	0	0	1	3.3	1	1.5
Electronic	5	13.2	1	3.3	6	8.8
Disabled	0	0	0	0	0	0
Total	38	100	30	100	68	100

3.4.3 Summary

There were roughly equal numbers of male and female patented inventors in this sample. Most of the young inventors were from economically developed areas of China and only few were from under-developed areas. In terms of the educational level of their parents, 47.4% fathers and 36.8% mothers of the patentees have gained a college degree or above.

In terms of the categories of the inventions made by this group of young inventors, the most frequent inventions were tools, amusement and clothes/accessories, which accounted for almost half of the total number of patented inventions. Maybe due to the small number of patented inventions reported by the participants, not all categories provided by the Patent Office were covered. No inventions about farm, pets, and for the disabled were reported.

CHAPTER 4 – DISCUSSION

The current study is a pioneering study about the individual and environmental profiles of a special creative group – the young inventors. Guided by a systems model of inventiveness, the study sought to answer five research questions: (1) How the individual and environmental factors are related to one another in predicting the inventiveness of young inventors? (2) In which individual and environmental aspects do the higher- and lower-level young inventors differ? (3) In which individual and environmental aspects do male and female young inventors differ? (4) In which individual and environmental aspects do the young inventors of various age groups differ? (5) Who are the young inventors and what do they invent? The discussion part will be structured in correspondence to the sequence of the results presented in the previous chapter.

4.1 Discussion about the major findings

4.1.1 Individual and environmental determinants of inventiveness

Interplay of motivation and personality and their relations to thinking styles

Considerable correlations were found within and among the motivational, personality, and thinking style variables. Subsequent factor analysis for all variables revealed a five-factor solution as a best-fit model. However, instead of differentiating motivation, personality, and thinking style, this model dichotomize the spectrum of motivational, personality, and thinking style variables into "creative" and "non-creative" sub-constructs. This is an interesting starting point for us to reflect on the relationship between personality, motivation, and the thinking style in creativity research.

In the existing literature about creativity research, quite often we see motivation and personality discussed together (e.g., Helson, 1999b; Runco, 2007). Runco (2007), in his latest book about creativity, admitted that it would be difficult to discuss personality without talking about motivation. He discussed both constructs within one chapter and came to the conclusion that creativity could be best captured only through the interactions among *traits, attitudes, abilities,* and *values*. Realizing the limitation of the personality traits study of the creative individuals, Amabile (1983a/b 1987, 1993) has spent over three decades pushing such studies one step further by exploring the motives that underlie the creative traits. It was through this continual research endeavor that she and her colleagues observed the existence of relatively stable motivational orientations, which in their words were "trait intrinsic motivation" and "trait extrinsic motivation" (Collins & Amabile, 1999). In constructing Work Preference Inventory, a nowadays widely used instrument assessing intrinsic and extrinsic motivation, Amabile and colleagues (1994) assessed motivational orientation "as a personality characteristic" (see Conti & Amabile, 1999, p. 253).

With regard to thinking style, the existing style constructs in the literature can be roughly categorized into three groups: cognition-based, personality-based, and activity-based (Sternberg & Grigorenko, 1997). The current study found that the creative thinking styles were loaded on the same factor as did creative personality and intrinsic motivation. This result implies that thinking styles as constructed on the basis of the Theory of Mental Self-government (Sternberg, 1988, 1997) might demonstrate a more personality function rather than a cognitive preference (Dai & Feldhusen, 1999). In particular, Dai and Feldhusen hypothesized that the three primary thinking styles that are constructed based on the three major functions of mental self-government (legislative, judicial, and executive) reflect general personal inclinations and are therefore more personality-based. With regard to the liberal style, they anticipated that it would be correlated with Openness, as both tap into intellectual rather than interpersonal styles. This hypothesis was partially supported by the current study. Though Openness was significantly related to all three other thinking styles, the correlation between Openness and liberal style produced the highest correlation coefficient ($r=.56$). The considerable correlation between thinking style and personality might be of similar feature to the overlap between learning styles and personality that was found in previous studies (Furnham et al., 1999; Jackson & Lawty-Jones, 1996). Based on the results, the authors concluded that learning styles are a sub-set of personality. The findings of the current study indicate that thinking styles might also be a sub-set of personality. Of course, a conclusion as such cannot be properly made until more comprehensive discriminant investigations that involve diverse samples have been conducted. Therefore, more research is invited to test this hypothesis.

In whichever case, it might be advisable to adopt a more inclusive concept of personality that integrates cognitive, motivational, and affective constructs for systematic research purposes. This recommendation is made as a possible solution to the bandwidthfidelity-dilemma (Cronbach & Gleser, 1965) that a systematic approach is likely to be confronted with while assessing a broad variety of variables at the same time. Among others, the definition of personality given by Helson (1999b) seems to bear a conspicuous *inclusive* nature. He defined personality as "the relatively enduring organization of motivations and cognitive and affective resources (traits) that any person manifests or that distinguishes one individual from another" (p. 361). In some recent creativity studies that investigated the individual and environmental variables within one research framework, attempts have already been made to restructure the personality construct to better accommodate the research purposes. For example, in their endeavor to develop a measurement for teachers to observe the personal creativity characteristics of elementary students, Proctor and Burnett (2004) decomposed the personality construct into *cognitive* components, including fluency, flexibility, originality, and elaboration sub-scales of creativity, and *dispositional* components, including intrinsic motivation and prominent creative traits such as risk-taking. In his initiative to explore potential psychological processes that mediate the effects of various individual and contextual variables on the creative performance of individuals, Choi (2004) chose to dichotomize the individual characteristics, including motivation and personality, so that the positive and negative predictors of creative achievement could be clearly discerned. Runco (2007) recommended a dichotomy of creativity-related personality traits (*indicative traits*) that are positively related to creativity and *contra-indicative traits* that are negatively related to creativity.

In sum, the correlation analysis and subsequent factor analysis run in the current study support a hypothesized dichotomy of *indicative* and *contra-indicative* traits to creativity (Runco, 2007). This result indicates a possible way of reducing predicting variables of creativity in a way of dichotomizing a spectrum of motivational, personality and thinking style variables into two major groups of variables. This method can be of particular value for further creativity studies that take a systematic approach, in which trade-off of the breadth and depth of the study is an issue.

Interplay among cognitive, non-cognitive, and environmental variables

Environmental variables, as measured by the encouragement and resources that the young inventors perceive in their family and school settings, are positively related to most of the creative non-cognitive factors, including intrinsic motivation, Openness, tolerance ambiguity, and creative thinking styles. This positive correlation was found in both family and school settings, indicating that a creativity-supportive environment has the effect to foster intrinsic motivation, creative personality traits, and creative thinking styles. These results are consistent with several previous studies. In their study about the profile of the motivation in gifted students, Phillips & Lindsay (2006) found that the support that the participants perceived from those around them both in and out of school in coping with difficulties was an important factor that sustains their motivation. In other studies, researchers found that children who perceived greater warmth in their teachers were more intrinsically motivated and more creative than children who did not perceive their teachers to be very warm (Picariello, 1991; Ryan & Grolnick, 1986). The same environmental variables, however, had only limited correlations to the cognitive variable of knowledge, but not technical construct ability. To be more exact, parental support, in terms of encouragement and resources that the children get, is conducive for children obtaining knowledge about invention.

Among the various personality variables, openness to experience was the factor most frequently associated with intelligence (Ackerman & Heggestad, 1997; Austin, Hofer, Deary, & Eber, 2000; Brand, 1994; Goff & Ackerman, 1992; Zeidner & Matthews, 2000). Previous studies revealed an overall correlation of r=.33 between Openness and intelligence (Austin et al., 2002; Ackerman & Heggestad, 1997). Though with r=.12, the correlation between Openness and technical construct ability found in the current study was less pronounced than what the literature states, this was the biggest correlation coefficient between technical construct ability and other variables. Technical construct ability was also positively related to liberal thinking style (r=.11). Given the fact that Openness and liberal thinking style were highly correlated (r=.56), the result was not surprising. Though it was not the purpose of the current study to determine the potential individual predictors of technical construct ability, these results seem to indicate that students who are more open to new experience and more liberal in thinking are more likely to develop and strengthen their technical construct ability. The reason might be that an open mind to experiences and a liberal thinking style can give an individual more flexibility to play with different ideas in their visual world and prevent them from premature closure (Basadur, 1994).

Predictors of individual sub-scale of inventiveness

The current study is based on a hypothesized systems model of inventiveness, which postulates the predictive potential of the cognitive constructs (knowledge and technical construct ability) with non-cognitive personality constructs (motivation, personality and thinking style) and environmental constructs (encouragement and resources at family and school settings) as possible moderators. Though the cognitive diagram is only part of the systematic design, the regression analyses seem to amplify the unique predictive power of the knowledge and technical construct ability on inventiveness. Of all the variables entered the regression models, only the two cognitive constructs were proved to be predictive of *originality* and *practicality* features of the inventions. These cognitive factors together with Openness also significantly predicted *aesthetic appeal* criterion of inventiveness. Though there was no relation between technical construct ability and communication, knowledge still stayed in the model, which together with legislative thinking style, predicted the communication criterion of inventiveness. However, these results are worth careful interpretation, as the percentage of variance explained by the proved predictors for each model was very small (from 3% to 7%). These limited variances might be due to the *mismatch* of the psychologically defined predictors and the socially evaluated criterion variables. This view will be discussed in depth later. In this part, I will concentrate on the most consistent result of the four regression models. That is, of all hypothesized predictors, knowledge was the only variable that made contributions to each criterion of inventiveness.

The importance of knowledge for invention has been proved by a few previous studies. In their intervention-observation study about the inventing process of designing a recycling device among the primary school students, it was observed that children who possessed a broader knowledge of the recycling tended to produce devices that were more original and functional (Webster, Campbell, Jane, 2006). In another experimental study about the effectiveness of a training program on the inventive behavior of a group of 4th to 8th grade students, Westberg (1996) designed eight lessons to teach the students invention process, including one introductory session at the beginning. This introductory session provided information about the definition of invention, stories about the creation of some inventions, and examples of students' inventions. While the experimental group received all eight lessons which also included concrete skills to make an invention, the control group got only the first introductory and exposure lesson. The results were partially surprising. The experimental group surpassed the control group in *quantity* of invention but did not show significant strength in quality (originality, technical goodness, and aesthetic appeal) of inventions. The limited variance that knowledge accounted for the quality of invention might be due to the flaw of the research design. The students in the control group were not completely "insulated" from the treatment. In contrary, they were given the introductory session, which served the function to familiarize the students with basic declarative knowledge about invention, including definitions, processes, and concrete examples. This exposure, not necessarily long and complex, seems to be crucial to lead the students to the field of invention and prepare an invention-relevant *mindset* for them. It is possible that this small but essential intervention has filled the gap between the two groups regarding the quality of their invention. Another point that is worth noting is that Westberg did not adopt a longitudinal design. Changes do not happen overnight. It takes longer time to see qualitative changes than the quantitative ones. With a longitudinal design, the accumulative effect of knowledge on the quality of inventions can be anticipated. The importance of knowledge is even more emphasized among adult inventors. While recognizing "knowledge and memory" as one of the most important indicators of successful inventors, they also acknowledged that "lack of knowledge" was one greatest obstacle for them to progress in their inventing career (Rossman, 1964).

Parallel to knowledge, technical construct ability also accounted for the originality, practicality, and aesthetic subsets of inventiveness, but not for communication. The technical construct ability is of particularly importance for inventive individuals to use mental models and mechanical representations to develop their projects. Mental models are the ideas and concepts an inventor has about his or her invention (Carlson & Gorman, 1992). The process of invention typically generates multiple representations of an object or how an object functions. Technical construct ability enables inventors to construct different mental models, work on individual sections of all possible solutions to an invention problem, and allows them to move back and forth between different mental models. With the flexibility of playing around with different mental representations in their mind's eye, the chance for the inventors to construct a large quantity of products is bigger. With increment in quantity the likelihood of the increment in quality, in terms of originality, practicality, and aesthetic appeal, will also increase. Such a positive relationship between the quantity and quality of ideas is a direct implication of the "blind-variation-and-selective-retention process" suggested by Campbell (1960). A recent 40-year follow-up study of the Torrance Tests of Creative Thinking has also lent support for such a relationship (Cramond et al., 2005).

The communication sub-scale of the test was designed to ask the participants to name their invention, introduce each part of the product, describe the advantages of their inventions, and provide evidence in which way their inventions would excel the existing ones. The results of the current study suggest that such an extra skill which experts expect in young inventors is independent from the technical construct ability, although knowledge still plays an important role. By nature, this criterion is a social skill that an inventive individual uses to "sell" his or her inventions. In order to "sell" their inventions well, inventors need sufficient knowledge about their own products as well as the relevant materials, available technology, and the gaps they might be able to bridge between the existing technology and their inventions. That's why knowledge was found to be able to predict the communication level of the participants.

As mentioned earlier, for each regression model the predictors accounted for only limited variance in the criterion measures of inventiveness. These limited results seem to be caused by the *discrepancy* between the theories developed by field psychologists and the assessment of inventiveness adopted by the practitioners outside of the field of psychology (Westmeyer, 1998). According to Westmeyer, the creativity of products (in this study, invention) is a *socially defined* concept that is constructed by groups of persons authorized to do so and endowed with the required definitional power by certain institutions. In reality, it is this group of experts (in this study, the patent examiners and experts of intellectual property rights) act as "gate-keepers" of certain field. Psychologically defined concepts, such as motivation, personality, cognitive ability, etc, are constructions of single psychological scientists or of small groups of such persons. Some of these constructions are gaining ground within more extended parts of the scientific community, while others do not succeed. It is the conceptual *disunity* of these two sides that might have caused methodological difficulties in any empirical attempt to accommodate both within one empirical study. In making his assertion, Westmeyer particularly pointed at the Investment Theory of Creativity and argued that "the investment theory may be confirmed and refuted with regard to data of the same persons and the same performance products" (p. 19) simply because the empirical content of this theory was missing. In addition, he listed some key questions to be taken into consideration in the course of testing the investment theory, ranging from *assessment* of the six resources, *evaluation* of the creative products and the relevant *statistical* procedures. All these points are worth careful accommodation in future studies related to the investment theory.

Putting research to use

In the field of creativity study, the assessment of creativity seems to be the most controversial one that has caused so much discussion, disagreement, dissatisfaction, and even despair that makes the image of creativity even more "elusive" (Treffinger, 2003). Lack of comfort and consensus about an operational concept of creativity and a compatible assessment of this concept left the studies of creativity for a long time running on thin ice. On the one hand, no matter how fine-grained the whole research project is, once the creativity test is simplified the reliability and range of the criterion will be limited and the true size of the relationship between predictors and criterion will be underestimated. In his attempt to construct a cognitive model for technical creativity, Hany (1995) adopted a longitudinal and cross-sectional design to test a causal model with a variety of cognitive constructs as predictors and the quantity and quality of technical creativity as criteria. For a technical creativity test, he asked the participants to design a cart for the convenient transport of articles required for a day at the beach. Then the products of the participants were scored on two criteria, including productivity (e.g., the number of finished sketches of carts and number of words written, etc.) and technical problem solving quality (e.g., ease of handling, suitability, and locomotion). Though he could find considerable correlations among the predictors, including successful confirmation of two sub-models for scientific/technical activities/achievement and problem solving competence in physics and technology, the final model for technical creativity was not supported. Similarly, in the current study, the inventiveness test was composed of one test. Though the test is a combination of verbal and nonverbal tests and a panel of qualified expert raters was used for scoring, the uni-faceted nature of the test constrains the validity of the criterion.

Creativity/inventiveness is a multifaceted concept. In order to measure the multiple dimensions of this construct, several different tests should be combined in future studies. For example, Iowa Inventiveness Inventory (III; Colangelo et al., 1992) has been developed based on field studies with adult inventors and has been cross-validated with both adult and young inventive samples. This inventory would be a good choice to measure attitudes and characteristics of inventors. Moreover, Invent Iowa Evaluation

Rubric (IIER; Colangelo et al., 2003) adopts the criteria of the patent office to assess inventive products and, with its rubric design, has provided elaborations at different mastery levels of inventions. This instrument can provide a useful tool for both expert and non-expert evaluators to rate the inventions of other students. In addition, Hocevar and Bachelor (1989) have suggested that the self-report inventory is the most easily defended method of assessing both creative achievement and creative talent. Most such inventories are checklists that are easily administered. Among others, the Creative Achievement Questionnaire (CAQ; Carson, Peterson, & Higgins, 2005) which was newly published in the *Creativity Research Journal* demonstrates high reliability (test-retest reliability .81; internal consistency reliability .96), impressive predictive validity (.59 for artistic achievement) and moderate convergent validity with other creative potential constructs. Most importantly, invention is one sub-scale of the instrument, which covers eight level of inventiveness. Depending on the expected inventiveness level of the sample, this subscale can be partly or completely used in studies about young inventors.

On the other hand, only multi-sourced instruments won't suffice the validity of the creativity assessment, particularly if the assessment also includes product evaluation, which is the case of inventiveness assessment. An unavoidable issue of product evaluation is "objectivity". Like other social phenomenon such as beauty, creativity is a subjective judgment. As the tastes of people differ, the judgments of the same product vary. The bigger the variations of the judgments, the less convincing the creative value of the product is. As there is almost no way to accommodate all tastes, the so-called "objectivity" of creativity assessment can never be guaranteed. To overcome this difficulty, a different perspective and technique is needed. In 1982, Amabile published her solution for this issue. She argued "a search for specific, objectively identifiable features common to all creative products will not be fruitful." (Amabile, 1982a, p. 999). The reason is self-explaining: creativity depends on judgment and judgment itself is subjective. So the process of assessing creativity can't be completely objective. Nevertheless there are ways to help us reach certain level of objectivity throughout the subjective assessment process. Though not explicitly stated, the Consensual Assessment Technique (CAT) is an excellent application of a statistic method called "maximum likelihood estimation". By focusing on "novelty" and "appropriateness", which are the two mostly agreed criteria of creativity, she maximized the probability that the most relevant parameters were included. By stressing "consensus" in making judgments, she maximized the likelihood that discrepancies among different judgments were controlled. To put it in a formula, the principle that underlies CAT is

Maximum likelihood of assessing creativity objectively =

applying maximally agreed criteria + maximally controlling disagreement on criteria

Since its existence, CAT has been widely applied in different creativity studies (mostly artistic and verbal tasks) with satisfactory inter-rater reliabilities (e.g., Baer, Kaufman, & Gentile, 2004; Conti, Coon, & Amabile, 1996; Hennessey, 1994; Hickey, 2001; Kaufman, Lee, Baer, & Lee, 2007). Some cross-cultural studies have also provided support for this method (e.g., Chen, Kasof, Himsel, Greenberger, Dong, & Xue, 2002; Niu & Sternberg, 2001). Most recently, CAT has even been embedded into a web-based tool called "The Creative Task Creator" (Pretz, 2008) as one scoring alternative in parallel to the traditional Torrance scoring method for some divergent thinking and open-ended creativity tests. It seems in the new millennium a favorable consensus for CAT is prevailing in the field of creativity.

The acclaim for CAT is not surprising when we take a brief review of the history of creativity study. Treffinger and colleagues (Treffinger et al., 1993) divided the history of modern creativity study into three eras, namely the "Creativity is Divergent" Era (1950s-1960s), the "Packages and Programs" Era (1970s-1980s) and the "Ecological" Era (1990s). The first era was inspired and strongly impacted by Guilford's (1959, 1967) concept of divergent thinking. The major focus of this era, particularly in relation to the nurturing and development of creativity, was promoting divergent thinking. Accordingly, pioneering efforts were made to develop creativity constructs or models, including some that are still in wide use till today. For example, Osborn's "brainstorming" (1953), Torrance Test of Creative Thinking (Torrance, 1966) and a group of personality psychologists who started to explore creativity-related personality traits (e.g., Barron, 1968, 1969; MacKinnon, 1962, 1965). Creativity assessment in this era almost exclusively concentrated on creative personality traits and divergent thinking. The second era was called "Packages and Programs" Era, because on the basis of the creativity research and initial application praxis of the first era, numerous creativity training models and programs were developed in this era, including the complex Creative Problem Solving (CPS; Noller, Parnes, & Biondi, 1976; Parnes, Noller, & Biondi, 1977) project. A major advance in this era, as summarized by the authors, was a shift from an exclusive focus on divergent thinking to an emphasis on multiple criteria which combined divergent thinking with convergent thinking and problem solving with decision making. Starting in late 1970s and thriving through the 1980s and 1990s, the construction of a number of giftedness models (e.g., Gagné , 1985; Gardner, 1983, 1993; Heller & Hany, 1986; Renzulli, 1978; Sternberg, 1985a) challenged the traditional view of intelligence as unidimensional and expanded the conception of giftedness to a *multidimensional/typological* ability constructs. This shift brought the creativity study into a new era, which Treffinger and his colleagues called "Ecological" Era. Characterized by an inclusive ecological view of creativity, studies and assessment of creativity take into account a variety of personal, process, and situational factors. It was under this background that CAT was developed. Stressing the role of the social context, CAT not only clearly describes the criteria of creativity but also the subjective methodology of creativity assessment. The subjective approach of creativity assessment is crucial as it reveals the essence of creativity – a phenomenon that origins in a certain social context, emerges when its value is recognized by the mainstream of society, and dies out when its merits are not or no more valued. It is the subjective view of the social context, usually represented by a group of "gate-keepers" of the field that determines the existence or nonexistence of creativity. In other words, CAT reflects the "interactive" nature of creativity, which is regarded as "a phenomenon that is constructed through an interaction between producer and audience" (Csikszentmihalyi & Wolfe, 2000, p. 82). Though nobody has labeled the era the current creativity studies are in, with the affiliation of new discipline (such as neo-biology) to the field of creativity study, the ecological system of creativity will be even more extended. On the other hand, with increasing globalization and the assistance of Internet, more cross-cultural studies about creativity are anticipated. All this implies, CAT, with its sound theoretical ground will continue to make contributions to creativity studies.

