

# Can Traditional Divergent Thinking Tests Be Trusted in Measuring and Predicting Real-World Creativity?

Liang Zeng, Robert W. Proctor, and Gavriel Salvendy  
*Purdue University*

Derived from the psychometric tradition of creativity research, divergent thinking (DT) tests are the major instrument for measuring people's creative potential. Although still prevalent, DT testing has received substantial criticism of its validity and practical value. This article focuses on the issue of how to reliably and validly assess and predict people's real-world creative potential. Based on reviews of the literatures on the concept of creativity, creative thinking process, the psychometric approach, and DT tests, we examine 6 major weaknesses of traditional DT instruments: lack of construct validity; not testing the integrated general creative process; neglect of domain specificity and expertise; and poor predictive, ecological, and discriminant validities. This evaluation calls for development of improved psychometric instruments to better capture people's creativity in specific professional domains of interest. Broadening the conceptions of creativity and assessment instruments should allow development of more realistic models and theories and enable the psychometric approach to studying creativity to thrive.

To pursue sustained development, society has placed more emphasis on creativity than ever before. It has been appreciated that creativity is a powerful propellant for social transformation and economic growth (Shneiderman, Fischer, Czerwinski, Myers, & Resnick, 2005), and that without creativity there would be no potential for continuous product/service innovation (Howard, Culley, & Dekoninck, 2008). Despite its importance, creativity has been covered by a patina of mystery throughout history, and its complexity leads many researchers to shun studying this phenomenon. Guilford's (1950) historical presidential address to the American Psychological Association motivated researchers to study this abstruse topic and inspired the now-thriving research field of creativity (Kurtzberg & Amabile, 2000–2001).

Over decades of research, creativity has been demystified to a large extent. However, a number of controversies still exist that are yet to be fully resolved. Among them, two of the most critical issues are: (a) How can an individual's real-life creative potential be reliably

and validly measured? (b) What constitutes the general creative process, and how can people's creativity be sparked? Answers to these two questions are still far from being complete, which affords broad room for further investigation. As to the first issue, researchers largely resort to the psychometric approach and rely heavily on divergent thinking (DT) tests to measure people's creativity. Yet, traditional DT instruments have been criticized for a perceived lack of validity and over-reliance on content generality, which has caused many researchers and practitioners to dismiss the psychometric approach (Chase, 1985; Gardner, 1988; Plucker, 1999). But, rashly abandoning the psychometric tradition may not buy researchers much. Instead, a careful appraisal of the weaknesses of conventional DT tests may help improve the measurement quality of current psychometric instruments and open doors to new research (Plucker & Runco, 1998). As to the second question, researchers have made rapid progress in unraveling the processes that underlie creative cognition, and thus understanding of the creative process has been expanded. General models of the creative thinking process have been proposed, but their validity has yet to be evaluated (Howard et al., 2008; Zeng, Proctor, & Salvendy, 2009b, 2010).

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Correspondence should be sent to Liang Zeng, School of Industrial Engineering, Purdue University, 315 N. Grant St., West Lafayette, IN 47907. E-mail: zeng@purdue.edu

This article concentrates on addressing the issue of how to reliably, validly assess and predict people's real-world creative potential. We review relevant literatures regarding the concept of creativity, creative process, the psychometric approach, and DT tests to pinpoint weaknesses of traditional DT instruments. We then summarize insights derived from this evaluation and discuss the benefit of developing creativity assessment tools tailored for specific professional domains.

## THE CONCEPT OF CREATIVITY

In developing a measure of creativity, it is important to first clarify the theoretical position the researcher holds, define the concept to be measured and its constitutional constructs, and specify the measurement criteria (Fishkin & Johnson, 1998; Kilgour, 2006). There is consensus that creativity is a multifaceted phenomenon, which renders it complex and suggests that a definition of creativity should depend on specific research interests. In the literature on creativity, Rhodes' (1961) four-perspective (4-Ps) model has gained wide acceptance. This model views creativity as a dynamic phenomenon comprised of four interactive components: person (people), process, product, and press (Couger, Higgins, & McIntyre, 1993; Fishkin & Johnson, 1998; Thompson & Lordan, 1999; Zeng et al., 2010).