Despite its obvious advantages and great potentials, CAT shows its limitation for large-scale studies, for which practical considerations are primary. It is because of the time and costs reasons that I could not "sell" this technique to the evaluation board. It is like an invention, no matter how tactfully and beautifully it is designed, once the cost is too high, its application will suffer. But there are at least two possible ways to solve this problem. Firstly, the scope of the study can be limited to a manageable level so that the relevant costs can be lowered. Secondly, if for the research purposes, the scope of the study can not be limited, the researchers should try ways to get more resources (e.g., more personnel and more time) to make sure that the multi-assessment process can be implemented.

To sum up, though the predictive role of the cognitive factors, particularly knowledge, on each criterion measure of inventiveness was confirmed by the current study, the moderating role of the non-cognitive personality factors and environmental factors were not proved. The limited relationship between the predicting variables and criterion measures might be due to the gap between the theories developed by psychologies and the evaluation criteria and process of inventiveness adopted by practitioners outside of the field of psychology. For future studies about young inventors, multi-sourced instrument which employs a well-developed technique such as CAT is highly recommended.

4.1.2 Differences between the higher- and lower-level young inventors

Higher-level young inventors have higher intrinsic motivation

Through the comparison of the young patentees (higher-level young inventors) and non-patentees (lower-level inventors), it was found that these two groups did not differ in cognitive factors or their inventiveness level. Rather, the differences lie in motivation, personality and school environment. The non-existence of differences in cognitive and criterion domain imply that, though there were no uniform requirements from the organizing committee on the selection criteria, participating schools of the contest implicitly adopted similar intellectual (in terms of technical construct ability, invention- and patent-related knowledge and inventiveness) standards for their selection. The intellectual comparability of the whole sample makes me more confident about the *homogeneous* character of the sample, thus making the following interpretation of the significant differences between these two groups more convincing.

The higher level young inventors differentiate themselves from the lower level ones in their higher intrinsic motivation. This result is in line with the studies about adult inventors. In his survey about the patented inventors of different disciplines, Rossman (1964) found "love of inventing" and "desire to improve" stood out as the most frequently mentioned motives for making inventions. In the same study, Rossman found that perseverance was listed as one of the most distinct characteristics of inventors. All these factors can find their sources in intrinsic motivation. Results of two recent studies also present an intrinsically motivated profile of the adult inventors in terms of their "love of work" or "passion for work" (Colangelo et al., 1993) and highly intrinsically oriented goal structures (Henderson, 2004b). Inventing is a highly demanding process, which is quite often accompanied with setbacks, unexpected accidents, no immediate rewards, and threat of failure. Only people who are making inventions for the pure interest, love or a sense of destination are able to endure the hardship and persevere in the process.

Of course, compared to eminent creators/inventors, young inventors might be confronted with only limited challenges and stress, but intrinsic motivation is of the same, if not less, importance to the young inventive. A child will not choose to put the effort into constructing an original interpretations and creating something new unless he or she is motivated to do so. From the perspective of developmental psychology, children are all capable of doing, but capability itself does not guarantee that children will actually do it. Children will adapt because they are intrinsically motivated to understand (Piaget, 1970, 1976). The higher intrinsic motivation of the inventors, no matter younger or older, is obviously an essential drive for them to make and sustain inventive efforts. In the family of creative geniuses, inventors are in most cases "silent contributors" to our daily lives (Jardin, 1999; Rogers & Larsen, 1986). On the one hand, historically, most inventions have been anonymous (Lemelson-MIT Program, 2004). On the other hand, people seem to easily get used to new inventions and become ignorant to how the inventions came into being. Indeed, the endeavor of inventing does not necessarily lead to immediate fame and economic returns. This means to enter the field of invention itself requires courage, aloofness, and determination. Only strong intrinsic motivation driven by a burning desire to create, sheer enjoyment of inventing, or satisfaction of solving problems can draw people to invest their energy in inventing. In addition, the process of invention is both intellectually challenging and emotionally demanding. While exerting efforts to defying the majority, breaking conventional rules, and creating something new, inventors quite often expose themselves to the misunderstanding of the mundane, the threat of failure, and, sometimes, financial pressure. It is, therefore, very important that the inventors can persist in front of failure, delay in problem foreclosure, and stay detached from material temptation. According to Amabile's (1983b) intrinsic motivation theory of creativity, intrinsic motivation is conducive to creativity and extrinsic motivation can be detrimental, primarily when the extrinsic incentive is experienced as controlling.

Also in the fields outside of invention, such as art, science, engineering, etc. personal dispositions such as persistence (Newell et al., 1962), devotion (Henle, 1962), driving absorption (Roe, 1952), flow (Csikszentmihalyi, 1990b; Csikszentmihalyi & Csikszentmihalyi, 1988), and sustained involvement (Gruber & Davis, 1988) have been very often associated with high creativity and these dispositions can all find their source in intrinsic motivation. Rahn (1986) studied 1,123 German winners of the annual competition *Jugend forscht* (youth researchers) at the state and national level from 1966 to 1984. By studying the course of the winners' school, university, professional and general lives, he found that interests and individual goals as well as achievement motivation are more important than intelligence factors. Mehr and Shaver (1996) did an interesting experiment to examine the goal structures of the high creative and low creative among a group of college students and found that in the creative settings, high and low creative individuals differed significantly in the ratings they assigned to *person* and *product*. While high creative individuals placed more emphasis on the *person* (in terms of how they felt or thought about themselves and how they wanted to present themselves), low creative individuals placed more emphasis on the creative *product*. Trost and Sieglen (1992) studied early biographical indicators of exceptional scientific and technological professional performance in West Germany. Through 17 years follow-up, they could measure creative achievement in terms of publications, patents, and income, etc. Of all predictors under investigation, motivation and ability to solve problem stood out as the most powerful long-range predictors of professional success (with a d value of .71).

Higher-level young inventors are more open

While more intrinsically motivated, the higher level young inventors were also more open to new experiences than the lower level inventive ones. This result is coherent with the results of a series of previous studies about creativity and Openness, which have been addressed in Chapter I of this dissertation (e.g., Costa & McCrae, 1980; Feist, 1998; George & Zhou, 2001; MacKinnon, 1992; McCrae, 1987;). In this part, I will relate this result to the special case of invention with the aim to help us understand why Openness stands out as a marked personality trait that distinguishes the higher level young inventors from the lower ones.

In his study about adult inventors, Rossman (1964) found that originality and imagination were among the most frequently listed characteristics of inventors. Comparing these characteristics to the sub-scales of Openness, we know that imagination is a typical cognitive manifestation of Openness. Exploring the same issue by comparing the personal dispositions of the product inventors with similarly trained but non-inventing professionals, Henderson (2004b) also found that the inventors scored significantly higher in Openness than their non-inventive counterparts. In another large-scale study about inventors (Lemelson-MIT Program, 2003), researchers identified some distinct dispositions that are associated with productive inventors. While some of these dispositions are *cognitive* manifestations of Openness, including resourcefulness, resilience, and mental flexibility, some are *motivational/affective* manifestations of Openness, such as nonconformity and tolerance for complexity/ambiguity. Among others, the researchers stressed that the *alertness* to practical problems and opportunities and *mix* of scientific and hands-on knowledge are of particular relevance to inventors. With a flexible cognitive ability and resilient personality traits, an open person is more likely to break boundaries, try new things, seek different experiences, and tolerate the co-existence of various possibilities. All this enables the individual to actively explore the different perspectives of life. This wide exposure to different experiences provides the individual with rich opportunities to detect problems. Meanwhile, characterized as having high curiosity, strong intrinsic motivation, and broad interests, an open person is always more ready to learn. This will help them accumulate an array of knowledge, including the knowledge from other disciplines. The importance of knowledge for inventiveness has been discussed in the preceding part.

From the process perspective, Openness is especially conducive for invention. Lemelson-MIT Program (2003) conceptualized the process of invention as *heuristic*, which entails a wide range of heuristics or strategies for dealing with recurrent process dilemmas. Altogether, they identified seven invention strategies, most of which requires Openness. For example, one strategy is called "sub-goaling", meaning to decompose a problem into independent sub-problems. An open person with a resourceful and flexible mind will find it easier to partition problems. Another strategy is "repurposing", meaning to find novel uses for existing artifacts. With his or her wide exposure to different perspectives and experiences, the possibility for an open person to match novelty with usefulness is higher. Two other very common strategies are "combining" (combine existing artifacts, materials, concepts, principles, and processes into new configurations) and "analogy" (inventors see analogies between different processes and devices). Benefiting from his or her openness to something new, an open person can easily accumulate a reservoir of different artifacts, materials, concepts, and processes. Then with the flexibility and imaginativeness in mind, they will be more capable of seeing analogies among things and combining them in an original way. In addition, one distinct characteristics of invention is that it is a *recursive* (Wolf & Mieg, 2008) process that involves massive "exhaustive research" (Lemelson-MIT Program, 2003) for new solutions. A well-known example of this strategy is that the Edison laboratory tested approximately a thousand different materials before finally going back to carbon filament for the electric light bulb. Such a recursive process causes considerable emotional and intellectual stress. Only those highly open people who possess distinct resilience, high tolerance of ambiguity, and extraordinary flexibility with unpredictable situations can survive the process and thrive within it.

In summary, the young patentees outscored the non-patentees in their stronger intrinsic motivation for invention and on the personality scale of Openness, both of which have been verified by psychologists as essential personality traits for creative behavior. These results can be applied for praxis related to inventiveness identification and intervention.

Higher level young inventors are from more supportive school environment

The patentee group reported significantly more encouragement and resources for invention from their schools than did the non-patentee group. Logistic regression analysis showed school encouragement was the only factor that made substantial contribution to the prediction of the membership of being patentee or non-patentee. In the current study, school encouragement was measured by the creative atmosphere at school and in the classroom, encouragement for being inventive, and encouragement for participation in inventive activities. School resources were measured with items describing whether there was an "inventing place" for the students and whether needed materials for making inventions were available at school.

Previous studies about the role of school in inhibiting or fostering inventiveness is contradictory. While some studies (e.g., Colangelo et al., 1993) did not recognize a supportive role that school plays, other studies (e.g., Colangelo et al., 2003; Henderson, 2004b) found the opposite. The discrepant results might be due to the fact that the first study was conducted with a group who attended schools in 1930s and 1940s, when the Open Education (Bader & Blackmon, 1978) campaign had not yet been introduced to schools in the USA. Results of the two recent studies about young and adult inventors indicate that the school environments have been changed and the efforts that schools have been made to foster creativity/inventiveness among students have been recognized by the inventive individuals. With a large Chinese sample, the current study highlights the importance of a supportive school environment for the development of students' inventive talent.

Social psychological theories state that people's behavior does not occur in a vacuum. Rather, it is the result of the interaction of the person and the environment. Therefore, the results are more appropriately interpreted by relating the non-cognitive factors to the environmental conditions. In the current study, the higher level inventive students showed significantly higher intrinsic motivation for making inventions and demonstrated a more open personality profile. Meanwhile, they reported more encouragement and resources from their schools for their inventive endeavor. The results imply that there is a *positive reciprocal* between the stimulating environment and the creative personality of the students. A school which has a strong inventive atmosphere, recognizes and encourages inventiveness and provides resources for inventive endeavor is more likely to see students that are highly motivated to invent and are open to different experience and vice versa. Theories of positive psychology can lend a good explanation to these findings. Seligman, the father of the modern positive psychology movement, pointed out that there had been a preoccupation with addressing weaknesses in the field of psychology since the World War II and urged psychologists to shift their focus to also building people's strengths (Seligman & Csikszentmihalyi, 2000). A major implication of this shift is "the assumption that environments can be promoted to foster individual strengths such as resiliency, competence, and optimism through attention to prevention and the development of positive institutions" (Clonan, Chafouleas, McDougal, & Riley-Tillman, 2004). Creativity is often seen as an important personal strength (Peterson & Seligman, 2004). There is evidence that the development of personal strengths, particularly those promote positive emotions, is associated with creativity (Isen, Daubman, & Nowicki, 1987).

Putting research to use

The comparison between the higher- and lower-level young inventors highlights the importance of non-cognitive personality traits and a supportive environment in helping students transforming their inventive potential into inventive products. This major finding has many implications for teachers and parents on how to foster inventiveness among children and adolescents.

There has been evidence that while IQ is fairly stable after the first ten years of life, non-cognitive factors such as motivation are more malleable at later ages (Lian, 2007). In their daily life and work, parents and teachers should be observant to their children's motivational reactions to things. Creatively gifted children often appear to be highly interested and persistent in the domain that has attracted their attention (Runco, 2005b). Once parents or teachers have observed high level of motivation in children, which is usually manifested as intense interest, high curiosity, and great passion, subsequent actions should be taken to maintain this intrinsic motivation. The awareness and appreciation of such intrinsic motivation is a good starting point for parents and teachers to foster inventiveness among children and adolescents. Awareness comes from parents' and teachers' close attention to their kids. Researchers have shown a close teacher-student relation (Cole, Sugioka, & Yamagata-Lynch, 1999) and an active parental involvements (Dacey, 1989) in children's education are conducive to the development of students' creativity. In reality, however, quite often parents are too busy with their work and social life that they spend only limited time with their children. Teachers, particularly those in normal public schools in China, are always overloaded with teaching work caused by a big group of students (usually 40-60 students per class) and do not have enough time to make person-to-person contact with each individual child. Not being discovered in time, the fragile interest of some of the children in making inventions might die out after several trial and errors without concrete progress.

Appreciation has roots in respect, trust, and impartiality. Unfortunately, adults seem to have biased views of the creativity of children. In their eyes, creativity has immediate and almost exclusive association with art and they are more ready to appreciate and foster the artistic creativity of the children. In a recent study about teachers' conceptions of creativity and creative students, researchers asked about the teachers' implicit understanding of creativity, 35.3% of the teachers related creativity to "art products" and only 8.8% also thought of inventiveness. This study is among a bunch of previous studies where the similar "Art Bias" (Runco, 2007, p. 384) view about creativity are shared by teachers from USA (Runco, Johnson, & Bear, 1993), Germany (Busse, Dahme, Wagner, & Wieczerkowski, 1986), and Singapore (Tan, 2000b). This limited view about creativity will prevent teachers from appreciating the inventive talent of their students, let alone fostering it. Another common bias about creativity is what Beghetto (2007) called "major breakthrough pitfall" in that teachers tend to think that only the highest level of creativity (Big-Cs) are real creativity and the "little-c" of children are something they needn't take seriously. He warned too great a focus on the highest forms of creativity may reinforce misconceptions about creativity among students and may not leave so much room for recognizing the creative potential and production of young students. So the first thing we should do is to reflect on our own perceptions about inventiveness and get rid of misconceptions about the inventiveness among children and adolescents. As argued earlier, our daily life is full of more small inventions than the great ones. Though their limited knowledge and experiences in a domain might prevent children and adolescents to make "earth-shaking" inventions, a supportive school environment that recognizes the inventive potential of the youngsters and provides enough supports/resources to foster inventiveness is more likely to see the inventiveness of the students blossom and even bear fruits (getting patents). In other words, inventiveness should have place at schools and in classrooms. This awareness and acknowledgement of the possibility of fostering inventiveness among children and adolescents is the premise of meaningful exploration of further educational implications of the results of the study.

With the ample evidence about the effectiveness of creativity and inventiveness training (refer to Chapter I for a review), school administrative and teachers should have confidence to believe that every child has the potential to be creative/inventive and such traits and skills can be nurtured through well-designed curricula and activities. As a famous Chinese educator Tao, Xingzhi said, "Education itself might not be able to create very concrete products, but it can inspire creativity among children, thus motivate them to undertake creative works." There are many ways that teachers and parents can do to inspire and motivate their students/kids to invent.

(1) *Arousing and maintaining curiosity/interest.* Students' curiosity and interest are the main sources of potential creativity (Csikszentmihalyi, 1996). So teachers and parents should get to know the special interests and inclinations of the children and provide opportunities for children to explore their own interests. Sternberg (2007) emphasized the importance of helping children find what they love to do thus to unleash best creative performances in children. With his framework of intrinsic motivation, Malone (1981)

made suggestions to educators on how to make the learning environments more engaging by increasing challenge, fantasy, and curiosity.

(2) *Providing cognitive tools for making inventions.* Based on analyses of over 200 studies on motivation, Deci and Ryan (1985) formulated a theory of human motivation. They found that when children feel competent, it motivates them to exercise and elaborate their abilities. So besides providing opportunities for children to pursue their curiosity and explore their interests, teachers and parents should also provide some cognitive tools for their children to conduct inventive activities. Since 1980s, a number of training programs have been developed to foster inventiveness among children and adolescents in the USA. Evaluation studies about these programs have provided evidence for the effectiveness of such pedagogical intervention (e.g., Invention Workshops, Camp Invention – refer to 1.2.2 for more details). It would be recommendable to indigenizing these experiences to different cultures. Besides, the TRIZ (Altshuller, 1973, 1984)—the Russian acronym for Theory of Inventive Problem-solving — has won wide application in the field of invention. It would be worthwhile to tailor the 40 fundamental principles to the inventiveness training for children and adolescents.

(3) *Giving enough autonomy and self-determination.* Origin orientation is conceptualized as the degree to which children perceived their classroom environment as supportive of their self-determination (Ryan & Grolnick, 1986). Studies have shown that students with a high origin orientation were more intrinsically motivated and more creative than those with lower origin orientation (Picariello, 1991). Therefore, teachers and parents should give children enough autonomy and self-determination at home and school. In fostering inventiveness, for example, teachers and parents can encourage inventive thinking by having children and adolescents define/redefine their own problems and choose their own topics for invention projects.

(4) *Reinforcing intrinsic stimuli.* If students learn to enjoy the acquisition of knowledge for its own sake, they will be more likely to engage in extended exploration and experimentation (Amabile, 1983a). Teachers and parents should reinforce intrinsic stimuli during learning such as the acquisition of knowledge, self-improvement, mastery goal, and discovery orientation, etc. In fostering inventiveness, parents and teachers can make sense of the knowledge or heuristics by eliciting active involvement of their children in "hands-on" activities, such as "Children Reinvent the Invention" (confronting the youngsters with

a genuine problem faced by an early inventor and encourage the children to reinvent the invention with modern materials), "Children Reinvent the Inventor" (asking the youngsters investigate the inventors' appearance, personality, achievements and influences on society and then imitate them), and "Children as Inventors" (encouraging the youngsters to use readily available junk materials to create their own invention) (McCormack, 1981, 1984).

(5) *Inhibiting the controlling effect of extrinsic stimuli.* Studies have shown that salient, controlling extrinsic motivation such as surveillance (Lepper & Greene, 1975), time pressure (Amabile, DeJong, & Lepper, 1976), and expectations of evaluation (Amabile, 1979) undermine intrinsic motivation. Teachers and parents should critically review the incentive and feedback systems and try to eliminate the controlling factors by giving the students more autonomy, enough time to accomplish a task and providing informative rather than summative evaluation. A patent is an exclusive right granted for an inventor to protect his/her invention from being commercially made, used, distributed or sold without the patent owner's consent (WIPO, 2008). Teachers and parents should use "patent" carefully to motivate their children to make inventions. If they emphasize too much on gaining a patent to show one's superiority or to serve some instrumental purposes (e.g., young patent-holders have privilege to be accepted by prestigious universities in China), the controlling effect of "patent" becomes salient and the students' intrinsic motivation will decrease. Instead, parents and teachers should emphasize the social influence of good invention, inspire pride and passion among children to make inventions, and inform them of the possibility of gaining patents at the end as a possible reward of their perseverant efforts.

(6) *Role-modeling inventive cognition and personalities.* Creativity researchers have argued that the best way to promote student creativity is for teachers to encourage and model the creative attitudes, creative thinking and creative behaviors in the classroom (Davis, 2003; Sternberg & Grigorenko, 2004). To teach students to invent, teachers should know enough about the history of invention, biographical profiles of well-known inventors, basic rules and principles of a certain field, methods/heuristics of invention, and major items of patent law, etc. Above and beyond role-modeling the cognitive antecedents of inventiveness, teachers should also stress the non-cognitive personality traits of inventive individuals. In their teaching praxis, they should constantly examine and re-examine their own thinking and behavior to make sure that they set good examples for their students in

term of enjoying the pleasure of inventing, delaying of gratification, being tolerant of ambiguity, being perseverant, and taking failure as learning opportunity, etc.

(7) *Executing constructive creativity in education.* In order to help teachers better engage in creativity education, Tan and Wong (2007) have developed a framework of constructive creativity in education. This framework draws on important results of creativity studies from the fields of social psychology, cognitive psychology, and general psychology and proposed four constructive frameworks: (a) The goal of education is to develop a person fully. So teachers should promote their understanding of creativity within the ecological, philosophical, cultural, political, and historical contexts; (b) Education is a process to become a person who self-cares and cares for others. Therefore, teachers should expose themselves to the scientific theories and findings of creativity, thus being able to develop their own indigenous understandings of creativity education; (c) Education is experiential, individualized, and social. Teachers should become and stay open to multiple perspectives and affirm the use of multiple methods integrated for a robust understanding of creativity education. (d) Education is about self-transformation. Teachers are encouraged to employ effective tools such as dialogue, intervention, and problem posing to better implement this process.

4.1.3 Gender differences

As hypothesized, not many gender differences were found in inventiveness and inventiveness-related cognitive or non-cognitive factors. Gender differences were not prominent if examined within each age group. Taken as a whole group, significant gender differences were found in aesthetic appeal subscale of inventiveness and two personal dispositions, namely openness to experience and executive thinking style. Surprisingly, girls scored better on all these scales. In spite of this, girls reported less encouragement from their parents to develop their inventive potential.

Girls scored higher in aesthetic appeal than boys

While male and female participants of the current study made inventions of similar level of novelty and practical use, the inventions of girls were rated higher by experts in their aesthetic appeal. In the current study, aesthetic appeal was assessed by the "pure aesthetic" qualities of the invention – that is, how much the pleasingness and elegance of the invention were recognized by the raters. Some studies about gender differences in artistic creativity and personality traits can lend explanation to this result. Niu and Sternberg (2001) asked a group of American and Chinese undergraduate students to make a collage and draw an extraterrestrial alien. The artistic works of the participants were given to an independent group of judges that were composed of equal number of psychological graduate students from both cultures. It was found that the artworks of females were rated by the judges from both cultures as more creative and aesthetically more pleasing than those made by their male counterparts. The higher score in aesthetic appeal for girls can be also attributed to the personality traits of females. In a study about vocational interests in an adult sample, it was found that women scored higher in "aesthetic interests" and this type of vocational interest is positively related to openness to aesthetics (Costa, McCrae, & Holland, 1984). Females' special tendencies and openness to aesthetics was re-evidenced by a large-scale cross-cultural study with a sample of 23,031 participants (both adult and student samples) from 26 different countries (Costa, Terracciano, & McCrae, 2001). In this study, they were able to observe consistent results across cultures about women's higher score in openness to aesthetics, feelings, and actions. The personality traits of women in these aspects might make them more sensitive to and aware of the aesthetic appeal of their invention, thus stimulating them to make special efforts to make their creative products aesthetically more appealing.

Girls are more open than boys and scored lower on executive thinking

Stereotypically, boys are expected to be more aggressive and are allowed to participate in physical activities including some risky ones, whereas girls are more encouraged to have "pro-social" behaviors such as helping, cooperating, sharing, and being conformist (Vernon, 1989; Kerr, 1997). Particularly in a Confucian culture which is characterized by male-dominance, the development of leadership for men and the maintenance of obedience for women are emphasized (Chung, 1994). Under such a sex role expectation and cultural influence, it seems more likely that girls are less open and more executive in thinking style. However, the results of the current study obviously challenge the traditional biased views against the inventive creativity of girls in China. Compared to their male counterparts, girls in the current study reported higher appreciation for aesthetics, more sensitivity to moods and emotions, and more intellectual curiosity and behavioral flexibility, which amount for a significantly higher score on Openness to Experience than their male peers. Interestingly, this *girls-as-more-open* profile has also been found in some previous studies. McCrae and colleagues (2002) measured the personality (with the Revised NEO Personality Inventory) of 230 sixth-grade gifted students by using a longitudinal design with four years time interval. They found, at both points of measurement, girls scored higher in Openness than did boys. With the aim to investigate if the same result would be tenable for an average population, the researches recruited a large sample of 1,947 average high school students for a second study. Also in this normal sample, they found that girls scored significantly higher on Openness than boys. The same result was echoed by Misra's (2003) study about 156 Indian students, where higher ratings on Openness were given by females. In spite of this, it is worth noting that this gender difference appears not obvious in elder samples. In their study about 2,375 college students and non-management job applicants, Hakstian and Farrell (2001) found college male and female students were more or less the same open to experience. Harris (2004) compared both genders in a sample of 404 undergraduates and did not find any gender differences in Openness.

Taken together, the available evidence seems to suggest that girls, against the stereotyping views about their creative potential, actually demonstrate certain important creative personality such as Openness, and this superiority maintains at least until the end of the secondary education. This is an important information that worth serious attention of the creativity researchers and practitioners, given the fact that there are ample empirical evidence that openness to experience correlates strongly with creativity (e.g., Amabile, Philips, & Collins, 1993; Dollinger et al., 2004; Feist, 1999; Helson, 1999b; MacKinnon, 1992; McCarea, 1987). This finding has important implications for school teachers and counselors as well as for parents.

Besides the superiority in Openness, no evidence about girls' inferiority in thinking style was found in the current study. In contrast, on the scale of executive thinking style, our gifted females shake the conventional conceptions again. They scored significantly lower on this thinking style. Executive thinking style is conceptualized as a cognitive preference for fixed rules or regulations, tendency to doing tasks that have clear structures and inclination to fitting into existing structures rather than to create the structure themselves. It is a typical norm-favoring tendency that denotes lower levels of cognitive complexity (Zhang & Sternberg, 2005). And such a thinking style is negatively related to creativity (Sternberg & Lubart, 1991). The fact that girls scored relatively lower on executive thinking style might be due to the fact that nowadays more women than men are holding managerial positions at primary and secondary schools and there are more female than male student leaders in classrooms. This *female-dominance* in the school-setting might have strong influence on girls' thinking and behavior and makes them not so ready to take orders or make executions as they used to be. In contrast, under the influence of the female role-models around them and as a result of their functioning as a student leader, their inclination to adopt an executive thinking style is even lower than the boys. However, it would be plausible to infer that Chinese gifted boys are more likely to take orders and conduct well-structured routines (executive thinking style). As a matter of fact, in the current study, both boys and girls scored pretty high on the scale of executive thinking style with a mean score of 4.16 (SD=.98) for girls and 4.37 (SD=.92) for boys (note that the highest score is 7.00). Rather, it seems more reasonable to interpret this finding through the correlation of this construct with the construct of Openness on which girls scored significantly higher. In this study it was found that Openness was negatively correlated with executive thinking style ($r=-.11$, $p<.01$). Therefore, girls' lower scores on executive thinking style can be seen as an additional proof of their higher scores on Openness. The negative correlation between Openness and the executive thinking style has been verified in a systematic analysis of the relationship between the Thinking Styles Inventory (TSI; Sternberg & Wagner, 1992) and the NEO Five-Factor Inventory (NEO-FFI, Costa & McCrae, 1992), where they found a Pearson's r of -.25 between these two constructs (Zhang, 2002a).

Girls reported as having less encouragement from their parents for invention

In spite of their favorable personal traits for inventiveness (in terms of more open and lower executive thinking style), girls reported as getting less encouragement from their parents for engaging in inventive activities. To be more exact, the parental encouragements, as measured in terms of encouragement for being open, perseverant and inventive, were reported as not optimal for girls. Given the fact that these gifted girls are equals of their male counterparts in intrinsic motivation, technical construct ability and knowledge level about invention and they actually present higher aesthetic appeal in their invention, it is a pity that their inventive exploration are not encouraged enough at home.

The parents' conservative views about their daughters' inventive behavior can be easily understood if we take a social psychological perspective and revisit the topic of "gender-role" stereotype. Eagly (1987) explained that most gender differences result from the adoption of gender roles, which determine appropriate conduct for men and women. He defined gender roles as shared expectations of men's and women's attributes and social behavior, and such gender roles are internalized early in development. In her book about smart girls, Kerr (1997) described vividly how American parents enthusiastically shape their children's behavior toward gender roles of the masculine or the feminine. She described: sex-typed colors, clothes, toys, and nicknames are given to girls along with the adults' expectations for girls to be quiet, gentle, cared, and protected. The way how parents care for their male and female infants and toddlers are also different. It has been observed that parents generally respond to a newborn girl's cries more quickly than they do to a newborn boy's (Jacklin, 1989). When their children go to primary school and start to learn to write and do basic arithmetic, parents are more likely rush to help when their daughters have difficulties with a task while they will give their sons more time for exploration. In general, adults give boys more freedom for intellectual and physical explorations and are more tolerant if their boys take things apart or express their aggression by hitting, poking, or throwing things at each other. Though the Chinese parents will be more likely to react at equal speeds to the cries of the baby no matter if it is a girl or boy, as it is their only baby (due to the one child policy), they really seem more ready to help their frustrated girls out, as they have the deep-rooted perception that girls are too fragile to be hurt. Like American parents, Chinese parents are also less tolerant for their daughters' "misbehavior" such as taking toys apart or behaving aggressively. Whenever they see their daughters behave in this way, quite often the parents will frown and intervene by saying "Stop behaving like a naughty boy. Behave like a girl/lady!" Educating their daughters in a restricted way to build their "feminine modesty", parents are consciously or unconsciously depriving their daughters' opportunities to explore their inventive potential.

Take the above-mentioned two "misbehaviors" for example. Through interview with adult inventors, Colangelo and his colleagues (1993) found that all inventors reported making some gadgets or modifying tools or toys when they were young and several mentioned that as children they were more interested in taking toys apart than simply playing with them. Later on, when developing the Iowa Inventiveness Inventory (III) to measure attitudes and characteristics of inventors, the researchers even included two items describing this "mischief" of taking things apart. In a recent study about the relation between aggression and the creative behavior among children, researchers (Tacher & Readdick, 2006) found that children's, particularly boys', aggressive expression was positively related to their performances in the Torrance Tests of Creative Thinking. They explained this phenomenon as "children's experiences establishing dominance and self-protection in everyday situations perceived as difficult are parlayed into performance requiring verbal and figural creativity skills." (p.261). Of course, it is not my purpose to ask parents to encourage their daughters to destroy everything at home and to train them to be fierce shrews. Rather, the point that I would like to make is that the gender-role stereotype that we have inherited from our parents and grand-parents sets too many restrictions to the natural growth of girls and it is detrimental to the recognition and development of the creative/inventive potential of girls. Researches have found that parents who are open to non-traditional gender roles tend to have children who express greater creativity than those parents who have more rigidly set sex-typed views (Fielding, 1983). This finding is easily understood if we look at if from a humanistic point of view. As Maslow (1976) maintained, *freedom*, *boldness*, and *self-acceptance* lead people to realize their full potential. He also stressed that children can experience creativity only when they feel free to play in their thinking, experiments, exploration, and imagination.

Environmental inhibitors for females to become inventive

For creativity to happen, one needs "initial requirements" including notably intelligence, motivation, and suitable environment (Baer & Kaufman, 2005a/b; Kaufman & Baer, 2004, 2005). But for females, the initial requirement of a conducive environment seems to be difficult to satisfy, because compared to males, females are quite often confronted with more environmental inhibitors. One of the principal inhibitors for females is the *non-recognition* of creativity among girls/women. In the past, girls were not encouraged or allowed to engage in intellectual pursuits. They usually received less education than boys, and were often denied access to teachers and opportunities to develop their potential, including creative potential. From one generation to another, women have been taught that creativity is a rare, non-domestic, and, above all, a male characteristic. Schaefer (1980), in his study of 10 highly creative adolescent girls, suggested that their need for autonomy and achievement conflicted with their need for parental and peer group acceptance, which required being feminine and socially acceptable.

The second most common external barrier is the *devaluation* of female's creativity. In her research about women issues, Reis (1987, 1995, 1998) observed that some women's talents are diversified across multiple areas in their lives, including relationships, work related to family at home, personal interests, aesthetic sensitivities, and appearances. Instead of displaying *single-minded* devotion to a certain domain, these women choose to diversify their creative efforts into different things at the same time (Reis, 2005). However, *single-mindedness* has been regarded as necessary for creative accomplishments that will be recognized by the traditional evaluation system (Piirto, 1991; Subotnik & Arnold, 1995a). Except for the creative accomplishments that women have made at workplace, other creative products that they have made for their households or creative solutions they have found in dealing with relationships are regarded as minor, and therefore not valued or devalued by society.

The third external barrier is actually the result of the first two barriers – the price that a woman must pay to reject her stereotype and compete against men in a male-dominant society. For biological reasons, including pregnancy, childbirth, and lactation, females are bestowed the role of breeding and nurturing new generations. Therefore, most of the men and women are ready to accept that a woman's own "real" achievement is defined in terms of motherhood and nurturance. Once a woman has decided to challenge this traditional role-stereotype and aim to achieve high-level scientific or entrepreneur careers, very often they may encounter considerable stress related to role conflict and overload (Ochse, 1991; Piirto, 1991, Reis, 1987, 1998). Furthermore, in a society where men dominate most fields, most of the evaluation criteria are set based on men's perceptions and preferences, which makes it even more difficult for a woman to compete against men and have their creativity recognized.

Putting research to use

Recognizing that girls might be confronted with special environmental barriers to translate their creative/inventive potentials into achievement, parents should try ways to remove these barriers and create a creativity-stimulating family setting for their girls.

(1) Parents should know traditional sex-role stereotype can lead to misconceptions about creativity, which are detrimental to the development of creativity in children, particularly in girls. Maccoby and Jacklin (1974) warned that many of the widely accepted beliefs about abilities and personalities of the genders are just traditional stereotypes that are not confirmed by controlled investigations. Regarding girls' creative potential or behavior, there is abundant empirical evidence for the actual lead of girls. For example, Baer and

Kaufman (2008) reviewed over 70 studies that have examined gender differences in creativity and found most of the studies issued mixed results for gender comparisons and therefore a consistent *lack* of gender differences both in creativity tests and in the creative accomplishments of boys and girls did immerge. Meanwhile, they also noticed that studies in which girls and women score higher are actually more numerous, so it would be hard to make a case for an overall male advantage. Also in invention, which is commonly perceived as being even more masculine, it might be astonishing to see that girls achieve actually the same or even better than boys in various inventiveness tests. In their study about technical creativity among primary students, a group of Australian science and technology educators (Webster et al., 2006) asked the students to design a recycling device for garden and household use. Surprisingly, they found that the young kids had developed several quite complex paper recycling devices, among which most of the complex "inventions" were made by girls. In their study about young inventors in the USA, Colangelo and colleagues (2003) compared the female and male young inventors regarding their perceptions about inventiveness process, attitudes towards school and students as well as their inventions. Results challenged the stereotyped view of *invention-as-masculine* from each perspective. Firstly, inventive girls are similar to inventive boys, and in some way, similar to adult inventors, in terms of their perceptions about the inventiveness process. Secondly, inventive girls are similar to inventive boys in their attitudes toward school and students. When ranking the sort of "cool" student in their hearts, girls ranked "inventors" higher than did boys, indicating that girls value inventiveness even more than boys. Thirdly, in terms of the productivity of inventions, girls show comparable inventiveness to boys in terms of the quality and quantity of the inventions that they have made.

(2) Parents should remove misconceptions of invention and inventiveness. Among others, four major misconceptions about inventors/invention are pervasive: *invention must be BIG*, *inventing is IMPOSSIBLE for normal people*, *invention is a MALE thing,* and *invention is an ADULT thing.*

Misconception 1: Invention must be BIG. As already discussed in the Introduction part, our life is pervaded with inventions, most of which are actually small inventions such as stamps, paperclips, post-it, kitchen vessels, etc. So inventions must NOT necessarily be earth-shaking. Inventions can also be small. Inventive inspiration favors those who can break the "BIG" myth and concentrate on their own inventive endeavor, bringing changes bit by bit step by step. To help kids break this myth is particularly important, as it will awaken their awareness of inventing and will urge them to become observant and pro-active participants of life instead of passive receivers of existing living conditions. To tell kids that inventions are everywhere and can be small is a good invitation for them to "step into" the field of invention and do their bit. Numerous evaluation studies of inventiveness training programs have found that the awareness of inventing once awoken among children and adolescents has very positive influence on their intellectual and motivational development, including more involvement in active learning and exploration (Saxon et al., 2003), greater improvement in flexibility and originality in creative thinking, increased confidence about their problem-solving abilities and more interest in science and technology (McCormack, 1984), higher motivation for invention (McCormack, 1984; Shlesinger, 1982), improved knowledge about inventing process, and increased collaborative skills (Plucker & Gorman, 1999).

Misconception 2: Inventing is IMPOSSIBLE for normal people. This view holds that that inventing is a complex and mysterious process which can be done only by very small number of extremely intelligent people. Inventing is, therefore, IMPOSSIBLE for normal people. This is the typical "genius" view (Weisberg, 1986) about creativity/inventiveness. As early as in 1980s, a group of cognitive psychologies started to challenge the "genius" view of creativity and gradually formed the "nothing-special view" of creativity (Langley & Jones, 1988; Perkins, 1981, 1988; Weisberg, 1986). This approach proposes that insightful and creative problem solving is basically the same as routine problem solving, in which we use what already know to generate the new. With his treatise about the possibility of invention, Perkins (1988) maintained that invention is better seen as an act of combination rather than an act of *ex nihilo* (Latin expression for "out of nothing; from nothing") creation. He argued invention is actual and is therefore possible and "Given certain prevailing conditions, invention becomes not only possible but also more or less inevitable…" (p. 381). Nowadays, books about how to make inventions (e.g., Altshuller, 1973, 1984; Luo, 2003) are on sale in the bookstore. Websites (e.g., http://inventors.about.com/) introducing the history of invention and providing updates of latest inventions and invention events are open to everybody and inventiveness training programs (e.g., InventTeams, Camp

Invention, Invent Iowa, Easy Inventing, etc.) are accessible to interested parents and kids. Good use of these resources has proved and will continue to prove that it is POSSIBLE for children and adolescents to make inventions.

Misconception 3: Invention is a MALE thing. Most of us believe that invention is a MALE thing and it is nothing for women. No doubt, throughout history and across countries, the field of invention is over-occupied by male inventors. However, this phenomenon is more a reflection of the strong impact of the traditional stereotypes about boys and girls than a reflection of the differences between the two genders regarding their inventive potential or ability. As stated in the About.com:Inventors (2009) website, in the old days women were not allowed equal rights of property ownership. Since patents are a form of intellectual property, the female inventors had to patent their inventions under their husband's or father's names. Because of the hostile atmosphere against women's involvement in invention, women had to choose fields outside of invention, leaving their inventive potential strangled or not fully unfolded. Even today, it is difficult for us to know all the women who deserve credit for their creative labor, as most of the Patent and Trademark Offices all over the world do not require gender, age, racial, or ethnic identification in patent or trademark applications, including the Patent and Trademark Office in mainland China. The following are some highlights of recent statistical analysis that were provided by About.com:Inventors (2009) which might be helpful for us to get rid of our misconception about the MALE image of an inventor and give reasons to encourage girls and women to pursue science-, math-, and technology-based courses and careers:

> - The women inventor patent share of annually granted U.S. origin patents rose from 2.6 percent in 1977 to 10.3 percent in 1998.
> - The majority of the U.S. origin woman-inventor patents are in the chemical technologies.
> - In 1996, 11.2 percent of the U.S. origin patent grants which were owned by the Federal Government at the time of grant included a woman inventor.
> - In the past 20 years, about 83 percent of the U.S. origin patent grants to women were for utility patents, 16.5 percent for design patents, and 0.5 for plant patents.

> Today, hundreds of thousands of women apply for and receive a patent every year. So the real answer to the question "how many women inventors are there?" is more than you can count and growing. About 20% of all inventors are currently female and that number should quickly rise to 50% over the next generation. ("How many women inventors", n.d.)

Misconception 4: Invention is an ADULT thing. Most of us are inclined to believe that children and adolescents are too young to make inventions, because invention is an ADULT thing. People who hold such a view ignore the fact that most prominent inventors started their inventing endeavor when they were very young. Examples of young inventors and their inventions have already been introduced in the Introduction part and will not be repeated here. The point I would like to make here is that no matter how biased most of us are about the inventiveness of children and adolescents, there is so far no evidence either from the history of invention or from the research of cognitive psychologists to suggest that children older than 10 cannot create original and useful things. Parents should, therefore communicate the unbiased views about inventors and inventions to their children, encourage inventiveness among them, and encourage it for boys and girls impartially.