With regard to the first component, creativity is assumed to be present in every individual, although creative geniuses are rare (Kurtzberg & Amabile, 2000–2001). It is found that the creative elite possess certain personality traits that would assist the creative thinking process. Creative thinking process, also referred to as creative cognition, involves cognitive processes and metacognitive strategies used by people to generate creative productions (Satzinger, Garfield, & Nagasundaram, 1999; Zeng et al., 2009b). A creative product should be one that is both novel and of value (Horn & Salvendy, 2006; Paulus, 2000; Runco & Charles, 1993; Zeng, Salvendy, & Zhang, 2009a). Researchers have developed quantitative tools to measure creativity of traditional hardware products and Web sites (e.g., Amabile, 1982; Besemer & O'Quin, 1986; Horn & Salvendy, 2009; Zeng et al., 2009a). Finally, the term *press* refers to the environmental or contextual factors affecting germination of creative productions (Couger et al., 1993; Thompson & Lordan, 1999).

This 4-Ps model suggests that researchers can delve into creativity from distinct approaches, and thus a definition of creativity should reflect the specific aspects of research interest. Although the multiple facets discussed previously make it difficult to provide a precise, unified definition of this elusive phenomenon, the literature has given multiple generic definitions that regard the

outcome aspect (i.e., product) as the distinguishing sign of creativity (Amabile, 1983). The rationale is that not only must a creative individual's personality characteristics be justified via the final work, but any cognitive process identified as creative must also be judged on its fruit. In addition, the influences of press can only be examined on a reliable, valid measure of the creative product (Amabile, 1982; Horn & Salvendy, 2006; Zeng et al., 2009b).

Based on a comprehensive review of over 50 years of research, the *Handbook of Creativity* (Sternberg, 1999) summarized various definitions of creativity as the "creation of new and useful products including ideas as well as concrete objects" (Mayer, 1999, p. 450). Horn and Salvendy (2006) defined creativity as "the individual or group process that results in an artifact (solution, thought, product, art, music, etc.) that is judged as original and useful" (p. 157). In addition, Weisberg (2006) defined creativity to be "the goal-oriented production of novelty" (p. 761).

These definitions indicate that two predominant attributes of creative products, novelty and appropriateness, are key in defining creativity (Zeng et al., 2009b). This contention is consonant with the perspective of creative realism that Finke (1995) suggested to adopt in the context of business and industry. Creative realism advocates the notion that a creative product should not only be original and inspiring, it must also effectively tackle real-world issues to satisfy shareholders' wants. In his research framework, Finke contrasted creative realism with three other views: creative idealism, conservative realism, and conservative idealism. Among the four, only creative realism emphasizes that novel creations should make sense in actuality. It requires a creative solution to be original and meaningful, but not excessively fanciful and infeasible. A product that is only novel, but odd, bizarre, and serves no purpose should not be considered as truly creative at all. The theoretical position of creative realism undergirds the most widely accepted two-aspect criteria of creativity, novelty and appropriateness (Amabile, 1998; Horn & Salvendy, 2006; Paulus, 2000; Warr & O'Neill, 2005; Zeng et al., 2010).

For the purpose of this study, creativity is broadly defined as the goal-oriented individual/team cognitive process that results in a product (idea, solution, service, etc.) that, being judged as novel and appropriate, evokes people's intention to purchase, adopt, use, and appreciate it. It should be noted that this definition emphasizes customer satisfaction and business success, reflecting the notion of commercial creativity (Zeng et al., 2009b, 2010). We argue that this emphasis should be applied to a variety of domains. Even in some special domains like art where self-actualization/self-expression is of much importance, customer reaction is still indispensable

in assessing the product's creativity if public recognition is desired.

### THE CREATIVE PROCESS

The creative thinking process refers to the sequence of cognitive activities that can lead to novel, yet appropriate, productions in a given problem context (Lubart, 2000–2001). Researchers who study the creative process are dedicated to unraveling the underlying cognitive constructs and subprocesses that inspire people's creativity. Historically, people have held that creativity is a special gift for a few select elite, and thus mundane people can hardly improve their creativity (Treffinger, Isaksen, & Dorval, 1994). Such a view leads to the assumption that the creative process is mysterious and cannot be studied rigorously. Yet, over decades of research, the seemingly abstruse phenomenon of creativity has been demystified, to a large extent, via the scientific approach. Researchers found that the so-called creative cognition and people's normative cognition share a lot in common in terms of basic cognitive operations. Creative cognition does not possess a specific, unitary cognitive process fundamentally different from that associated with standard cognition (Gardner, 1988; Smith, Ward, & Finke, 1995). Instead, it is the special combinations and patterns of the same cognitive elements as in noncreative endeavors that spur creative productions (Smith et al., 1995). This means that people can become more creative if they are trained to effectively apply appropriate metacognitive strategies to stimulate their creativity (Kilgour, 2006; Kurtzberg & Amabile, 2000–2001). The significance of studying the creative process thus becomes obvious: Although creativity is subject to the influences of a number of factors (e.g., personality, environment, etc.), it ultimately depends on how people think. Therefore, the creative process is deemed to be “the essence and the engine of any creative endeavor” (Smith et al., 1995, p. 1).

The creative process can be conceived of as a form of problem-defining and problem-solving. The abstract term *problem* refers to any goal an individual/team seeks to achieve, such as developing innovative products/services for a target market (Lubart, 2000–2001; Sternberg & Grigorenko, 2000–2001). A multitude of creative process models have been proposed in the literature, and a comprehensive review reveals that the general form of these models can be summarized as a linear sequence of four phases: problem analysis, ideation, evaluation, and implementation (Howard et al., 2008; Zeng et al., 2010; see Figure 1).

As the first phase, problem analysis initiates the entire creative process. The necessity of this stage is owing to the fact that an individual engaged in creative activities

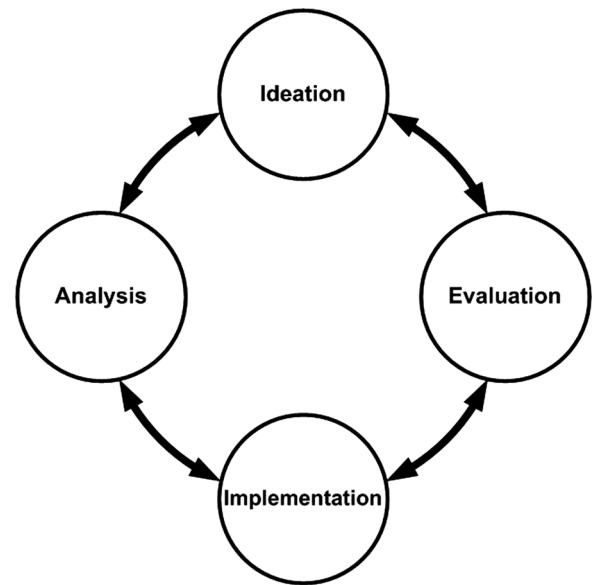


FIGURE 1 General model of the creative process.