(3) Through her survey among 247 corporate inventors, Henderson (2004b) postulated a conceptual map which contains the major features of a conducive environment for fostering inventiveness. Parents can compare their behavior with this conceptual map and try ways to nurture children's innate desire to explore. The ideas suggested by Henderson include: (1) support interest; (2) focus on intrinsic goals; (3) de-emphasize passive stimulus/response, extrinsic reward and competition; (4) challenge inventive spirit; (5) create joy and fun; (6) allow freedom and autonomy; (7) inspire children by involvement and role modeling; (8) recognize process-based accomplishment; (9) embrace diversity in people and in approach; (10) provide materials and resources as well as "fix it services"/ "how things work" fairs; (11) encourage trial-error and failure as opportunity.

To summarize, recent studies on the gender-specific development of the highly gifted tend to reveal a trend of girls' superiority in achievement than boys up to the end of secondary education (Heller, 2007; Kerr, 1997). In the current sample, girls scored higher in aesthetic sub-scale of inventiveness, were more open and scored lower in executive thinking style. Despite these cognitive and dispositional advantages, however, the current study revealed that girls get less encouragement from their parents to become inventive. Possible reasons were explored for this "bias" and suggestions were made for parents to better foster the development of their daughters' inventive potential.

4.1.4 Age-related differences

Uneven development from lower to higher grades in inventiveness and the relevant domains

The result of the current study did not provide support to a hypothesized growth among the students from the lower to the higher grades in inventiveness, particularly in originality and aesthetic appeal. The developmental hypotheses in both motivational and cognitive domains were only partially supported with a discontinuity of development in some non-cognitive personality traits from the junior high to the senior high level. All this depicts an *uneven* development of inventiveness among Chinese children and adolescents.

In his review about age dependence in exceptional achievements within science and technology, Heller (2007) observed an "age-correlated losses in creativity" among adult creative individuals and noted several internal and external causes for this decline. The drop of inventiveness (in terms of originality and aesthetic appeal), however, was already observed among the young inventive students when they move from primary to secondary schools. This discontinuity of development is alerting given the fact that from primary to junior high the inventive pupils' personality traits actually are developing toward a direction that is conducive to inventiveness and their knowledge about invention is increasing. Most surprising is a slump in knowledge about invention and patent law from the junior high to the senior high level. Normally, increasing knowledge is one of the most importanct factors in cognitive development and older children typically have more knowledge than do younger ones (Bjorklund, 2005). The overall developmental trend seems complex and inexplicable, as it is inconsistent with the findings that are mostly found in a Western culture. However, as Raina (1996) warned, "Creativity is an infinitely endlessly diverse phenomenon" and that different patterns of creativity development are "culturally rather than biologically related" (cited by Torrance, 2003, p. 279). Raina's conclusion is made by synthesizing the Torrance's major cross-sectional and longitudinal studies about creativity. Torranc's interest in the developmental question of creativity originated from his attempt to understand the "four-grade slump" in creative thinking (Torrance, 2003). As early as in 1960s, Torrance led a study involving about 1000 subjects in Grades 1 through 6 in different cultures, including India, Norway, Germany, Western Samoa, Australia, mainstream U.S. culture, and the segregated Black U. S. culture. Later in 1970s, he extended the study to more cultures including France, Greece, Mexico, and the

Chinese, British, Malay, and Tamil cultures in Singapore. Through these large-scale cross-cultural studies, Torrance found that almost all of the children in the cultures under investigation did experience a slump in creative thinking ability but at different times. While in some cultures this slump happened earlier, in other cultures it happened a bit late. Even some within-culture differences were observed where students from the same culture showed different developmental patterns in different types of schools. In general, there are two important implications of these cross-sectional studies about the development of creativity. Firstly, the developmental pattern of creativity is a diverse phenomenon whose characters differ from culture to culture. In seeking a culture-free generalization of developmental trend, one should be very cautious. Secondly, particularly for children, the discontinuity in the creativity development in certain period should be attributed more to the cultural than to the biological reasons.

It is worth noting that Torrance's view about the discontinuity of creativity development has some resemblance with Fischer's Skill Theory (Fischer, 1980; Fischer & Bidell, 1991, 1998), which is developed to account for the *unevenness* of cognitive function within a stage-like framework. Like Torrance, Fischer attaches great importance to the importance of environment in influencing children's development. His theory proposes that development is the result of a *dynamic interaction* between a child and the environment. Thus, only skills that are exercised in the most supportive environments will be developed to their highest level. Very importantly, Fischer (1980) pointed it out that it is inappropriate to think that the level of a certain skill that a child possess is fixed. Rather, "one's dynamic skills are always changing as a people adjust and reorganize their skills in response to situations in the environment" (cited by Bjorklund, 2005, p. 107).

Applying Torrance and Fischer's theories to the current study, I find that the crux of the problem of developmental discontinuity/unevenness might lie in the environments that students of different age groups are confronted with. The following part will go deep into the possible social-cultural factors that might account for the uneven development of students' inventiveness in China. Due to the diversity of cultures and sub-cultures, it is cautioned that generalization of these results to other situations and cultures should be carefully addressed.

Possible reasons for the discontinuity of development

Torrance (1975) noted that the discontinuities within the overall development of creativity occur within a culture whenever children in that culture are confronted with new stresses and demands. The educational environment in China is notoriously competitive. There are several reasons for this competitiveness. On the one hand, China has a Confucian tradition which attaches great importance to education. There is high motivation among the Chinese towards an excellent education, including the strong desire to obtain higher degrees and diplomas (Martinsons & Martinsons, 1996; Sorensen, 1994). On the other hand, there is a large population but only limited high-quality educational resources in China. The competition for a student to gain access to a prestigious university is extremely fierce in China. In addition, though *multi-dimensional* view of intelligence and talents have been introduced to China, a compatible more inclusive assessment system has not yet been established in China's educational system. The examination system for higher education selection still relies heavily on verbal aptitude, convergent thinking, analytical and synthetic abilities, but not on creative abilities such as divergent thinking and spatial reasoning. Therefore, most parents force their kids into a formal educational structure at very young age, leaving very little time for playing. There is evidence that play can ultimately lead a child to creative expression and insights (Richards, 1996) and that mother's restrictive attitude toward play has a negative impact on children's creativity (Bishop & Chace, 1971). Play facilitates creativity because play gives children the opportunity to discover new properties of objects, and because play stimulates fantasy (Hennessey & Amabile, 1987).

The educational environment becomes harsher, after the children enter the junior high school (starts at 7^{th}-grade), because since 7^{th}-grade, parents and teachers start to prepare the kids for a variety of examinations till the most competitive Gao Kao[5] (the National Higher Education Entrance Examination) which will be taken on the 12^{th} grade. An exclusive reliance on standardized testing for educational assessment forces parents and teachers to emphasize rote learning and memorizing, which ultimately limit creativity (see Kim, 2007). Between the 9^{th} and the 10^{th} grades, there is a Zhong Kao, which is also called "Small Gao Kao" or "Pre-Gao-Kao". This is a selection exam that determines what kind of senior high school the students can go. As the levels of the senior high schools vary

[5] Gao Kao is similar to SAT in the USA and Abitur in Germany. It is a prerequisite for entrance into almost all higher education institutions at the undergraduate level in mainland China.

dramatically in China, the access to a good senior high school implies a better chance to gain access to a good university. So the competition for this exam is also very intense.

After being accepted to a senior high school, however, the "examination life" of the students just begins. There are endless weekly, monthly, and quarterly exams. School administrators compare how many of their students have been successfully sent to what level universities and push the teachers to *cultivate* excellent Gao Kao exam-takers. Teachers get bonus and promotion as a reward to the good performance of their students in Gao Kao and get reduced payment or will even risk their career if they lack the ability to make their students excel in this competition. Parents invest enormous money buying books, learning software and paying for private tutors, with the hope that their children can get best prepared for the exam. Once the Gao Kao is over and the results have come out, successful exam-takers become the heroes of their peers. Schools print their photos out, stick them on the wall and ask the younger students to learn from these "role-models". Media interviews the students who have been accepted to prestigious universities, shows the interviews on TV or radio, or reports it in newspapers, making them "model students" for all children. With such strong social influence, there is almost no space for the senior high school students to pursue their own interests and explore their creative potentials. No wonder they were not doing better in the cognitive ability and inventiveness tests than their younger peers.

The interaction between the cultural influence and the creative behavior of children and adolescents can be better understood by applying Shi's (2004) "Intelligence Current" theory about creativity. This theory is based on a "System Model of Creativity" (Shi, 1995) which has been discussed in the preceding chapter. Active intelligence (also called "intelligence current") refers to that part of one's intelligence that is involved in or directed towards creative activities. According to him, it is attitude that determines if the "intelligence current" will be connected to the target activity. Four factors are involved in this process, including intelligence level which serves as a pre-requisite or "power supplier" for creative behavior; one's attitude toward creative action which is subject to the influence of many internal and external factors; the task that may be positively evaluated by oneself or society; the task that may never be positively evaluated. The role of attitude is crucial as it functions as a "power switch" that connects the intelligence to the tasks that are valued and disconnects the intelligence current to the tasks which are regarded not worthwhile. Shi also noted that both *intra-individual* factors such as interest, curiosity, persistence, motivation and *inter-individual* factors such as expectations/demands of parents and feedback evaluation from society have strong influence on an individual's attitude. Applying this model to the current study, the drop of inventiveness in higher grades can be explained as limited "intelligence current" that has been put to the inventive activities. Because of the dominant role of Gao Kao in the whole secondary education, particularly in the senior high level, most of the students' active intelligence has been invested to preparing for examinations but not to get acquaintant with the patent law, read anecdotes about inventors, learn invention methods or to do some hands-on inventing activities. As a result, the invention-related knowledge level and technical construct ability of the oldest group are the lowest among the three groups and their inventive level is also significantly lower than the youngest group.

This model, however, cannot completely explain why from primary to junior high, the students' creative personality traits develop while their inventive level drops. High level Openness and risk-taking and low level executive thinking style are all conducive to creativity. In large part, there are manifestations of a positive attitude. But why this dispositional improvement does not lead to an increase in inventiveness in this young adolescents group? It seems that the attitudinal "power switch" alone is not enough to resist the stronger social influence that the young adolescents are confronted with. Beside this pure *subjective* construct, there is another *objective* mechanism functioning, which determines if the attitude or determination of the person is strong enough to fight against an intangible but very powerful external influence and switch the current on. This objective intangible but powerful external influence is something can be called *mainstream mentality*, which is represented by a coherent value and evaluation system in a sub-cultural. An upgraded version of "mainstream mentality" would be Zeitgeist, which is defined by the Marriam-Webster's Online Dictionary as "the general intellectual, moral, and cultural climate of an era" (Zeitgeist, 2009). Such a common climate has, in most cases, stronger influence on an individual and determines, in large part, the behavior of an individual. I guess Simon will be happy with my explanation. But he will be even happier to hear that though the mainstream mentality in some sub-cultures of China is still creativity-unfriendly, creativity and innovation has become the Zeitgeist in China since the new millennium. At the end of 2005, the Chinese Government has even made it an important guiding policy of the county to "construct China into an innovative country". With such a

Zeitgeist, we are expecting to see more creativity/inventiveness being identified and fostered instead of being buried and stifled.

In conclusion, though the current study does not provide statistical support for a smooth developmental pattern in inventiveness, these results can be better understood if we have a close examination of the corresponding socio-cultural environments. The fact that the elder group scored lower in some components of inventiveness does not necessarily mean that their inventive level is significantly lower than the younger group. Rather, as both the Skill Theory (Fischer, 1980; Fischer & Bidell, 1991, 1998) and the Active Intelligence Theory (Shi, 2004) suggest, this result might be a reflection of children's adaptation and adjustment to the demands of the environment which attaches excessive importance to other intellectual activities (e.g., analytical and convergent thinking). With only limited amount of active intelligence invested to inventive activities, we can not expect too much from the elder group in their inventive achievement.

Putting research to use

A pro-creativity environment is conducive to the development of creativity, including inventive creativity. But changes will not happen over-night. In mainland China, there is still a long to-do list for parents and teachers. The following are some of the most urgent tasks that should be accomplished if we want to better foster inventiveness among children and adolescents in China:

(1) *Making education individualized by applying multi-dimensional view of intelligence.* The educational system in China still has a dominant emphasis on analytical ability of the students. A multi-dimensional view of intelligence should be embedded to the educational system. Viewing intelligence as "mental activity directed toward purposive adaptation to, and selection and shaping of, real-world environments relevant to one's life" (Sternberg, 1985a, p. 45), Sternberg differentiates three sub-theories of intelligence, including componential (analytical), experiential (creative), and contextual (practical). According to Sternberg (2005), creative work requires applying and balancing these three intellectual abilities. While creative ability is used to generate different ideas, analytical ability helps an individual to interpret the meanings of each creative idea and to test it. Practical ability enters a bit late to help a creative individual to "sell" the creative idea to other people. With his theory of multiple intelligences, Gardner (1983, 1993) challenges the traditional

view of intelligence, which is more IQ-biased. The original seven core multiple intelligences of his theory are *linguistic, logical-mathematical, spatial, bodily-kinesthetic, musical, interpersonal,* and *intrapersonal.* Through his case study of seven eminent creators, one for each type of intelligence, Gardner (1993) observed that each of them had their own intellectual strengths and weaknesses and none of them were excellent in every intellectual domain. This result implies, ideally, there should be equal chance for person to develop different types of intelligences. In reality, however, Gardner (1999) observed that while linguistic and logical-mathematical intelligences have been typically valued and fostered in traditional schools, the spatial intelligence which has special association with arts and the "personal intelligences" of inter- and intra-personal intelligences are not sufficiently developed at school. A multi-dimensional view of intelligence implies that in reality there is co-existence of different "creativities" but not only one "creativity". And for any type of creativity to occur, an application of a synthesis of different intellectual abilities is necessary. So parents and teachers should be aware that a narrow and biased view of intelligence is detrimental to the development of different types of creativity. Each individual is unique and might follow a different development pattern, so education should be tailored to accommodate the needs of different individuals, thus helping them to be able to capitalize on their strengths and make up for the weaknesses – the idea of Sternberg's successful intelligence (Sternberg, 1996).

(2) Using authentic assessment. The application of the multiple intelligences theories to education calls for a move from the use of standardized measures of ability and achievement to more authentic assessment techniques. Authentic assessment, a concept promoted by Grant Wiggins (1989), refers to the effort to assess a person's learning or accomplishment in ways that is related meaningfully to the use/application of real-world problems or under conditions that approximate real situations. While standardized tests, such as multiple-choice tests, fill-in-the-blanks, and true-false, etc. examines whether the students can and how they recall the knowledge, authentic assessments often ask students to analyze, synthesize and apply what they have learned in a substantial manner. Through this active, self-directed and constructive learning process, quite often students will create new meanings and find novel solutions to problems. In his review of assessment and measurement in creativity and creative problem solving, Treffinger (2003) recognized authentic assessment as one of the most promising future directions for creativity measurement. Meanwhile, he also acknowledged the challenges of the implementation of

this highly demanding assessment and has made valuable recommendations for educational practitioners.

(3) *Change the educational system from examination-driven to personal-strength-driven*. The examination-driven system draws the attention of the teachers, parents, and students only to standardized tests. In such a system, education becomes only a journey to memorize key points for examinations, improve examination-taking skills, and get good scores from examinations. It is a great waste of the intelligence and creativity of teachers, parents and children. Positivist psychologists suggest that creativity is an important personal strength (Peterson & Seligman, 2004) and such personal strengths should be promoted at home and in school. Lian (2007) proposed a personal strengths framework which consists of two intra-personal balance strengths (emotional awareness and self-control), two inter-personal balance strengths (empathy and social competence), and two focus strengths (self-efficacy and problem-solving skills). All these strengths are closely related to mental health and creativity. Lian also made valuable suggestions on how to implement this model in schools. His framework is recommendable to change our educational system from examination-driven to personal-strength-driven.

(4) *Make learning enjoyable*. East Asian educational philosophy maintains that a strong work ethic and devotion to learning are ultimately more important to achievement than an inherently gifted mind (Kim, 2005). Learning therefore means hard work, effort, diligence, endurance, perseverance, etc. In whichever case, learning means taking pains and is not an enjoyable and appealing thing. Such a view about learning is very likely to cause negative emotion such as fear and stress in children. Though there is still controversy about the nature and form of affect-creativity relationship (see Amabile et al., 2005), the existing empirical literature is more consistent in its support for a positive rather than a negative link between affect and creativity. For example, in Isen's (1999a, 1999b) program of laboratory research, it has been consistently found that induced positive mood leads to higher levels of performance on dimensions relating to creativity. Other studies have shown that subjects in happy moods display greater fluency, generating more responses and more divergent responses than subjects in neutral or sad moods (Hirt, Melton, McDonald, & Harackiewicz, 1996). Hence, parents and teachers should try ways to make learning more enjoyable and inviting. Parents should give their children enough time to play and try ways to guide their kids to learn from playing. Teachers should make their

teaching more interesting by designing problem-based learning, discovery learning, and by applying new technology to facilitate teaching.

4.1.5 Who are the young inventors and what do they invent?

Stereotypically, invention has been associated more with males than with females (e.g., Burkhardt & Greif, 2001; Giuri et al., 2007; Henderson, 2004b; Whittington & Smith-Doerr, 2008). For example, in a recent summary of women's contribution to patents in Europe, it was found that in the 14 countries under investigation, only an average of 6.7% of the patent-holders are women (Frietsch et al., 2008). In her survey about entrepreneur inventors in the USA, Henderson (2004b) reached 81% male inventors and 19% female inventors. However, at least in this nation-wide event for young inventors in China, there was no proof for "male-dominance". As a matter of fact, boys and girls were almost equally represented in this event with a bit more girls (51.2%) than boys. Also, the male to female ratio in the patentee group is almost 1:1. This result is consistent with the finding of the previous study about the American young inventors (Colangelo et al., 2003). In there study, they also saw more girls, accounting for 56.9% of the participants, in their invention program. Participation in such a highly demanding event can be a reflection of the interests of the students. The results of the current study show that, at least up to 12th grade, the Chinese boys and girls are comparably interested in invention contests. The fact that there end up to be very few female inventors might be due to a variety of internal and external barriers, such as "Horner Effect", "Cinderella Complex", "Imposter Phenomenon" (Kerr, 1997; Kerr & Nicpon, 2003), dysfunctional attribution style of the gifted girls (Ziegler & Heller, 2000) and the tendency of underrating the creative works produced by women (Fausto-Sterling, 1981; McDaniel, Cummins & Beauchamp, 1988).

Over half of the young inventors were from the economically developed areas of China. This result implies that economic developmental level of a region might play a part in facilitating and fostering the development of inventive abilities of children and adolescents. Existing literature, though not much, has provided support for this result. Srivastava (1982) administered a creativity test to 80 students from urban and rural areas of India and found that urban and middle-SES (social economic status) students scored higher than their rural and low-SES counterparts. In her study about adolescents' creative thinking, Heinla (2006) found that the adolescents who scored higher in the creative thinking test were from the families that were situated in economically more developed capital cities. In China, Shi and Shen (2007) investigated the relationship of family SES, intelligence and scientific creativity among 415 8th and 11th grade students. It was found that the SES of family, which is a direct indicator of the SES of a region, predicted creativity even more remarkably than intelligence and intrinsic motivation. Economically more developed areas usually have more and better quality of educational resources (e.g., schools, universities, research institutions, libraries, museums, etc.). There is evidence that inventiveness can be effectively fostered among children and adolescents (McCormack, 1984; Plucker & Gorman, 1999; Saxon et al., 2003; Shlesinger, 1982). Easier access to better education opportunities which the children and adolescents of the economically more advanced areas have will give them advantages in having their inventive potential identified and fostered. People in economically more developed areas also have more contact with the outside world, whether through local collaboration with domestic sub-cultures or through international exchange/cooperation projects with foreign cultures. Such exposition to a variety of cultures and sub-cultures will help the people inside widen the field of their visions and keep open to different cultural customs, new science and technology, and modern arts. The positive relation between Openness and creativity has been discussed several times so far and needs not to be repeated again.

The relationship between the social-economic status of a region and the level of creativity of the region can also be looked at from another way: due to their higher economic status, the rich regions are not only able to cultivate but also attract and retain the creative genius more easily than the poorer regions. With a number of creative talents living and being active in these regions a creative atmosphere is more likely to be formed, which is subsequently conducive to creativity. Through his study about creative talents from seven different fields, Gardner (1993) noticed that most of the creative figures in his study were either from or had lived certain period of time in a city, where it was regarded as the center of their respective fields. Of course, the link between the SES status and the level of the development of creativity of the region also triggers the question of "educational equity". In order to optimally foster inventiveness among children and adolescents, equal attention should be given to the children and adolescents from economically less developed regions.

In terms of parents' education, the young patent-holders are from families where both fathers and mothers have relatively higher level of education. With 47% fathers and 37%

mothers having gained a college degree or above, these ratios are significantly higher than the ratio of the Chinese adults who have got higher education. According to the statistics issued by the National Bureau of Statistics in China (2006) based on 1% population sample survey in China, among the 1.3 billion Chinese populations, only about 67.64 million (accounting for 5.2%) have had an education up to the college level. This result is consistent with Rossman's (1964) study about adult inventors in the USA, where he found that the inventors were from families that belong to the "superior stock". In Estonia, Heinla (2006) found that the creative thinking of the 16-17 year-old adolescents is higher in the group where one or both parents have university education. In Poland, Mendecka (1995) also found that the fathers of the entrepreneur inventors had got better education than the fathers of a control group whose inventiveness failed to be displayed in their work. Studies from the fields of social sciences and medicine have consistently proved that a higher level of education is related to a healthier life (Wang, Berglund, & Kessler, 2000; Winkleby, Jatulis, Frank, & Fortmann, 1992). Most recent studies have found that education increases the sense of control for both males and females and a higher level of education is related to lower depression and more work creativity, particularly for women (e.g., Ross, 2006). The physical and mental well-being of their parents can function as a good role-model for the young inventive, and role-modeling has been recognized as one effective factor to foster creativity (Gardner, 1993; Runco, 2005b; Simonton, 1975, 1977, 1988; Sternberg, 2003). On the other hand, higher education is quite often associated with higher payment and better economic status, which makes it a relatively easier decision for parents to invest in their children's invention pursuit. After all, invention is not a cheap endeavor. In the whole process of and after invention, considerable money shall be spent to develop a mental conception, make a model, go through endless trials, make improvements, pay registration fee to enter the patent application process. Even after one has got the patent, the yearly patent maintenance fee is also not a light economic investment for a normal family.

In terms of the categories of the inventions, the current study found that tools are the most popular inventions made by this group of young inventors in China. In their study about young inventors in the USA, Colangelo and colleagues (2003) also found that tools were the most popular categories of inventions. The dominant portion that tools hold in this list of inventions reflects the importance of tools in the history of invention. For example, tools made of stones such as stone knives, choppers, and hammers are documented as the oldest inventions of human beings (Leakey, 1971). Since then, with the discovery or synthesis of new materials, tools are under constant improvement. Inventions, such as tools, have close and direct link to human being's needs to survive and to improve. As human being is constantly challenged by survival or developmental problems, tools – with their nature to help people perform tasks or solve problems – are ubiquitous in every sector of life since the beginning of human civilization. No wonder they are also the most popular inventions of the young inventors. In parallel to tools, the category of Amusement is also popular with the Chinese young inventors. In the previous study, however, inventions categorized as Kitchen and Bath ranked the second most popular while Amusement ranked the 7th most popular among the American young inventors (Colangelo et al., 2003). According to the definition given by the U.S. Patent and Trademark Office, Inventions categorized as Amusement include "sporting goods, toys, games, and devices or methods related to music" and those categorized as Kitchen and Bath include "devices or methods used in baths, closets, sinks, and spittoons, cutlery, refrigeration, food and beverage preparation, treating, preservation, and power-driven conveyors" (cited by Colangelo et al., 2003, p. 292). The zest of the Chinese young inventors to bring something new to their recreation instead of the household might be due to their less interest and chance in doing home chores. In China, because of the execution of the one-child policy, the only child of the family usually gets much care and ample attention from their parents. They are so used to having food cooked for them and clothes cleaned by others that they are normally not very enthusiastic about doing these things themselves. Studies in China found that the children who did not have siblings at home were less willing to undertake physical work at home and school (Chen, 1985) and "laziness" is one of the biggest weaknesses of the children who do not have siblings (Feng, 2000). A cross-cultural study also reported that mothers of 5th graders in Beijing estimated that their children spent 25 minutes per day on chores while the time for chores reported by the U. S. 5th graders were about 40 minutes (Stevenson & Stigler, 1992). As the Chinese youths in general need not to take care of house-chores, it is more likely that they have more time to entertain themselves. Therefore, the chance that they bring something new to the ways how they entertain is also bigger. Unfortunately, the previous study conducted with the American sample only presented the results but did not provide any interpretation, so the reason why the Kitchen/Bath inventions were the second popular inventions of the American young inventors remains unclear. However, the result found in the previous study seems to suggest that compared to the Chinese young inventors, the American young inventors have more interest in making domestic necessities.

In sum, the last research theme is an additional one to the other topics. Based on the biographical data of the young patentees and the descriptive data of their patented inventions, this part enriches our knowledge about this special inventive group through the findings with regard to specific issues related to gender, parents' educational level, SES of the region where they come from, as well as the inventions that they make. In order to deepen our understanding of the relevant aspects, further studies that employ not only descriptive analysis but also more complicated multivariate methods are invited.

4.2 Limitations

The present study is unique in two ways. Firstly, the focus of the study is a young inventive group that is usually neglected by the creativity researchers. Secondly, the current study adopts the systematic approach, which is highly recommended but rarely applied in empirical studies about creativity. Despite the advantages of examining a relevant but rarely investigated sample by means of a recommended but scarcely implemented approach, there are some limitations of the study that are worth mentioning:

(1) One obvious limitation, among others, was the adoption of an inventiveness test that has not yet been used in previous creativity studies. Though this instrument has been designed by professionals of the field under investigation and presented satisfactory internal consistency (Cronbach's α=.76) in this study, the unavailability of the validation process of the instrument triggers the issue of legitimacy. It can be argued that the limited correlations between the independent and dependent variables found in this study might be due to the low validity of the inventiveness instrument. However, without actual testing steps and statistic evidence, it would be premature to draw this conclusion, as limited correlations can also be due to the fact that different instruments are measuring different aspects of the same construct. In whichever case, it would be necessary for future studies to test the reliability and validity of this inventiveness instrument.

(2) Another limitation was the inclusion of limited number of measures in the inventiveness test limited our understanding of this construct. Inventive creativity (or inventiveness) as a topic of scientific study is still new. Due to scanty literature, much

still keeps unknown about the definition and major components of this construct. For example, is there any relationship between students' problem solving skills in physics/technology and inventiveness? What is the relationship between scientific creativity and inventive creativity? How is this special creativity related to and discriminant from the traditional creative thinking skills as assessed by TTCT (1966, 1974)? All this raises the issue of instrument development and validation. Csikszentmihalyi (1994) suggested, the domain of creativity is an *interdisciplinary* domain in which experts from different disciplines retain their own conceptual tools and approaches but find a way of integrating them to the study of creativity. Particularly for inventiveness, which is not yet well researched, such a cross-disciplinary collaboration is imperative for any instrument development efforts.

(3) In addition, the non-implementation of the Consensual Assessment Technique (CAT) undermines the value of the use of expert rating. Though it is usually more difficult and costly to execute CAT among expert raters, the advantage of adopting this technique with expert raters has been empirically proved. A recent study comparing expert and non-expert creativity ratings of poems revealed that expert ratings of creativity were significantly more consistent (showing higher interrater reliability) than non-expert ratings (Kaufman, Baer, Cole, & Sexton, 2008). In further studies, researchers should communicate the importance of CAT to the practitioners outside of psychology and make sure that this technique will be embedded into the evaluation process.

It is worth noting that the above-mentioned limitations are all concerned with the assessment and related concepts of creativity, which is a common controversy of the creativity field. Bearing these limitations in mind, it is cautioned that the results related to the first research question of the study should be generalized with caution, as these results were obtained from the data analysis related to the inventiveness test. Nevertheless, these limitations would not undermine other attempts of the study, which is based on a more objective measure of inventiveness – if the participants had a patent or not. Walberg and Paik (2005) call for objective measures of accomplishment in children such as winning a science fair. This proposition has been welcomed and highly recommended by Mayer (2005). According to Mayer, "The most useful measures of accomplishment focus on objective performance within a specific field…" (p. 444). Despite, some limitations about the comparative studies should also be mentioned:

(4) Due to the wide geographical scatter of the sample, a control group that was comparable to the patent sample in terms of biographical, cognitive, and non-cognitive features could not be obtained in the current study. As a result, only implications based on the *within-group* differences of a highly inventive group were addressed in this study. Future studies might consider including a more rigorous control group, for instance, by limiting the scale of the study. The inclusion of a more rigorous control group will allow the emergence of clearer discrimination between the inventive and non-inventive groups, thus enriching our knowledge about the distinct characteristics of the inventive individuals through *between-group* comparisons.

(5) An obvious limitation also rests with the cross-sectional design for approaching the developmental issues. Compared with cross-sectional design, a longitudinal design has many advantages in exploring the developmental change in giftedness and talent (Subotnik & Arnold, 1995b). In order to detect a variety of changes, many more studies actually adopted a combined design of cross-sectional and longitudinal studies (e.g., Hany, 1995; Heller & Perleth, 2004; Perleth & Heller, 1995). However, due to the restricted time-frame allowed for a PhD study, a longitudinal design was not feasible. In order to examine the development trend of inventiveness in more depth, a combination of cross-sectional and longitudinal design is recommended for future studies.

(6) Perhaps, one other limitation was the complete reliance on self-rating in personality assessment. Costa and McCrae (1992) warned that there are doubtless occasions when self-reported personality tests are not trust-worthy, given that the testees may be uncooperative or may have powerful incentives to distort self-presentation. In order to cope with this, they have developed and validated the observer rating form of the NEO-PI and strongly suggested using ratings from knowledgeable informants (such as parents) as an adjunct to or substitute for self-reports. Depending on the availability of the significant others of the sample, further studies should consider including other-ratings in personality assessment.

Lastly, though not necessarily a limitation, it is worth mentioning that one inherent dilemma of any systematic design is the trade-off between depth and breadth. While examining a broad variety of individual and environmental variables within one framework of study, the depth of each relevant perspective can be undermined. The current study is no exception to this methodological dilemma. However, as the depth and breadth issue is still a general methodological controversy of scientific studies, no better suggestions can be made than calling for more systematic studies about creativity, because only by doing so, can researchers provide experiential inputs to this issue.

CHAPTER 5 – CONCLUSION

Applying a systems approach, the current study attempts to explore the individual and environmental attributes of inventiveness among children and adolescents, a minority group in the field of creativity study whose existence is usually neglected. In order to present a holistic view of this special group, effects such as the inventive level, gender, and grade were addressed through multivariate analyses of the data. In addition, results of a descriptive analysis of the biographical data of the young patentees and their inventions were also presented with the aim to enrich our knowledge about this group. In concluding the research, I would like to summarize the major findings of the study and make research desiderata and recommendations for fostering inventiveness among children and adolescents.

5.1 Individual attributes of inventiveness among children and adolescents

Summary of results

Both *cognitive* and *non-cognitive* individual attributes of inventiveness have been investigated throughout the current study. Cognitive variables include technical construct ability and knowledge. Non-cognitive variables include motivation, personality, and thinking style. The comparison between the higher-level and lower-level young inventors did not reveal many individual differences. Higher-level young inventors neither surpassed their lower-level counterparts in cognitive ability nor in knowledge; nor did the two groups differ in thinking style, risk-taking, or tolerance of ambiguity. The only individual differences between these two groups were in motivation and Openness. Higher-level young inventors were more intrinsically motivated for inventive endeavours and were more open to new experiences. Likewise, individual differences between male and female young inventors were also not very pronounced. Again, no differences were found between boys and girls in cognitive ability or in knowledge. Both genders were similarly motivated to pursue their inventive endeavours. Surprisingly, the minimal significant gender differences found in the current study put girls in a more promising position. Girls scored higher in the aesthetic appeal measure of inventiveness and the scales of Openness. They were, moreover, less likely to adopt an executive style in comparison to their male counterparts. Results from the cross-sectional study of the different age groups have depicted an uneven developmental trend of the individual factors both in the cognitive and motivation domains. In the cognitive domain, the eldest group scored the lowest in both cognitive ability and knowledge tests; the youngest group scored the highest in originality and aesthetic appeal measures of inventiveness. In the motivational domain, growth of some creative personality traits (Openness and risk-taking) as well as in executive thinking style from primary to junior high schools did not continue beyond the students' entry to the senior level.

Implications for fostering inventiveness among children and adolescents

In gifted education, researchers, educational practitioners and policy-makers are always confronted with the challenge of how to identify creative talents and how to nurture their special talents in an optimal way. It has been emphasized that, before identifying and assessing the gifted and talented youth, parents and educators should have clear conceptions of the nature and manifestations of giftedness and talent (Feldhusen & Jarwan, 2002). In practice, however, creativity as a research construct is still fraught with definition ambiguity and assessment difficulty. Teachers have been found to lack understanding of the nature of creativity and the characteristics of creative students (Aljughaiman & Mowrer-Reynolds, 2005; Fleith, 2000; Reid & McGuire, 1995; Slabbert, 1994; Torrance & Safter, 1986) and, in general, teachers hold a negative attitude toward creative students (Bachtold, 1974; Dawson, 1997; Stone, 1980; Torrance, 1963). The findings of the current study shed light on the identification and assessment of inventiveness among children and adolescents by pinpointing two most salient characteristics of the successful young inventors: high intrinsic motivation and openness to experiences. As a result, information of the sub-scales of each construct can enrich the knowledge of the researchers and practitioners in their research or diagnosis of inventive creativity. To be more specific, intrinsic motivation as manifested with *self-determination*, *task involvement*, *curiosity*, *enjoyment, interest* and Openness as manifested with openness to *fantasy*, *aesthetics, feelings,* and *ideas* should be highlighted in the checklist, if any, of inventive talents.

As the only factor that accounts consistently for each criterion of inventiveness, the importance of knowledge becomes highlighted. Accumulation of knowledge and expertise is a long process. Psychologists of giftedness have observed that many creative achievements were made as a result of deliberate practice (Ericsson, 1996) in a domain. In particular, there is the "ten years rule" (Bloom, 1985; Gardner, 1993; Hayes, 1989; Simonton, 1994a) in the field of giftedness, whereby significant creative production or achievement seems to require at least 10 years (or 10,000 hours) of active work in a field. Invention is no exception to this rule. It is quite usual for an invention to take years, lifetimes or generations to be produced, tested, and constantly improved. During this lengthy process, the maintenance of high motivation and an open mind to new ideas and solutions are crucial. The accumulation of domain-specific knowledge and formation of expertise is one of the direct results of this commitment. Therefore, the "10 years' rule" and its relevant examples should be addressed in the teacher/parents training programs and need to be further communicated to children and adolescents in order to draw their attention to and thus raise their awareness of the motivational and personality prerequisites of inventiveness.

Mönks, Heller, and Passow (2002) warned that most of the focus of curriculum design for the gifted is on cognitive development and far less attention is given to the non-cognitive development of the gifted. Results of the current study suggest that insufficient attention to the non-cognitive development of the inventive talents might make such curriculum less effective. Instead, successful inventiveness programs, regardless of whichever form or in whichever country, have almost all taken non-cognitive components as an integral part of the training system. As the first implementation step of the "Invention Workshops" (McCormack, 1981, 1984), program organizers provide training for classroom teachers to remove their suspicion about children's inventive potential and teach them how to stimulate and encourage students to make inventions. Considerable verbal and non-verbal encouragement will be given to students to help them overcome the "I can't do it" syndrome. In his experience of teaching students how to invent, Westberg (1996) always starts by telling stories about the creation of inventions and presenting examples of students' inventions with the purpose of awakening an awareness of invention among the students. With empirical data, the author has proven that the conceptual and motivational intervention had very strong impact on the inventive performance of the participants. "Camp Invention" (Saxon et al., 2003) integrates "fun" as a major component of each of their training module. Their belief is: children learn better when they have fun. During the training, quite a few interactions take place between students and trainers and among students with the aim to stimulate inventive exploration and to maintain high involvement. Such an emphasis on the socio-emotional component is rewarding. This program has received positive comments from participants, parents, and the teaching staff.

Fanhua Luo, initiator of the "Easy Inventing" program and promoter of inventiveness education in primary and secondary schools in China, is very famous for his talent for motivating kids to invent. Like Westberg, he also starts his training course by telling stories about inventors and inventions (Luo, 2003). Then, after showing the students concrete examples of inventive products of children and adolescents, he brings inventions closer and closer to the conceptual and experiential milieu of the students. The cognitive input of different invention methods always comes only after the motivational and emotional "warming-up" phase. Luo's inventiveness program is successful. After over ten years' work in the applied field, he has encouraged millions of children and adolescents to make inventions, among whom over 1000 have got at least one patent from the Patent Office of China and five have won the tile of a "Young Scientist". Japan has a longer history of inventiveness fostering. As early as in 1960s, the Invention Association of Japan set up Youth Invention Club in different cities of the country. Since then, school teachers, entrepreneur engineers, and university academics have made joint efforts to train children and adolescents to make inventions. It was reported that one of the major components of this club is to provide "failure education" to the future inventors (Zhai, 2003). The rationale behind this is that invention is associated with trial and error, frustration and failure. Children and adolescents must be deliberately trained to be firm and perseverant throughout this "failure education". This hence thoroughly provides them with the motivational and dispositional preparation for their inventive journey. Indeed, as Heller (2007) stated, "It seems that the key to success in the nurturing of the highly gifted and talented youth in mathematics, the natural sciences and the technology lies primarily in the motivational and self-concept prerequisites" (p. 227).

The results of gender differences in the individual domain provide further support to the *discouragement* of a wide-shared belief of an overall male lead in creativity (Baer & Kaufman, 2008). At least two points are useful for teachers and educators: Firstly, there are not so many overall gender-related differences between boys and girls in their dispositional and cognitive attributes of inventiveness. Secondly, numerous studies actually show a trend of girls' superiority in academic and creative achievement in comparison to boys up to the end of secondary education (Baer & Kaufman, 2008; Heller, 2007; Kerr, 1997; Piirto, 1991). Traditionally, girls' creative engagement and achievement have been discouraged, disrespected and underestimated. In a new millennium when equality of education is accepted by most cultures and nations, teachers and educators should try to free themselves from the old, out-of-dated, and misleading prejudice against girls' potential and competence. Equal attention, stimulation, opportunities, materials and encouragement need to be given to girls and boys to help them unleash their creative potential and grow. Due to biological and social reasons, gifted girls are confronted with more affective, cognitive, and motivational challenges in their development. For example, studies have shown that girls are more vulnerable to the detrimental effect of external rewards, competitions or anticipated evaluations in their creative endeavours (Baer, 1997, 1998; Conti, Collins, & Picariello, 2001) and they attribute their success significantly more frequently to external factors (such as luck) and their failures to their lack of talent (Dweck & Repucci, 1973; Nicholls, 1975; Ryckman & Peckham, 1987). An international study on gifted students from the East and West showed that even among high-track students, girls use superficial cognitive strategies more often than boys in learning science (Tang & Neber, 2008). Therefore, despite their marginal lead in certain motivational and cognitive aspects related to inventiveness, girls still deserve special attention and support in their development of creative talents. The encouraging aspect is that some motivational training programs targeting reducing gender differences among the gifted population in science and technology education has gained significant results (e.g., Heller & Ziegler, 1996; Schober & Ziegler, 2002; Ziegler & Stöger, 2004). We should, therefore, be confident in the better development of girls' giftedness given the external social-cultural environment also provides sufficient recognition and opportunities for girls' further development in the creative/inventive field. Environmental inhibitors for females to become inventive have been discussed in detail in the previous part (pp. 161-162). Research desiderata and application recommendations of the environmental impact on the development of inventiveness among boys and girls will be the topic of the second part of this chapter.

From the developmental perspective, the current study has not provided evidence for a smooth developmental trend of inventiveness from younger to elder students. Rather, the developmental trend was uneven and discontinued. Following the suggestion of previous researchers (Raina, 1996; Torrance, 2003), I excavated social-cultural and educational environments that different age groups were in. In particular, I found the Skill Theory

(Fischer, 1980; Fischer & Bidell, 1991, 1998) and the Active Intelligence Theory (Shi, 2004) very helpful for us to understand this developmental trend. Both theories posit optimal development, such as creativity, as the result of a *dynamic interaction* between a child and the environment. Thus, only skills that are exercised with sufficient "intelligence current" in the most supportive environments will be developed to their highest level. The educational implication of these theories is self-explaining: teachers and parents should provide consistently supportive environments to foster the inventiveness of children and adolescents. If the environmental conditions are not sufficiently conducive to inventiveness, the development process of children and adolescents might stop or even regress. Environmental attributes of inventiveness and the interaction of individual and environmental attributes in fostering or hindering inventiveness among children and adolescents will be discussed in the following part.