often works in a problem-space that is initially not well defined. This entails appreciable redefining of the problem-space, reorganizing and narrowing down of operations, and so forth (Gardner, 1988). In this phase, people look for information to help them fully understand the immediate problem context and subsequently set up concrete problems to solve. Problem-finding and problem-formulating are the two major subprocesses in problem analysis (Isaksen & Treffinger, 2004; Lubart, 2000–2001). Problem-finding requires an individual to actively and continuously seek new opportunities that could help accomplish prespecified fundamental goals. Finding new and meaningful problems to solve is deemed to be more critical than merely finding solutions to already identified problems (Basadur, 1994). Subsequently, problem-formulating asks one to frame a general (and often vague) problem in multiple meaningful and concrete ways that would suggest possible solutions. It is suggested that one could discover even more new questions and possibilities by formulating a problem from multiple perspectives and at different levels of abstraction (Csikszentmihalyi & Getzels, 1971; Smith et al., 1995; Zeng et al., 2009b, 2010). Problem analysis is an indispensable stage in the creative process, and the way of defining a problem has a significant effect on the creativity of the final product (Kilgour, 2006; Volkema & Evans, 1995). In our opinion, this proposition should hold across different domains, even in art where self-expression is of much concern. In fact, a seminal study has evinced that the amount of effort made in problem analysis can significantly predict the creativity of artwork (Csikszentmihalyi & Getzels, 1971).

The second stage, ideation, motivates an individual to generate a variety of alternative solutions to already identified problems by employing DT. Evaluation is not allowed in this phase to support sustained idea generation (Basadur, 1994; De Bono, 1973). DT, in which unconventional possibilities, associates, and interpretations are explored, is the key engine to produce a wide range of ideas to a problem where more than one solution would work (Dacey, 1989). Ideation involves the following cognitive subprocesses: retrieval of pertinent information and categories from long-term memory, formation of links among those categories and their combinations, mental synthesis of new categories, mental transformation of existing categories into new forms, and analogical transfer of categories from one domain to another (Ward, Smith, & Finke, 1999).

With mainly convergent thinking involved, evaluation calls for specifying a set of criteria derived from those preidentified fundamental goals, and then using such criteria to analyze, refine, and select ideas generated. It helps the problem solver to see both positive and negative aspects of each proposed solution, refine, combine, and finally select the most promising ideas for implementation (Basadur, 1994; Lobert & Dologite, 1994). Evaluation also requires one to analyze the feedback information gleaned from actual implementation and then make necessary adjustment accordingly (Zeng et al., 2009a).

Finally, the stage of implementation recognizes that having proposed promising solutions is merely the end of the beginning. Unless the selected proposal is effectively executed and widely accepted, the creative process will not be considered as complete or successful (Basadur, 1994).

It is important to note that this general model of the creative process does not suggest a simple linear pattern composed of four segmented phases. Rather, the creative process should be recursive, dynamic, and evolving, instead of being a simple, static process where sequentially going through the four stages would guarantee producing highly creative solutions. The feedback from implementation may evoke the discovery of new challenges and possibilities as the press (or environment) reacts to the impact of implementation. Furthermore, the output from each of the four phases may indicate potential opportunities for adjustment, improvement, etc., which will suggest proceeding into subsequent phases or returning to previous stages for any necessary adjustment (Basadur, 1994; Lubart, 2000–2001; Zeng et al., 2010).

Last, but not least, it should be noted that there may never be a unitary model to completely capture humans' creative processes (Simonton & Damian, *in press*). There may exist a variety of mental processes that can stimulate creativity under different circumstances, which challenge an exhaustive search for the phases in creative

cognition (Mayer, 1999). The intent of our proposing a general creative process model is to lay a preliminary theoretical foundation that helps explain people's creative cognition and may even suggest possible interventions that can manipulate and enhance human creativity (Zeng et al., 2010). The proposed model of creative process is general, operational, and developmental, rather than unitary, prescriptive, and complete. The underlying rationale of proposing this model is not to assume the existence of a single, correct creative process, but to provide a theory that can be tested and may benefit human creativity development, rather than hold a worthless stance that creativity is mysterious and its process cannot be explained.

### THE PSYCHOMETRIC APPROACH TO MEASURING CREATIVITY

A wealth of research over past decades has developed diversified instruments to measure creativity, each focusing on specific aspects of creativity. Presently available measures of creativity can be classified into 10 categories: psychometric tools (DT tests), personality inventories, attitude and interest batteries, biographical inventories, peer nominations, teacher nominations, supervisor ratings, judgments of productions, eminence, and self-reported creative activities and achievements (Hocevar, 1981). Developing an appropriate instrument for assessing creativity thus hinges on the specific definition and research interests pertaining to this concept.