5.2 Environmental attributes of inventiveness among children and adolescents

Summary of results

Regarding the environmental attributes of inventiveness, the current study concentrated on encouragement and resources, two important stimulating factors for creativity. These attributes were examined in both family and school settings. The comparison between the higher- and lower-level young inventors revealed that higher-level young inventors reported significantly more encouragement and resources for pursuing inventive activities from their schools. Among others (also the previously mentioned individual attributes), school encouragement was the factor that distinguished these two groups significantly. Environmental differences were also found between boys and girls. Albeit the more advantageous personal profile of girls in inventiveness, girls got less encouragement from their environment, particularly from their parents, to make inventions. Cross-sectional investigation of the environmental attributes has not shown any clear differences among these age groups regarding either their family background or school settings. This makes the relationship between the age differences in the individual domain and the responsive social environments unclear. However, an examination of the environment on the *macro-level*, the educational system and social-cultural environment, accounted substantially for the uneven developmental trend of inventiveness among the participants. Descriptive analysis of the biographical data of the participants who held a patent (or patents) suggested a positive link between students' inventive achievement and the SES of the region where they come from as well as the educational level of their parents. To summarize, results of the current study highlight the critical role that social and cultural environments play in fostering or hindering the inventiveness among children and adolescents in mainland China.

Implications for fostering inventiveness among children and adolescents

Based on his experience of teaching kids to invent, McCormack (1984) summarized "all children have some inborn creative potential, but the degree on which this ability develops is linked to environmental influences" (p. 249). Other psychologists in the field of giftedness also maintain that high-level performance is determined by the interaction of many factors such as cognitive, affective, and social (Mönks et al., 2002). In the current study, the higher level inventive students showed significantly higher intrinsic motivation for making inventions and demonstrated a more open personality profile. Meanwhile, they also reported having more encouragement from their schools. This finding challenges the traditional perception of creativity as a primary function of an individual's personal traits or cognitive processes but echoes a bulk of existing literature in the field of giftedness about emotional support and encouragement as effective motivators for gifted children's development of creativity (e.g., Bloom, 1985; Bloom & Sosniak, 1981; Feldman & Goldsmith, 1986; Gogel et al., 1985; Kulieke & Olszewski-Kubilius, 1989; Philips & Lindsay, 2006; Robinson & Noble, 1991). Rogers (1961) described the importance of *unconditional positive regards* to support the unfolding and experiencing of all possible human experiences. He (Rogers, 1962) further highlighted the role that a *psychologically safe environment* plays in fostering creativity. Tan (2005) maintained that creativity education is experiential and a person must feel accepted and supported in order to embark on the journey of being open and creative. The implication for inventiveness development is obvious: inventive creativity of children and adolescents will flourish if they are explicitly encouraged. Therefore, teachers and parents should not be hesitant to motivate and encourage their children to pursue their inventive potential. In addition, teachers and parents also need to provide opportunities and resources for the children and adolescents to conduct inventive endeavours.

In the previous chapter, I made suggestions to parents and teachers on how to inspire and motivate their students/kids to invent (refer to pp. 153-156). These suggestions were made mainly within the context of the formal school education. It is worth noting that formal education is by no means the only context for the development of inventiveness (Lemelson-MIT Program, 2004). Learning experiences outside school are also necessary and useful for the development of giftedness, especially creative productivity (Mönks et al., 2002). Therefore, conclusion about the environmental attributes to inventiveness would not be complete without discussing the importance and application implications of extracurricular or leisure time activities.

In the field of giftedness, the importance of leisure time activities has been recognized and researched since late 1980s. Throughout two decades of exploration, evidence has been given that activities in a certain domain as a child or adolescent lead to real-world creative accomplishments in that domain as an adult (Milgram & Hong, 1995, 1999; Milgram, Hong, Shavit, & Peled, 1997); out-of-school activities in adolescence predicted the domain of vocational activity in adulthood both in adolescents who were intellectually gifted (Milgram *et al.*, 1997) as well as in adolescents varying widely in intellectual ability (Hong, Milgram, & Whiston, 1993); and people whose activities in adolescence matched their adult occupation had a higher level of work accomplishment and satisfaction than those for whom such a match was absent (Milgram *et al.*, 1997). Taking an retrospective approach, Hany (1996) found that highly intelligent and successful people, including some patented inventors, spent more of their free time on *self-realizing activities* (i.e. creating artwork, playing an instrument, and conducting research, etc.) both during adolescents and in later years. These social elites also showed a rising frequency of intellectually demanding activities with growing age. Results of a research on adult inventors provide further support to this finding. It was reported while 61% of the less successful inventors referred to their early engagement with inventive activities a remarkably high proportion of 92% of the more successful inventors mentioned this early occupation (Mehlhorn, 1988).

There are several application implications of the above-mentioned studies. Firstly, students' leisure time activities can be applied for talent search. Traditional creativity tests are incomplete. Creative personality inventories measure personality and motivational dispositions. Divergent thinking tests measure some divergent thinking abilities. Information about students' past and present creativity involvement including those in their leisure time covers both aspects – and more (Davis, 2003). Hence, examination of the quality and quantity of out-of-school activities in children and adolescents can help find hidden abilities, thus reducing talent loss (Milgram & Hong, 1995). Milgram and Hong are not alone in this campaign. A school of psychologists have suggested that portfolios, measures of leisure activities and actual creative achievements be used for the identification of creative talents (e.g., Hocevar, 1981; Holland, 1961; Wallach & Wing, 1969). Secondly, students' leisure time activities can be structured and guided as supplementary to formal education. Traditional formal education, which has more emphasis on analytical thinking abilities and less room for hands-on practical abilities, usually does not suffice the needs of the students who have inventive potential. Popular visions of the inventors, such as Thomas Edison and Dean Kamen, often picture them as being home-educated or educated through self-directed learning. A contemporary example from China also lends valuable pedagogical implications for the fostering of inventiveness. Wu Yulu, a Chinese farmer who has got only five-year formal education and no degree in physics or technology, invented 26 robots mainly from scrap metal (Calvert, 2004). The myth of his inventive achievement, as reported, was his perseverant self-education through learning from mistakes. These examples point to the fact that inventors tend to actively seek knowledge which also falls outside of schoolwork. This kind of pursuit should be recognized, encouraged, and facilitated by parents and teachers. Thirdly, students' leisure time activities can be structured and designed in a way that will train students to be better self-regulated learners. Researchers have brought us to the stage where we can differentiate self-actualizing activities (Hany, 1996), self-defining activities (Coatsworth et al, 2005) or structured voluntary activities (Larson, 2000) from other activities which are less stimulant to creativity. Such activities are self-motivated or voluntary instead of being forced or pushed by others (Larson, 2000); and they are complex and challenging and entail constructive attention (Csikszentmihalyi, 1978, 1993, 1996; Csikszentmihalyi & Larson, 1984) and concerted effort (Larson, 2000). Such activities entail considerable self-regulation in meta-cognition, motivation, and behaviour. Hence, parents and teachers should provide the students with a context or scenario that will allow them to define the problems and explore the solutions on their own.

The results of gender differences in the environmental measures revealed that girls' leading performance in certain cognitive and personality measures of inventiveness is in conflict with the restricted encouragement that they reported from their parents. This reflects that gender-role stereotype still has a strong influence on parents' expectations and support of girls' inventiveness. It is worth repeating that many of the widely accepted beliefs about abilities and personalities of the genders are just traditional stereotypes that are not confirmed by controlled investigations (Maccoby & Jacklin, 1974). In the previous part, I have pointed out four pervasive misconceptions people usually hold about inventors/invention, including *invention must be BIG*, *inventing is IMPOSSIBLE for normal people*, *invention is a MALE thing,* and *invention is an ADULT thing* (refer to pp. 167-169 for a review). These misconceptions, especially the misconception of invention being a MALE and ADULT thing would have stronger effect on girls' development of inventiveness, as it has been reported that girls react more strongly than boys to the influence of the social models (cf. Kohlberg, 1966) and a lack of female role models for typical male activities, such as invention, aggravates the situation for gifted girls (Heller & Ziegler, 1996). An observable consequence of this socialization process is that fewer gifted women than gifted men make use of the right to education or much more rarely choose study subjects or careers in the fields of mathematics, sciences and technology (Milgram, 1988; Milgram & Hong, 1995). In attempting to remedy such tendencies, it has been suggested that motivational and self-concept related attributes combined with mentoring play a particularly important role (Heller, 2007). Nevertheless, it is worth noting that social cultural factors have very strong influence on the thinking and behaviour of the persons inside, therefore it will take time for substantial changes to occur with regard to girls' motivation and self-concept of being inventive. Simonton (1994a) pointed out three such factors, including different socialization practices for girls and boys; different costs of marriage and family for men and women; as well as the effects of a "gender ambience of a particular civilization at a given time…not very sympathetic to female attainments" (p. 36). In other words, as Baer and Kaufman (2008) argued, a large part of gender differences is environmental, including differences in adult expectations of girls and boys, differences in opportunities available to male and female children and adults, the kinds of experiences women and men are likely to have, as well as how different kinds of creative works are valued by society. As a result, cultural factors such as creative zeitgeist, levels of machismo mentality, and sexist ideologies (cf. Simonton, 1992b) should be put under investigation in future research about gender differences in inventiveness. Baer and Kaufman (2008) recommended two new directions of gender studies about creativity, including looking for gender differences in the interactions among aptitudes, motivations, and opportunities as well as examination of changes over time in situations where gender bias has been reduced.

From the developmental perspective, the impact of social cultural environments on the development of inventiveness among children and adolescents becomes even more obvious. It has been discussed that the lower level of the eldest group in inventiveness and its cognitive attributes might be a reflection of children's *adaptation* and *adjustment* to the demands of the environment, which is examination-driven and attaches excessive importance to other intellectual activities such as analytical and convergent thinking. Hence, recommendations were given on how to improve the educational system in China towards a creativity-friendly direction, particularly for the senior graders in the secondary education (refer to pp. 172-175). For further studies, a combination of longitudinal and cross-sectional design would be more desirable, as it will enable us to explore more developmental details such as intra-individual change and inter- and intra-individual differences (Buss, 1979; Schneider, 1989).

5.3 Recommendations for future systemic research on inventiveness

It is worth mentioning that though this chapter is organized in a way that individual and environmental attributes were discussed separately, it does not mean that factors from these two domains should be examined and interpreted independently. On the contrary, the development of giftedness (including inventiveness) is a function of individual characteristics, environmental experiences, and the interaction between both factors. That is why one major attempt of the study was to test a systems model of inventiveness, which takes cognitive factors (cognitive ability and knowledge) as predictors and non-cognitive personality traits and environmental factors as moderators. With a small percentage of variance explained by the hypothesized predictors, however, the tenability of the model was not impressive. It was discussed that this result was possibly mainly due to the conceptual *disunity* of the psychological attributes of creativity and the socially defined and determined construct of creativity (Westmeyer, 1998). In order to bridge this gap, future test of systems models of inventiveness calls for *cross-disciplinary* collaboration between psychological researchers and domain experts. The areas worth further investigating include the exploration of inventiveness models, the development of inventiveness instruments as well as the execution of the evaluation of inventiveness. In particular, further research about inventiveness among children and adolescents should consider the following:

(1) More basic research. Inventive creativity (or inventiveness) as an independent psychological construct has not yet been well researched, leaving many important questions yet to be answered. To start with, scientific examination of the implicit and explicit theories of inventiveness might be beneficial. Implicit theories are constructions by people, psychologists and laymen alike, which reside in the minds of these persons (Sternberg, 1985b). Explicit theories, in contrast, are developed through empirical data and techniques, thus held by researchers and usually shared through publications and professional meetings (Runco, Nemiro, & Walberg, 1998). Understanding implicit theories can help us understand explicit theories, because explicit theories derive, in part, from scientists' implicit theories of the construct under investigation. Therefore, Sternberg (1985b) argued that when definitions of certain constructs are not yet clear, implicit theories can be useful for providing a conceptual framework for the development of explicit theories. Systems study of inventiveness can start with scientific exploration of the implicit theories of inventiveness held by psychologists, field experts (e.g., patent attorneys and patent examiners), business practitioners as well as laymen. Implicit theories held by laypersons from different domains should be considered, because in research and applied milieus it is these people who judge the value, rate of adoption (Henderson, 2004b), and the possible forms of rewards (Lemelson-MIT Program, 2003) of inventions. As a second step, the so-called "personal explicit theories" of creativity (Runco et al., 1998) held by creativity researchers should be summarized and compared with the aim of identifying major controversies and agreements of the explicit theories. Successful implementation of such studies will be facilitated through the cross-disciplinary collaboration of psychological researchers and practitioners outside of the field of psychology.

(2) Combination of *domain-specific* and *domain-general* measures of inventiveness. After more than half a century's efforts, creativity researchers tend to agree that creativity has both domain-specific and domain-general elements (Sternberg, 2006). Applying this concept to the assessment of creativity, researchers proposed that "…the ideal creativity assessment would be one based on a hierarchical model of creativity, one that posits both domain-general and domain-specific elements" (Kaufman, Plucker, & Baer, 2008, p. 155). In researching inventiveness, multi-sourced instruments should be used to measure the domain-general and domain-specific aspects of inventiveness. *Domain-specific* measures of inventiveness, following the results of the previous studies about inventors (e.g., Colangelo et al., 1992, 1993, 2003; Henderson, 2003, 2004a, 2004b; Rossman, 1964; Weisberg, 1986, 1993, 2006), should encompass participants' cognitive familiarity with and perceptions about inventiveness, including knowledge about invention, inventors and invention heuristics (e.g., Altshuller, 1973, 1984; Luo, 2003; McCormack, 1981; 1984); attitudes towards invention (Colangelo, 1992); role identity as an inventor (Henderson, 2004b); and evaluation of the inventive products (e.g., Colangelo et al., 2003). Likewise, *domain-general* measures of inventiveness should also comprise both cognitive and motivational measures such as divergent thinking (Guilford, 1950, 1956, 1986; Torrance, 1966, 1974; Wallach & Kogan, 1965); breaking cognitive set (Newell et al., 1962); and creative self-efficacy (Beghetto, 2006). Of course, the choice of *domain-specific* and *domain-general* measures of inventiveness has to be grounded on basic research about the nature of inventiveness and tailored in a way that will best accommodate the purposes of the study. Good choices are more likely to be made when experts from different disciplines retain their own conceptual tools and approaches but find a way of integrating them to the collaborative study of creativity (Csikszentmihalyi, 1994).

(3) Combination of qualitative and quantitative methods. A qualitative and quantitative method each has its strengths and weaknesses in studying creativity. While qualitative methods, such as case studies, can provide authentic narratives and in-depth analyses of typical cases, quantitative methods, such as psychometric approach, can enable us to test hypotheses regarding different ability, ethnic, gender or age groups. In order to better address the unique needs of creativity research, creative combination of the classic qualitative and quantitative methods is encouraged (Mayer, 1999). Future research of inventiveness among children and adolescents, besides following a mainstream quantitative design, also enables to consider collecting qualitative data about the inventive sample through open-ended questions, interview, observation, and protocols, etc. For example, collection of the data of students' leisure time activities should be a worthwhile attempt. Because the forms of leisure activities vary from person to person and people's perceptions of the same leisure activity differ, pure reliance on the quantitative methods would not suffice. As Heller (1988) stressed "Depending on the goals set for each research project (about leisure time behaviour), both descriptive hypotheses (analysing the phenomenon itself) and explanatory hypotheses (causal or developmental analyses) will be necessary" (p.13). Results of the qualitative data can provide supplementary information for more thorough interpretations of the quantitative data, thus deepening our understanding of this special inventive group.

(4) CAT plus expert rating. Design of future research about inventiveness, no matter in whichever form, cannot be methodologically convincing unless a panel of qualified patent examiners are used as expert raters of the inventive products. In other words, if possible, non-expert raters should be discouraged for inventiveness studies even though employing non-expert raters is much more convenient and cost-effective. This is because patent examiners are trained professionals for evaluating inventions and there is no evidence that the expertise and authority of patent examiners can be easily replaced by non-experts. Consensual Assessment Technique (Amabile, 1982a) has sometimes been called the "gold standard" of creativity assessment (Carson, 2006). This technique should be also treated as a default of the evaluation of inventiveness. With the aim to get a reasonable inter-rater reliability, it has been suggested that at least 5-10 judges be used for CAT (Kaufman et al., 2008). Implementation of CAT with expert raters for inventiveness studies, again, necessitates the cross-border collaboration of psychologists and the practitioners from the field under investigation.

(5) Deeper examination of the environment. The current study also bears implications on some directions for a deeper examination of the environment. Firstly, the present study shows examination of the *micro-level* environments (e.g., school and family) sometimes is insufficient to account for the inventive phenomenon. Therefore, *macro-level* measures, such as cultural values, social expectations, the educational system, and the appraisal system, etc. are suggestible for future systems studies of inventiveness. Secondly, future research about inventiveness ought to consider taking participants' leisure time activities as a possible predictor of their inventive achievement (e.g., holding a patent or not), and compare the predictive strength of this variable with other variables under investigation. Thirdly, not as mature and invulnerable as adults, children and adolescents might be more susceptible to the environmental influence, which will result in negative or positive emotions. Affect and creativity is a relatively new, yet booming area in the field of creativity (e.g., Amabile et al., 2005; Forgas, 2001; Isen, 1999a, 1999b; Shaw & Runco, 1994). Including emotional variables as a possible co-variate in a systems study of inventiveness would help us gain a better understanding of the pathways between individual, environment and inventiveness.

Altogether, the findings of the present exploratory study contribute to the current literature about creativity by enriching it with an examination of a relevant but rarely investigated sample – young inventors. In particular, the current study adopts a systems approach which allows us to obtain scientific understanding of this special group in a yet not entirely, but still more holistic way. Through systematic analysis of the individual and environmental attributes of inventiveness, we obtain a clearer picture of a more open and higher intrinsic motivation profile of the more successful young inventors, a more supportive environment for inventiveness for the higher-level young inventors, a dispositionally more positive profile of the female young inventors, and a developmental discontinuity in both motivation and cognition for invention among these young inventors. The findings furthermore reveal that boys and girls were almost equally presented in the young patentee sample and there was a positive link between students' inventive achievement and the SES of the region where they come from as well as the educational level of their parents. Regarding the categories of inventions, there were both overlaps and differences between the results found in this sample and those found in a previous study with a US sample (Colangelo et al., 2003). As the primary purpose of this research attempt is to enrich our knowledge about this special group through comparisons with the published results, data were only analyzed in a way that was compatible to the previous study of Colangelo and colleagues. In order to know more about who the young inventors are and what they invent, further studies that employ not only descriptive analysis but also more complicated multivariate methods are needed.

Most importantly, with a large and representative sample, the current study highlights the important role that the environment plays in fostering or hindering the inventiveness among children and adolescents in mainland China. This result enhances the theoretical understanding of the systems approach of creativity by supplementing evidence of the environmental influences on creativity. It is noted that many of the environmental impediments to fostering inventiveness among the minority (young and/or female) inventive groups have their deep roots in people's perceptions about invention/ inventiveness. These conceptual impediments can be observed in the research field as well. The sparse literature about young inventors may have its origin in the suspicion that most researchers have about the inventiveness of children and adolescents. However, any sort of suspicion, prejudice, and biased views are of no help for our understanding of inventiveness among children and adolescents. More studies about young inventors and the individual and environmental attributes of their inventive talent ought to be conducted.

As an area so fundamental to human civilization, invention is substantially under-investigated in the scholarly literature. Inventiveness should have place in the field of creativity study. It should have place at schools and in classrooms. This awareness and acknowledgement of inventiveness studies and the possibility of fostering inventiveness among children and adolescents is the premise of meaningful exploration of the meaning of inventiveness. Inventiveness highly awakened and optimally fostered will function as fertile soil for the growth of inventiveness, thus providing the basic source for personal and social wellbeing.

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APPENDIX

Appendix 1: Student Questionnaire- Part I

Please fill in the blanks or make a circle on the answer that suits your situation.

Gender: __________ Birthday: __________Year_______Month_______Day

Code:________________________________ Grade: _______________________

School:____

(Are you willing to be contacted by us again? If yes, please provide your Email address:

My Email address is: ____)

1. Father's profession：

2. Mother's profession：

3. Father's educational level (please circle the right answer):

①primary school ②junior high school ③senior high school or middle-level professional school ④undergraduate ⑤ post-graduate ⑥ PhD

4. Mother's educational level (please circle the right answer):

①primary school ②junior high school ③senior high school or middle-level professional school ④undergraduate ⑤ post-graduate ⑥ PhD

5. In the most recent exams, I was ranked No.____ in our class (there are _______ students in our class)

6. Have you ever got patents for your invention?

① No!

②Yes!