Researchers who are interested in aspects of people and cognitive processes have been mainly relying on the psychometric approach to studying creativity. By far, the largest amount of research in creativity assessment has been derived from the psychometric tradition, which forms the foundation of current understanding of this concept (Gardner, 1988; Plucker & Runco, 1998). DT tests are the major type of psychometric instrument in creativity testing. DT, the ideation phase of the creative process where a variety of ideas are generated in a problem context, has been viewed as a major determinant of creativity. DT batteries yield observable and quantifiable measures representing the individual's creative potential (i.e., the likelihood of producing creative solutions in a problem context; Fishkin & Johnson, 1998). It is viewed that the quest to quantify the creative process and people's potential for creative productions by way of using DT inventories has been "a lightning rod for the psychometric study of creativity" (Plucker & Renzulli, 1999, p. 39). More than the contribution of any other approach to studying creativity, DT testing sets the stage for developing creativity training programs in education and business. In addition, the DT measures are frequently used to identify creative

students and researchers globally (Plucker, 1999). In this section, four predominant creative thinking tests in creativity research and education are reviewed. These four batteries are quite similar in terms of test structure. Because the Torrance Test of Creative Thinking (TTCT) is most widely used and accepted of the four, it will be reviewed in greater detail.

### Structure of the Intellect (SOI) Divergent Production Test

The SOI divergent production test is based on Guilford's (1967) SOI model. The SOI battery captures an individual's potential of divergent productions in several areas, involving those of semantic systems (e.g., thinking of consequences if people no longer need to sleep), figural systems (e.g., constructing meaningful figures from sets of elements), and symbolic units (relating a set of numbers in different ways to get a certain result). There are several dozen such tests in the SOI divergent production inventory, and the scoring mechanism is based on the four criteria: fluency (the number of relevant ideas), flexibility (the number of categories which the responses fall into), originality (the number of unusual answers determined by relative statistical frequency), and elaboration (the number of details for a response).

### Wallach–Kogan and Getzels–Jackson Tests of Creative Thinking

The Wallach–Kogan Creativity Tests (WKCT) and Getzels–Jackson Creativity Tests (GJCT) are quite similar to the SOI inventory and the TTCT. The development of the WKCT is based on the associative conception of creativity, “the forming of associative elements into new combinations which either meet specified requirements or are in some way useful” (Mednick, 1962, p. 221). Thus, the task performance is scored on the number of associational responses generated under various contexts and the uniqueness of these responses (Wallach & Kogan, 1965). Table 1 summarizes the test

activities in the WKCT with their descriptions and examples.

The Getzels–Jackson (1962) battery consists of five major subtests: word association (generating definitions to stimulus words), uses for things, hidden shapes (finding the geometric figure hidden in a more complex pattern), fables (composing different endings for a fable), and make-up problems (proposing math problems in a context). Scores of these tests are also based on fluency, flexibility, originality, and elaboration.

### TTCT

The TTCT is the most well-known and -researched creativity test, enjoying widespread international use (Almeida, Prieto, Ferrando, Oliveira, & Ferrandiz, 2008; Cramond, Matthews-Morgan, Bandalos, & Zuo, 2005; Kim, 2006; Plucker & Renzulli, 1999; Treffinger, 1985). This instrument was developed by E. P. Torrance (1966a) and is based on many aspects of the SOI test (Plucker & Renzulli, 1999). Torrance's aim of developing TTCT was to provide a tool that can better capture an individual's creative potentialities and can accommodate people with different demographic properties. According to an analysis of diversified definitions of creativity and the emphasis on scientific research creativity, Torrance (1966a, p. 6) defined creativity as

a process of becoming sensitive to problems, deficiencies, gaps 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.

This definition serves as the foundation for developing the TTCT, yet the test itself is not an entire operational translation of such definition, or in other words it does not test the whole part of the definition. Torrance (1966a) acknowledged that he was not prepared to claim

TABLE 1  
Test Activities in the Wallach–Kogan Creativity Tests

<i>Activity</i>	<i>Description</i>	<i>Examples</i>
1. Instances (Verbal)	Generate possible instances of a class concept.	“Name all the round things you can think of.” “Name all the things you can think of that move on wheels.”
2. Alternative uses (Verbal)	Think of possible uses for an object.	“Tell all the different ways you could use a newspaper.”
3. Similarities (Verbal)	List possible similarities between two objects.	“Tell all the ways in which a cat and a mouse are alike.”
4. Pattern meanings (Figural)	Figure out possible interpretations of the given pattern in a drawing.	“Tell all the things each complete drawing could be.”
5. Line meanings (Figural)	Guess possible meanings of the line shown in a drawing.	“Tell all the things each drawing of line could be.”

*Note.* This table is developed from the discussion in Wallach & Kogan (1965).

TABLE 2  
Test Activities in Torrance Test of Creative Thinking Verbal Form A

<i>Activity</i>	<i>Description</i>	<i>Rationale</i>
1. Asking	Ask questions to know for sure what is happening in the drawing.	The essence of thinking (especially scientific thinking) is captured by the abilities of asking and guessing, which also reveals one's curiosity.
2. Guessing causes	Give possible causes that lead to the action shown in the drawing.	
3. Guessing consequence	List possible consequences resulting from the action in the drawing.	
4. Product improvement	List the cleverest, most interesting and unusual ways of changing a stuff toy elephant to make it more fun to play with.	This complex task has high face validity and a desirable type of thinking is involved.
5. Unusual uses	Think out possible uses for cardboard boxes.	It is a test of one's ability to overcome mental fixation. To measure one's divergent power. This type of thinking is important in creative behavior, and the task attempts to be more effective with children.
6. Unusual questions	Propose questions about cardboard boxes.	
7. Just suppose	List things that would happen in an improbable situation (i.e., clouds had strings attached to them which hang down to earth).	

*Note.* This table is developed from the discussion in Torrance (1966a, 1990).

how many dimensions of creativity the TTCT assessed, nor did he suggest that the results of TTCT should be the basis for decision-making. With Torrance's focus on understanding and nurturing people's creativity, the TTCT is not designed merely as a measure of creativity, but serves to foster people's creative thinking.

This test battery has two forms, verbal and figural. The verbal test includes seven activities, and the figural test has three tasks. The activities as well as their descriptions and rationale for inclusion in the TTCT are summarized in Tables 2 and 3. It is argued that some of the most important creative products are generated from the cognitive process in verbal and figural forms, although creative thinking may manifest itself in additional forms. In addition, the two forms should not be viewed as redundant. On the one hand, very little correlation ( $r = 0.06$ ) was found between performance on the verbal and figural tests (Cramond et al., 2005). On the other hand, the figural test can be administered to individuals who have verbal disabilities, are international and thus have language problems, or are young children with quite limited literacy. The verbal test takes 45 min in total to administer, with each subtest taking 5

to 10 min. The figural test requires a little less time (30 min in total).

In regard to the scoring criteria, the TTCT figural test scores an individual's creative potential in terms of originality and elaboration, and task performance on the picture completion and parallel lines is scored on fluency and flexibility. The scoring of the TTCT verbal test is simplified to involve only fluency, flexibility, and originality, due to the difficulty in attaining satisfied interrater reliability on elaboration with untrained referees (Cramond et al., 2005; Torrance, 1966a). Scores of subtests on each form can be aggregated to give total scores such as figural fluency, figural flexibility, and so on. These aggregated scores can then be transformed into standard T scores (Torrance, 1966a). Intersubtest correlations are moderate, generally ranging from 0.30 to 0.50. Yet there are high intercorrelations among the verbal fluency, flexibility, and originality, ranging from 0.74 to 0.80. Therefore, there is considerable overlap between these criteria, and an overall score might have more summation power (Chase, 1985).