If Yes, how many？ ____________ What are they?_________________________________

Please describe each: ____

____

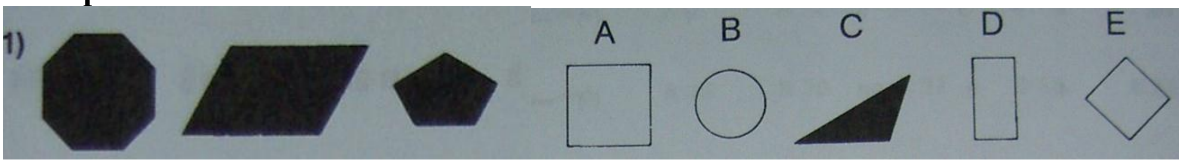
____

____

2. KFT-HB-Non-verbal Test 1 (10mins)

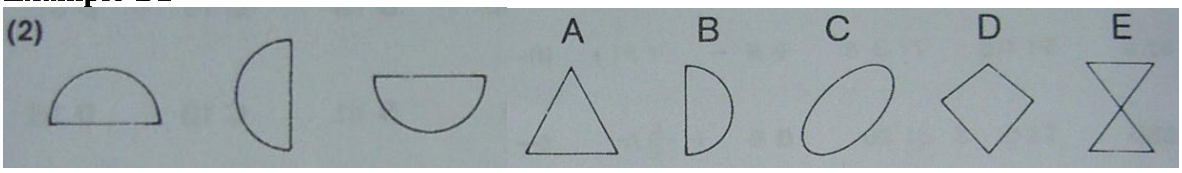
This test is composed of figures and symbols. Please compare the figures/symbols given on the left column with those on the right column and pick out the one on the right which belongs to the same category of those on the left.

Example-B1



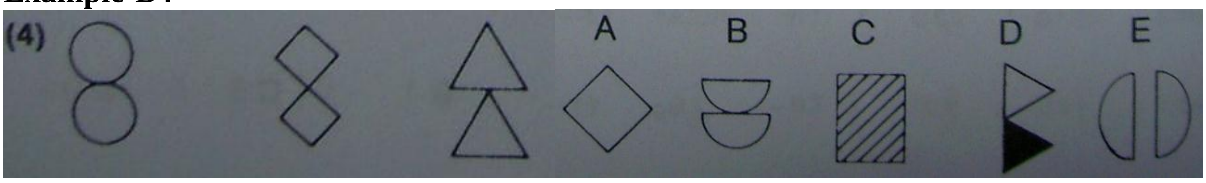
In this task (B1), all three figures on the left are solid. Among the five figures on the right, only the figure below the letter "C" is solid. So the right answer is "C". You should tick "C" with a "√".

Example-B2



In this task (B2), all three figures on the left are hollow semicircles. Among the five figures on the right, only the figure below the letter "B" is a hollow semicircle. So the right answer is "B". You should tick "B" with a "√".

Example-B4



Let us look at another example (B4). What would you choose now? The right answer is "B The reason is because the figures on the left are two same figures on the top of each other. Among the five figures on the right, only the figure below the letter "B" presents such a feature. ". You should tick "B" with a "√".

Important notes:

1. Depending on which grade you are currently in, you are asked to give answers to different items of the test. You should answer the prescribed items ONLY. Please make

sure that you have found the right items before you start to tick the answers.

Grades and the Relevant Items

Grade	Starts with	Ends with	Total of items
4	11	35	25
5	16	40	25
6	21	45	25
7	26	50	25
8	31	55	25
9	36	60	25
10	41	65	25
11	46	70	25
12	46	70	25

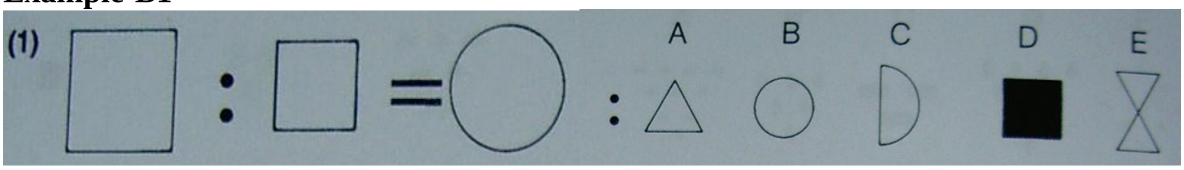
2. It is worth noting that some of the tasks are relatively easier while others are much difficult. It is advisable to finish the easy tasks first; then move on to the more difficult ones. Don't waste too much time on difficult tasks. We are not expecting you to finish all the prescribed tasks within the time limit. However, you should try your best to finish as many tasks as possible.

3. You will have 10 minutes to finish this test. Please follow the instruction of the teacher to start and end of the test.

3.KFT-HB-Non-verbal Test 2 (8mins)

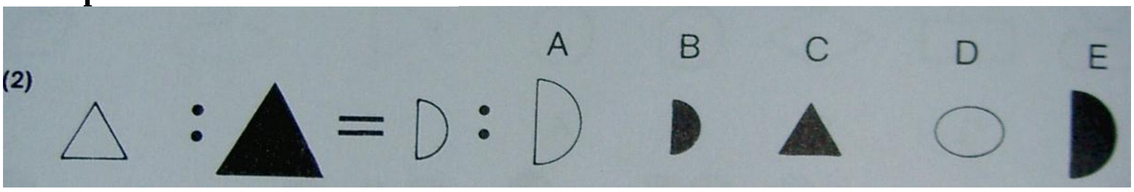
This test is also composed of figures and symbols. Unlike the former test, there is a"**:**" between the first two figures/symbols. "**:**"means the **relationship** between the two figures/symbols. Your task is to pick out one figure/symbol from the right column, which will complete the equation of the relationship chain.

Example-B1



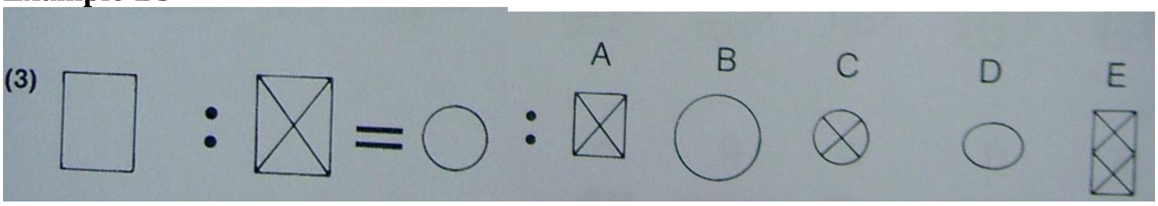
In this task (B1), the relationship between the two figures on the left is: a big and a small square. Such a relationship should equal to "a big circle and a ______"? It is obvious that the answer should be "B"- "small circle". So you should tick "B" with a "√".

Example-B2



In this task (B2), the relationship between the two figures on the left is: a small hollow triangle and a big solid triangle. Such a relationship should equal to "a small hollow semicircle and a **_______**"? You will find the right answer is "E"-"big solid semicircle". So you should tick "E" with a "√".

Example-B3



Let us look at another example. Which one shall well choose? It is obvious that the right answer is "C". So you should tick "C" with a "√".

Important notes:

1. Depending on which grade you are currently in, you are asked to give answers to different items of the test. You should answer the prescribed items ONLY. Please make sure that you have found the right items before you start to tick the answers.

Grades and the Relevant Items

Grade	Starts with	Ends with	Total of items
4	11	35	25
5	16	40	25
6	21	45	25
7	26	50	25
8	31	55	25
9	36	60	25
10	41	65	25
11	46	70	25
12	46	70	25

2. You will have **8 minutes** to finish this test. Please follow the instruction of the teacher to start and end of the test.

Appendix 2 : Student Questionnaire – Part II

Dear students:

Welcome back to our survey. In the last part, you might be a bit scared of the test of figures and symbols. This part, however, is only composed of *non-standard test*. There will be no right or wrong answers. The answer that suits you the best are the most valuable. So please be as honest as possible.

Each of your answer will be treated with high confidentiality and you needn't to worry that we will reveal your answers to others.

Enjoy answering the questions! Many thanks!

Yours,
Research team of the Project of Inventive Creativity Educational System

Please fill in the blanks or make a circle on the answer that suits your situation.

Gender: __________ Birthday: __________Year_______Month_______Day

Code:________________________________ Grade: _______________________

School:____

(Are you willing to be contacted by us again? If yes, please provide your Email address:

My Email address is: ____)

I. How much does each of the following description suit you when you are making invention? Please circle "1" if the description does not fit you at all and circle "5" if it suits you extremely well. Use the values in between to indicate how the description suits you in different degrees.

1=not at all true of me 2=somewhat true of me 3=moderately true of me
4=very true of me 5=completely true of me

When I am making invention, …

1	I am not that concerned about what other people think of my work.	1	2	3	4	5
2	I prefer having someone set clear goals for me.	1	2	3	4	5
3	the more difficult the problem, the more I enjoy trying to solve it.	1	2	3	4	5
4	I am keenly aware of the rewards that I will get.	1	2	3	4	5
5	I want my invention to provide me with opportunities for increasing my knowledge and skills.	1	2	3	4	5
6	success means doing better than other people.	1	2	3	4	5
7	I prefer to figure things out for myself.	1	2	3	4	5
8	no matter what the outcome of an invention, I am satisfied if I feel	1	2	3	4	5

	that I gained a new experience.					
9	I enjoy relatively simple, straight forward tasks.	1	2	3	4	5
10	I am keenly aware of the goals I have for myself.	1	2	3	4	5
11	curiosity is the driving force behind much of what I do.	1	2	3	4	5
12	I am less concerned with what work I do than what I get for it.	1	2	3	4	5
13	I enjoy tacking problems that are completely new to me.	1	2	3	4	5
14	I prefer work I know I can do well over work that stretches my abilities.	1	2	3	4	5
15	I am concerned about how other people think of my work.	1	2	3	4	5
16	I seldom think about results of rewards.	1	2	3	4	5
17	I am more comfortable when I can set my own goals.	1	2	3	4	5
18	I believe that there is no point in making an invention if nobody else knows about it.	1	2	3	4	5
19	I am strongly motivated by the rewards I can get.	1	2	3	4	5
20	it is important for me to be able to do what I most enjoy.	1	2	3	4	5
21	I prefer working on things with clearly specified procedures.	1	2	3	4	5
22	as long as I can do what I enjoy, I am not that concerned about exactly what awards I can earn.	1	2	3	4	5
23	I am so absorbed that I forget about everything else.	1	2	3	4	5
24	I am strongly motivated by the recognition I can earn from other people.	1	2	3	4	5
25	I have to feel that I am earning something for what I do.	1	2	3	4	5
26	I enjoy trying to solve complex problems.	1	2	3	4	5
27	it is important for me to have an outlet for self-expression.	1	2	3	4	5
28	I want to find out how good I really can be at it.	1	2	3	4	5
29	I want other people to find out how good I really can be at it.	1	2	3	4	5
30	what matters most to me is enjoying what I do.	1	2	3	4	5

II. Please read the following descriptions and choose the number that describes you the best. Please proceed at your own pace, but do not spend too much time on any one description.

1=not at all true of me 2=somewhat true of me 3=moderately true of me
4=very true of me 5=completely true of me

1	I am sophisticated in art, music or literature.	1	2	3	4	5
2	While I don't deliberately seek out activities that others disapprove of, I find that I often end up doing something that others disapproves of.	1	2	3	4	5
3	I am curious about many different things.	1	2	3	4	5
4	I do not like to get started in group projects unless I feel assured that the project will be successful.	1	2	3	4	5
5	I consider myself a risk-taker.	1	2	3	4	5
6	I have an active imagination.	1	2	3	4	5
7	I prefer the certainty of always being in control of myself.					

8	I often think about breaking some set rules.	1	2	3	4	5
9	I prefer work that is routine.	1	2	3	4	5
10	It would bother me if different close friends of mine had conflicting opinions of me.					
11	I often do things that I know my parents would disapprove of.	1	2	3	4	5
12	I like the feeling that comes with taking risks.	1	2	3	4	5
13	I like movies or stories with definite endings.					
14	I value artistic and aesthetic experiences.	1	2	3	4	5
15	I do not let the fact that the majority is opposing me stop me from doing things.	1	2	3	4	5
16	A problem has little attraction for me if I don't think it has a solution.	1	2	3	4	5
17	I am inventive.	1	2	3	4	5
18	I often think of doing things that I know my teachers would disapprove of.	1	2	3	4	5
19	In a decision-making situation in which there is not enough information to process the problem, I feel very uncomfortable.	1	2	3	4	5
20	I often think about doing things that I know my friends would disapprove of.	1	2	3	4	5
21	I have few artistic interests.	1	2	3	4	5
22	The greater the risk the more fun the activity.	1	2	3	4	5
23	I am original and always have new ideas.	1	2	3	4	5
24	Mysticism is too abstract and undefined for me to take seriously.					
25	I am ingenious and am a deep thinker.	1	2	3	4	5
26	Being afraid of doing something new often makes it more fun in the end.	1	2	3	4	5
27	I don't like to work on a problem unless there is a possibility of coming out with a clear-cut and unambiguous answer.	1	2	3	4	5
28	I like to reflect and play with ideas. .	1	2	3	4	5

III Below are statements about the ways how people use to solve problems. Please read each statement carefully and decide how each statement describes you. Use the scale provided to indicate how well the statement fits the way you typically do things.

This statement suits me

1=not at all well 2=not very well 3=slightly well 4=somewhat wel
5=well 6=very well 7=extremely well

1	I like to play with my ideas and see how far they go.	1	2	3	4	5	6	7
2	When discussing of writing down ideas, I like criticizing others' ways of doing things.	1	2	3	4	5	6	7
3	When discussing of writing down ideas, I follow formal rules of presentation.	1	2	3	4	5	6	7
4	I enjoy working on things that I can do by following directions.	1	2	3	4	5	6	7
5	I enjoy working on projects that allow me to try novel ways of doing things.	1	2	3	4	5	6	7

6	I enjoy work that involves analyzing, grading, or comparing things.	1	2	3	4	5	6	7
7	I like to challenge old ideas or ways of doing things and to seek better ones.	1	2	3	4	5	6	7
8	When making decisions, I tend to rely on my won ideas and ways of doing things.	1	2	3	4	5	6	7
9	When making a decision, I like to compare the opposing points of view.	1	2	3	4	5	6	7
10	When faced with a problem, I prefer to try new strategies or methods to solve it.	1	2	3	4	5	6	7
11	I like situations where I can use my own ideas and ways of doing things.	1	2	3	4	5	6	7
12	I like to follow definite rules or directions when solving a problem or doing a task.	1	2	3	4	5	6	7
13	I like projects that allow me to look at a situation form a new perspective.	1	2	3	4	5	6	7
14	I like situations where I can compare and rate different ways of doing things.	1	2	3	4	5	6	7
15	When working on a task, I like to start with my own ideas.	1	2	3	4	5	6	7
16	I like situations in which my role or the way I participate is clearly defined.	1	2	3	4	5	6	7
17	When faced with opposing ideas, I like to decide which is the right way to do something.	1	2	3	4	5	6	7
18	I like to check and rate opposing points of view or conflicting ideas.	1	2	3	4	5	6	7
19	I like to do things in new ways not used by others in the past.	1	2	3	4	5	6	7
20	When faced with a problem, I use my own ideas and strategies to solve it.	1	2	3	4	5	6	7
21	I am careful to use the proper method to solve any problem.	1	2	3	4	5	6	7
22	I prefer tasks or problems where I can grade the design or methods of others.	1	2	3	4	5	6	7
23	I like situations where I can try new ways of doing things.	1	2	3	4	5	6	7
24	I feel happier about a thing when I can decide for myself what and how to do it.	1	2	3	4	5	6	7
25	I like projects that have a clear structure and a set plan and goal.	1	2	3	4	5	6	7
26	I like to change routines in order to improve the way tasks are done.	1	2	3	4	5	6	7
27	I like problems where I can try my own way of solving them.	1	2	3	4	5	6	7
28	I like to figure out how to solve a problem following certain rules.	1	2	3	4	5	6	7
29	I like projects where I can study and rate different views and ideas.	1	2	3	4	5	6	7
30	Before starting a task, I like to figure out for myself how I will do my work.	1	2	3	4	5	6	7
31	Before starting a task, I check to see what method or procedure should be used.	1	2	3	4	5	6	7
32	I like to find old problems and find new methods to solve them.	1	2	3	4	5	6	7

IV. How much does each of the following description describe the environments of your school or family? Please circle "1" if the description does not fit you at all and circle "5" if it suits you extremely well. Use the values in between to indicate how the description suits you in different degrees.

1=not at all true 2=somewhat true 3=moderately true
4=very true 5=completely true

1	My parents encourage me to make inventions.	1	2	3	4	5
2	My parents encourage me to try new things.	1	2	3	4	5
3	In the process of making inventions, I can feel the encouragement of my parents.	1	2	3	4	5
4	If I meet some difficulties in making inventions, my parents will encourage me to carry on.	1	2	3	4	5
5	My parents don't encourage me to take risky activities[R].	1	2	3	4	5
6	My parents finance me to participate in this contest.	1	2	3	4	5
7	My parents finance me to make inventions in my spare time.	1	2	3	4	5
8	Whatever I need for making inventions, my parents will try their best to get it for me.	1	2	3	4	5
9	In our school we have a special place for making inventions.	1	2	3	4	5
10	In our invention place at school we have many materials.	1	2	3	4	5
11	Whatever I need for making inventions, my teachers will try their best to get it for me.	1	2	3	4	5
12	There is an inventive atmosphere in our school.	1	2	3	4	5
13	Our school encourages us to be inventive students.	1	2	3	4	5
14	In our school we are encouraged to participate in inventive activities.	1	2	3	4	5
15	In our school special teachers are assigned to teach us how to make inventions.	1	2	3	4	5
16	There is an inventive atmosphere in our class.	1	2	3	4	5
17	In our school inventive students will be praised and set as examples for other students to learn from.	1	2	3	4	5
18	In our class inventive students will be praised and set as example students for others to learn from.	1	2	3	4	5

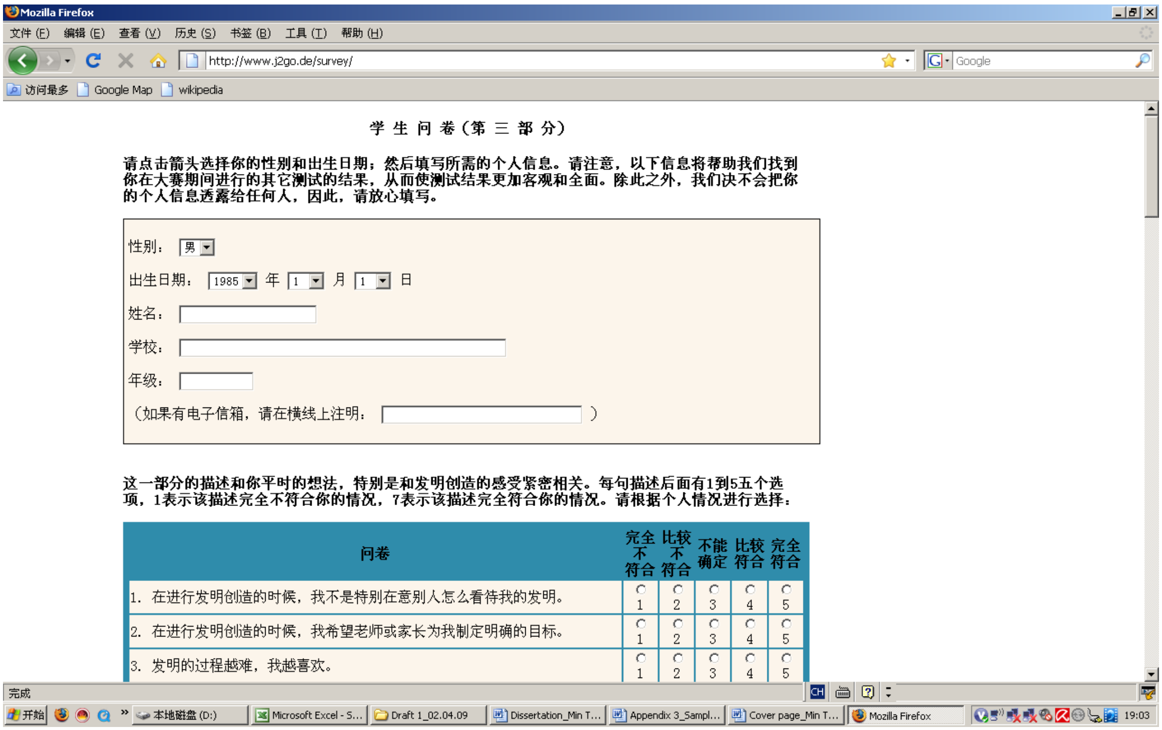
Note. Item 5 was deleted from the questionnaire after checking the factor loadings of the items (refer to pp97-99).

Thank you for your participation!

Appendix 3: Samples of students' invention schemes[6]

[6] The copy right of the invention schemes belongs to the Organizing Committee of the "Inventive Ideation Contest for Children and Adolescents in China" (IICCAC; Contact: Mr. Fanhua Luo; Email: cctv8001@126.com). Unless getting the approval of IICCAC, nobody is allowed to further copy and use these pictures for any commercial or publication purposes.

Appendix 4: Webpage of online survey (sample pages)



学 生 问 卷（第 三 部 分）

请点击箭头选择你的性别和出生日期；然后填写所需的个人信息。请注意，以下信息将帮助我们找到你在大赛期间进行的其它测试的结果，从而使测试结果更加客观和全面。除此之外，我们决不会把你的个人信息透露给任何人，因此，请放心填写。

性别： 男

出生日期： 1985 年 1 月 1 日

姓名：

学校：

年级：

（如果有电子信箱，请在横线上注明： ）

这一部分的描述和你平时的想法，特别是和发明创造的感受紧密相关。每句描述后面有1到5五个选项，1表示该描述完全不符合你的情况，7表示该描述完全符合你的情况。请根据个人情况进行选择：

问卷	完全不符合	比较不符合	不能确定	比较符合	完全符合
1. 在进行发明创造的时候，我不是特别在意别人怎么看待我的发明。	1	2	3	4	5
2. 在进行发明创造的时候，我希望老师或家长为我制定明确的目标。	1	2	3	4	5
3. 发明的过程越难，我越喜欢。	1	2	3	4	5

问卷	完全不符合	比较不符合	不能确定	比较符合	完全符合
3. 发明的过程越难，我越喜欢。	1	2	3	4	5
4. 参加创意大赛，我非常关注自己的表现和成绩如何。	1	2	3	4	5
5. 我希望通过发明创造这个过程增长知识、增加技能。	1	2	3	4	5
6. 对我而言，成功就是比别人做得好。	1	2	3	4	5
7. 我特别喜欢自己找到问题的答案。	1	2	3	4	5
8. 不管结果如何，只要感觉某件事情给我带来了新的经历，我就挺满意。	1	2	3	4	5
9. 我喜欢简单明了的任务。	1	2	3	4	5
10. 参加创意大赛，我非常清楚自己要达到的目标是什么。	1	2	3	4	5
11. 我做很多事情是因为好奇心的驱动。	1	2	3	4	5
12. 与发明的过程相比，我更关心发明的结果。	1	2	3	4	5
13. 我喜欢琢磨自己以前从来没有遇到过的难题。	1	2	3	4	5
14. 与其费尽心思去选择一个很难的题目，不如选择自己能够驾驭的选题。	1	2	3	4	5
15. 我很在意别人怎么看待我的观点。	1	2	3	4	5
16. 我很少想必须取得怎么样的成绩。	1	2	3	4	5
17. 我很高兴能让我自己设立目标。	1	2	3	4	5
18. 如果没有人知道你在做什么，你就没有必要把事情做得很好。	1	2	3	4	5
19. 好的名次对我来说是很好的激励。	1	2	3	4	5

Appendix 5: Brief definitions of U. S. Patent and Trade Mark Office patent classification

(1) Tools:

Inventions categorized as *Tools* include hand tools and presses.

(2) Kitchen and Bath:

Inventions categorized as *Kitchen and Bath* included devices or methods used in baths, closets, sinks, and spittoons, cutlery, refrigeration, food and beverage preparation, treating, and preservation, and power-driven conveyors.

(3) Organization:

Inventions categorized as *Organization* included packages, flexible/portable closures, partitions, or panels, special receptacles or packages, and support racks.

(4) Clothes and Accessories:

Inventions categorized as *Clothes and Accessories* included apparel, boots and shoes, buckles, and jewelry.

(5) Safety, Protection, and Rescue:

Inventions categorized as *Safety, Protection, and Rescue* included equipment used for body restraint or protective covering, rescue, or as a fire extinguisher or casing.

(6) Farm:

Inventions categorized as *Farm* included methods or devices used in animal husbandry, methods and structures used to raise and care for bees, and devices or methods for crop threshing or separating.

(7) Amusement:

Inventions categorized as *Amusement* include sporting, goods, toys, games, and devices or methods related to music.

(8) Pets:

Inventions categorized as *Pets* included harnesses fluid handling, farriery, and dispensing of solids.

(9) Automotive:

Inventions categorized as *Automotive* included devices and methods used by or for motor vehicles.

(10) Furniture:

Inventions categorized as *Furniture* included devices for supporting the weight of a person in seated position.

(11) Medical:

Inventions categorized as *Medical* included devices used in a variety of medical situations.

(12) Cleaning:

Inventions categorized as *Cleaning* included devices or chemicals used for the removal of foreign material.

(13) Electronic:

Inventions categorized as *Electronic* include devices for producing light or related to television functioning.

(14) For the Disabled:

Inventions categorized as *For the Disabled* included devices or methods used to accommodate people with physical disability.

Source:

Colangelo, N., Assouline, S., Croft, L., Baldus, C. & Ihrig, D. (2003). Young Inventors. In L. V. Shavinina (Ed.), *The International Handbook on Innovation* (Appendix B, p. 292). Elsevier Science Ltd.

Appendix 6: Results of data analyses with rank transformed (RT) data

Introduction:

As discussed in Chapter 3 (refer to 3.1.2, pp. 107-108), the same data analysis procedures were run for both original and rank transformed data. Tables in this appendix present the results of data analyses which were done on rank transformed data. For convenience, "RT" (stands for rank transformation) is put in front of the number of the table so that it is easier for the readers to relate the table to the relevant table in Chapter 3. For example, while reading "Table RT-3.3", you can refer to Table 3.3 in Chapter 3 and compare the results. In order for you to have an overview of the comparisons between the results with the original data and those with the rank transformed data, a short summary is given after each table.

5.1 Correlations among the independent and dependent variables

Table RT-3.2 Correlations among the independent and dependent variables (with RT data)

		1		2		3		4		5		6		7		8		9	
1	Intrinsic motivation	1																	
2	Extrinsic motivation	-0.07		1															
3	Openness	0.54	**	-0.06		1													
4	Risk-taking	0.30	**	-0.03		0.36	**	1											
5	Tolerance of ambiguity	0.28	**	-0.37	**	0.23	**	-0.01		1									
6	Legislative thinking	0.41	**	0.07		0.46	**	0.37	**	-0.00		1							
7	Judicial thinking	0.35	**	0.16	**	0.34	**	0.22	**	-0.05		0.46	**	1					
8	Executive thinking	0.00		0.34	**	-0.08	*	-0.17	**	-0.30	**	0.14	**	0.33	**	1			
9	Liberal thinking	0.62	**	-0.09	*	0.54	**	0.37	**	0.26	**	0.61	**	0.47	**	0.01		1	
10	Family encouragement	0.29	**	-0.04		0.29	**	-0.01		0.12	**	0.24	**	0.31	**	0.18	**	0.33	**
11	Family resources	0.31	**	-0.02		0.26	**	0.06		0.13	**	0.28	**	0.28	**	0.09	*	0.38	**
12	School encouragement	0.26	**	-0.02		0.27	**	0.01		0.09	*	0.19	**	0.22	**	0.12	**	0.31	**
13	School resources	0.35	**	-0.12	**	0.36	**	0.16	**	0.18	**	0.20	**	0.23	**	0.01		0.37	**
14	Tech. construct ability	0.06		-0.09	*	0.14	**	0.08		0.05		0.06		-0.01		-0.06		0.11	**
15	Knowledge	0.11	**	-0.01		0.15	**	0.02		0.09	*	0.18	**	0.03		-0.06		0.15	**
16	Originality	0.03		0.07		0.03		-0.04		0.04		0.03		0.07		0.07		0.04	
17	Practicality	0.02		0.05		0.06		0.03		0.01		0.05		0.02		0.03		0.04	
18	Aesthetic appeal	0.03		0.01		0.07		-0.03		0.00		-0.01		0.01		0.04		0.01	
19	Communication	0.05		0.08	*	0.02		-0.01		0.02		-0.06		0.04		0.05		-0.01	

*p<.05, **p<.01, (2-tailed test)

Table RT-3.2 (Continued)

		10	11	12	13	14	15	16	17	18	19
10	Family encouragement	1									
11	Family resources	0.58 **	1								
12	School encouragement	0.34 **	0.36 **	1							
13	School resources	0.29 **	0.33 **	0.42 **	1						
14	Tech. construct ability	0.03	0.01	0.01	0.07	1					
15	Knowledge	0.10 *	0.09 *	-0.02	0.05	0.29 **	1				
16	Originality	0.10 *	0.05	0.09 *	0.08	0.11 *	0.14 **	1			
17	Practicality	0.03	0.02	-0.06	-0.03	0.13 **	0.20 **	0.40 **	1		
18	Aesthetic appeal	0.05	0.04	0.03	0.01	0.20 **	0.25 **	0.46 **	0.59 **	1	
19	Communication	0.04	0.03	-0.05	-0.00	0.06	0.16 **	0.36 **	0.45 **	0.41 **	1

*p<0.05; **p<0.01 (2-tailed test)

<u>Summary:</u>

1. The same or similar correlation coefficients were found for most of the bivariate correlations with both original and rank transformed data.
2. Like the analysis with the original data, the analysis with the RT data revealed that inventiveness was substantially related to the cognitive variables.
3. Like the analysis with the original data, the analysis with the RT data also revealed significant correlations between originality and the "encouragement" sub-scale of the environmental variables.
4. Unlike the analysis with the original data, which revealed no significant correlations between inventiveness and non-cognitive variables, the analysis with the RT data revealed significant correlations between extrinsic motivation and the "communication" sub-scale of inventiveness. However, the correlation coefficient is rather small (r=.08).

5.2 Factor structure of all the variables under investigation

Table RT-3.3 Factor analysis of all independent and dependent variables (with RT data)

Variables	Factors					Dimension
	1	2	3	4	5	
Risk-taking	.80					Creative individual traits
Legislative thinking	.73					Creative individual traits
Liberal thinking	.70					Creative individual traits
Openness	.68					Creative individual traits
Intrinsic motivation	.61					Creative individual traits
Judicial thinking	.55					Creative individual traits
Practicality		.80				Inventiveness
Aesthetic appeal		.77				Inventiveness
Communication		.75				Inventiveness
Originality		.69				Inventiveness
Extrinsic motivation			.72			Non-creative individual traits
Tolerance of Ambiguity			-.71			Non-creative individual traits
Executive thinking			.71			Non-creative individual traits
Family encouragement				.74		Inventive environment
School resources				.72		Inventive environment
Family resources				.70		Inventive environment
School resources				.57		Inventive environment
Tech. construct ability					.81	Cognition
Knowledge					.76	Cognition
Eigenvalue	4.24	2.44	1.88	1.53	1.08	
Variance (%)	22.3	12.8	9.9	8.1	5.7	

Note. Factor analysis with Oblimin rotation. Only loadings larger than .04 are shown. All decimals are omitted.

<u>Summary:</u>

1. Like the results found with the original data, factor analysis with the rank transformed data also issued a five-factor solution, which accounted for 58.8% of the total variance.

2. Both the factor loadings and the percentage of variance are almost the same as the results with the original data.

5.3 Multiple regression: the predictors of inventiveness

TableRT-3.4 Regression analysis for the criterion of **originality** (with RT data)

	Originality (DV)	Tech. construct ability	Knowledge	B	SE B	β	ΔR^2
Tech. construct ability	.11			.10	.05	.10*	.02**
Knowledge	.13	.29	1	.09	.04	.10*	
Rank Mean	313	263	319				
SD	161	151	179				
						Adjusted	R^2 =.03**
							R=.24**

Note. R^2 = .02 for Step 1 (p<.05); ΔR^2 = .02 for Step 2 (p<.01); ΔR^2 = .01 for Step 3 (p>.05).
*p<.05; **p<.01

Table RT-3.5 Regression analysis for the criterion of **practicality** (with RT data)

	Practicality (DV)	Tech.construct ability	Knowledge	B	SE B	β	ΔR^2
Tech. construct ability	.13			.09	.05	.09	.04***
Knowledge	.17	.29	1	.01	.00	.15**	
Rank Mean	313	263	319				
SD	154	151	179				
						Adjusted	R^2 =.03***
							R=.25***

Note. R^2 = .01 for Step 1 (p>.05); ΔR^2 = .04 for Step 2 (p<.001); ΔR^2 = .01 for Step 3 (p>.05).
**p<.01; ***p<.001

Table RT-3.6 Regression analysis for the criterion of aesthetic appeal (with RT data)

	Aesthetic Appeal (DV)	Openness	Tech. construct ability	Knowledge	B	SE B	β	ΔR2
Openness	.11				.11	.05	.12*	
Tech. construct ability	.17	.12			.14	.05	.13**	.07***
Knowledge	.23	.17	.24		.19	.04	.21**	
Rank Mean	315	311	263	319				
SD	163	179	151	179				
							Adjusted	R^2 =.07*** R=30***

Note R^2 = .01 for Step 1 (p>.05); ΔR^2 = .07 for Step 2 (p<.001); ΔR^2 = .00 for Step 3 (p>.05).

*p<.05; **p<.01; ***p<.001

Table RT-3.7 Regression analysis for the criterion of communication (with RT data)

	Communication (DV)	Legislative style	Knowledge	B	SE B	β	ΔR2
Legislative style	-.04			-.13	.05	-.15*	.03**
Knowledge	.14	.16	1	.12	.04	.14**	
Mean	312	314	319				
SD	159	181	179				
						Adjusted	R^2 =.03** R=.25**

Note R^2 = .03 for Step 1 (>.05); ΔR^2 = .02 for Step 2 (p<.01); ΔR^2 = .01 for Step 3 (p>.05).

*p<.05; **p<.01

Summary:

1. Regression analysis with rank transformed data issued the same results as those got with the original data.
2. The two cognitive factors (technical construct ability and knowledge) were the only significant predictors for originality and practicality.
3. The two cognitive factors along with openness were significant predictors for aesthetic appeal.
4. Legislative thinking style and knowledge were significant predictors for communication. .

5.4 *t*-test: differences between the patentee and non-patentee groups

Table RT-3.8 *t*-test on the independent and dependent variables between the patentee and non-patentee groups (with RT data)

Variables	Group1 Non-patentees (n1=583)		Group 2 Patentees (n2=38)			
	MR	SD	MR	SD	*t*	g
Motivation						
Intrinsic motivation	308	179	362	177	-1.81*	.30
Extrinsic motivation	310	181	321	159	-.35	.06
Personality						
Openness	308	178	363	187	-1.84*	.31
Risk-taking	309	179	348	174	-1.32	.22
Tolerance of ambiguity	312	179	293	189	.65	.06
Thinking style						
Legislative thinking	311	178	311	206	.01	.00
Judicial thinking	311	178	314	203	-.10	.02
Executive thinking	308	180	358	171	-1.66*	.28
Liberal thinking	310	178	320	199	-.33	.06
Environment						
Family encouragement	311	178	314	191	-.10	.02
Family resources	309	177	346	183	-1.25	.21
School encouragement	303	179	434	128	-5.96***	1.00
School resources	305	179	397	153	-3.08***	.51
Tech. construct ability [a]	265	153	225	124	1.35	.23
Knowledge	313	179	279	188	1.14	.19
Inventiveness						
Originality	311	162	315	154	-.16	.03
Practicality	311	154	304	173	.29	.05
Aesthetic appeal	311	162	312	161	-.03	.01
Communication	312	161	299	154	.46	.08

a: n1=496, n2=28. *p<.05; ***p<.001 (1-tailed)

<u>**Summary:**</u>

1. Like the analysis with the original data, the analysis with the RT data revealed that the patentees were opener and more intrinsically motivated than the non-patentees. The patentees were also from schools that were more supportive for inventiveness.
2. In addition, results with the RT data also revealed that the patentees reported higher level executive thinking style than the non-patentees, but with g of .28, the effect size was not very big.

5.5 Logistic regression: dimension/s among which patentees and non-patentees differ

Table RT-3.9 Sequential logistic regression of environmental and individual factors on the membership of patentee or non-patentee (with RT data)

		B	SE	χ^2	Exp(B)	95.0% C.I.for EXP(B)	
						Lower	Upper
Model 1	School encouragement	.00	.00	10.93**	1.00	1.00	1.01
	School resources	.00	.00	1.78	1.00	1.00	1.00
	(Constant)	-4.73	.56	71.60	.01		
Model 2	School encouragement	.00	.00	8.94**	1.00	1.00	1.01
	School resources	.00	.00	1.43	1.00	1.00	1.00
	Intrinsic motivation	.00	.00	.01	1.00	1.00	1.00
	Openness	.00	.00	.04	1.00	1.00	1.00
	Executive thinking	.00	.00	1.38	1.00	1.00	1.00
	(Constant)	-5.11	.67	58.01	.01		

**p<.01

<u>Summary:</u>

In consistent with the results of the t-test, "executive thinking" was also entered into the regression model. However, the overall results stayed the same:

1. The environmental predictors, as a set, reliably distinguished between the patentee and the non-patentee groups.
2. Addition of the non-cognitive variables did not result in significant model effect, block $\chi^2(2, N=621)=1.44, p>.05$
3. Examined at the individual level, only school encouragement was found making a specific contribution to the prediction.
4. Classification based on the environmental variables was impressive for the non-patentee group, with 79.8% non-patentees correctly predicted, but unimpressive for the patentee group, with 36.8% of the patentees correctly predicted. The overall success rate was 77.1%.
5. The addition of the non-cognitive variables to the model slightly improved the correctness of prediction of membership, with 80.6% for the non-patentee group and 39.5% for the patentee group. The overall successful prediction rate for both groups was increased to 78.1%.

5.6 Gender differences

Table RT-3.10 Gender differences in all variables (with RT data)

	Girls n1=318		Boys n2=303			
Variables	M	SD	M	SD	F	eta^2
Motivation						
Intrinsic motivation	309	182	304	174	.00	.00
Extrinsic motivation	320	173	310	185	.40	.00
Personality						
Openness	325	182	296	176	2.92	.01
Risk-taking	300	182	319	178	1.64	.00
Tolerance of ambiguity	321	177	299	181	1.49	.00
Thinking style						
Legislative	317	184	311	177	.31	.00
Judicial	307	180	319	180	.87	.00
Executive	294	182	329	173	4.85*	.01
Liberal	302	181	322	178	2.04	.00
Environment						
Family encouragement	291	180	334	174	8.08**	.02
Family resources	309	174	311	184	.00	.00
School encouragement	321	181	293	177	3.14	.01
School resources	302	182	327	173	3.80	.01
Tech. construct ability [a]	264	154	260	148	.13	.00
Knowledge	331	172	306	186	2.17	.00
Inventiveness						
Originality	321	163	303	157	2.53	.01
Practicality	318	155	309	154	.80	.00
Aesthetic appeal	332	164	297	160	6.49*	.01
Communication	322	159	302	159	1.45	.00

*p<.05, **p<.01 (2-tailed test); [a] n for girls is 272, n for boys is 252.

<u>Summary:</u>

1. In comparison to the analysis with the original data, limited gender differences were found with the rank transformed data in that no significant differences were found in Openness.
2. For the variables of "executive thinking style" and "family encouragement", consistent results were found with original and rank transformed data (the same *p* level and the same eta^2).
3. Data analysis with RT data revealed smaller F value and lower eta^2 for aesthetic appeal.

5.7 Age-related differences

Table RT-3.11 Grade-level differences in all variables (with RT data)

Variables	Group 1 (4-6 grades) n1=228		Group 2 (7-9 grades) n2=163		Grade 3 (10-12 grades) n3=133			
	M	SD	M	SD	M	SD	F	eta^2
Motivation								
Intrinsic motivation	299	185	318	178	306	165	.69	.00
Extrinsic motivation	313	191	315	172	320	167	.08	.00
Personality								
Openness	288	179	340	178	316	177	4.23*	.02
Risk-taking	280	189	337	176	325	163	5.54**	.02
Tolerance of ambiguity	323	190	322	172	275	163	3.43*	.01
Thinking style								
Legislative	305	190	319	171	324	176	.54	.00
Judicial	313	184	299	184	330	166	1.04	.00
Executive	330	189	278	169	320	167	4.33*	.02
Liberal	320	190	316	164	290	178	1.29	.01
Environment								
Family encouragement	327	185	316	178	286	164	2.13	.01
Family resources	323	188	315	174	282	165	2.35	.01
School encouragement	324	175	287	189	306	173	1.95	.01
School resources	336	183	298	176	295	169	3.04*	.01
Tech. construct ability	285	159	289	151	191	111	21.40***	.08
Knowledge	345	179	386	171	193	113	56.51***	.18
Inventiveness								
Originality	361	142	265	153	289	178	20.34***	.07
Practicality	327	141	306	153	298	178	1.82	.01
Aesthetic appeal	344	147	305	165	279	177	7.33***	.03
Communication	329	160	300	140	298	177	2.22	.01

*p<.05, **p<.01, ***p<.001 (2-tailed test)

Summary:

1. In general, data analyses with RT data produced more differences among the age groups. Besides significant differences in Openness, risk-taking, executive thinking, technical construct ability, knowledge, originality, and aesthetic appeal, significant differences were also found in tolerance of ambiguity as well as school resources, where the eldest group scored significantly the lowest.
2. In terms of the F values, analyses with RT data seem to be more likely (57.9%) to produce bigger F values compared to the analyses with the original data.
3. In terms of the eta^2, analyses with RT data seem to be more likely to produce the same or larger eta^2 (e.g., for technical construct ability and knowledge) compared to the analyses with the original data.

Curriculum Vitae

Personal Data

Name	Min Tang （唐 敏）
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Education

10/2006 – 2/2010	PhD study at the Department of Psychology, Ludwig-Maximilians-University, Munich (LMU), Germany
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