The reliability of the TTCT battery involves two aspects, interrater consistency and test-retest consistency. High interrater consistency has been reported in the

TABLE 3  
Test Activities in Torrance Test of Creative Thinking Figural Form A

<i>Activity</i>	<i>Description</i>	<i>Rationale</i>
1. Picture construction	Draw a picture with a given tear drop shape as an integral part, and give a title for the drawing.	Test one's ability to find purposes and achieve them in different ways with adequate elaboration, which calls into play the tendency towards structuring and integrating.
2. Picture completion	Add lines to incomplete figures and give titles for the drawings.	
3. Parallel lines	Make picture from pairs of straight lines and entitle the drawings.	

*Note.* This table is developed from the discussion in Torrance (1966a, 1966b).

TABLE 4  
Similarities and Differences Between the Four Divergent Thinking Tests

<i>Similarities</i>	<i>Differences</i>
<ul style="list-style-type: none"> <li>• Mostly emphasizing the role of divergent thinking.</li> <li>• Similar task types, all requiring divergent generation of responses;</li> <li>• Similar scoring criteria, generally based on fluency, flexibility, originality, and elaboration.</li> <li>• Abstract tasks, most being different from real-world problems.</li> <li>• Mainly assessing children's creative potential for educational purpose, and accommodating people from children to adults.</li> </ul>	<ul style="list-style-type: none"> <li>• Task conditions: most batteries have time constraint in administration, while the WKCT does not.</li> <li>• Task contents: may be suitable for different domains.</li> </ul>

literature, ranging from 0.66 to 0.99 for trained classroom teachers (Chase, 1985). The test-retest studies reported consistency figures mostly lying between 0.50 and 0.93, which can be considered as satisfactory (Kim, 2006; Treffinger, 1985).

The validity of the TTCT mainly involves issues of construct validity and predictive validity. A majority of criticism has been directed toward its construct validity. It is not yet clear exactly what or how many dimensions of creativity is measured by the TTCT, as acknowledged by Torrance (1966a). In addition, it is doubtful whether individuals with high scores on the TTCT are truly creative (Sternberg & Lubart, 1996). Much of the research investigating the validity of the TTCT has taken a vulnerable approach by first sorting individuals on TTCT measures and then explaining the individual differences in terms of intelligence and personality (Chase, 1985). However, the correlation between the TTCT scores and measures of intelligence and personality does not make much sense due to a lack of theoretical backgrounds explaining what the real relation between those different measures should be (Chase, 1985). It is more desirable that examinees be first sorted on theoretically relevant objective criteria, and the construct validity of the TTCT battery can be upheld if the TTCT measures would agree with such sort.

With regard to its predictive validity, there is empirical evidence supporting that the TTCT measures can be significant predictors of later creative achievements. A 22-year follow-up study of elementary school students who took the TTCT indicated a predictive validity of 0.63, which is the value of a multiple correlation coefficient calculated from a stepwise multiple regression involving five criteria of creative achievement. A 40-year follow-up study of students from the same sample reported that TTCT could explain 23% of the variance in creative production (Cramond et al., 2005). Other variables such as motivation and opportunity can mediate creative productions.

So, to sum up, it is of paramount importance to recognize that the TTCT inventory only measures certain aspects of creative thinking abilities, but not all

dimensions of creativity. It has adequate reliability, yet does not have a firm base for its construct validity. Its scoring mechanisms could be further improved. The merits of the TTCT lie in that it has one of the largest norm samples and has been subjected to extensive longitudinal validations to demonstrate its predictive validity over wide age groups (Chase, 1985; Kim, 2006; Treffinger, 1985).

Table 4 summarizes similarities and differences between these four most widely used DT batteries. All of them are similar to each other in terms of test structure and scoring criteria. The major difference lies in administration conditions. Unlike other batteries with strict time limits, the WKCT adopts game-like, permissive, and untimed administration. The introspections of highly creative individuals suggested that a relaxed, permissive atmosphere is more conducive than a coercing, evaluative atmosphere to maximizing the generation of association. However, the effects of different test conditions on creative productions are far from being conclusive (Crockerberg, 1972; Plucker & Renzulli, 1999). It is interesting to note that those most popular DT instruments reviewed in this article have changed very little since their debut, which may indicate that this line of research is not inexhaustible (Plucker & Renzulli, 1999). Nonetheless, great room for improvement in testing creative thinking abilities can be identified upon scrutinizing presently existing DT batteries.

#### APPRAISAL OF TRADITIONAL CREATIVE THINKING BATTERIES

Although they are still popular measurement tools for people's creative potential, DT inventories have received substantial criticism of their value. Besides positive results, an amount of negative evidence has also accumulated, which indicates underlying limitations of current DT batteries and considerable room for further development. In this section, we appraise the weaknesses of conventional DT tests in six major aspects that weaken both reliability and validity of DT instruments, with the goal of identifying opportunities for amelioration.

### Construct Validity: Neglect of the Critical Criterion of Appropriateness

An assessment instrument should be designed in terms of the definition of the construct that it is supposed to measure. According to the definition of creativity in the literature, two crucial evaluation aspects (i.e., novelty and appropriateness) have been highly emphasized and most widely accepted, especially when the topic is real-life creativity (e.g., Amabile, 1998; Horn & Salvendy, 2006; Paulus, 2000; Weisberg, 2006; Zeng et al., 2009b, 2010). Empirical evidence has accumulated to substantiate that both novelty and appropriateness are indispensable in defining creativity across various domains, for example, creativity of traditional hardware products (Horn & Salvendy, 2009), of information technology products/services (Couger & Dengate, 1992; Zeng et al., 2009a; Zeng et al., 2010), and in the advertising industry (Kilgour, 2006).

Although the requirement of novelty/originality is represented in the scoring mechanism of presently available creative thinking tests, the criterion of appropriateness is neglected in those most popular DT inventories. Appropriateness refers to the extent to which a proposed solution can satisfy the demands posed in a problem context. Under the most prevalent scoring mechanism (i.e., fluency, flexibility, originality, and elaboration) as advocated by the TTCT, whether the response to a problem is appropriate and of practical value is not considered. The fluency and originality view of creativity held in conventional DT tests leads to considerable vulnerability of the current psychometric approach, because any idea, no matter how bizarre and inappropriate, would count as evidence of creativity. It is no wonder that some researchers have concluded that “fluency, flexibility, originality, and elaboration scores failed to capture the concept of creativity” (Sternberg & Lubart, 1996, p. 681).

One might argue that this problem can be easily fixed by adding *appropriateness* as a scoring criterion. However, should it be that simple, why would those developers of traditional DT tests not have tackled this issue? We argue that the key reason is that tasks in conventional DT tests do not have innate goals, which is possibly caused by employing abstract, unrealistic tasks. Evaluating an idea's appropriateness is not operational if fundamental goals of problem-solving cannot be clearly identified. For instance, to a DT task such as “list as many uses of a brick as possible,” a crazy idea such as “use the brick to hit an old lady's head” would at least score on fluency, originality, and flexibility, providing that few others gave this use. In most real-world situations, this idea would be regarded as malicious, inappropriate, and not truly creative. Yet, it might be novel and appropriate under some special circumstances.

Consequently, the lack of problem contexts in prevalent DT tests makes it impossible to clearly identify fundamental goals that solutions should meet, and thus validly measuring the real creativity of interest becomes questionable.

Admittedly, some researchers have tried to incorporate the criterion of appropriateness (or similar criteria such as quality and effectiveness) in assessing creative performance (e.g., Cropley & Cropley, 2000; Mumford, Supinski, Baughman, Costanza, & Threlfall, 1997; Runco & Charles, 1993; Runco, Illies, & Eisenman, 2005). However, this is not yet a standard practice of employing DT measurements, and appropriateness is not a scoring criterion of the four most prevalent DT inventories at all. Furthermore, due to the employment of abstract tasks lacking meaningful contexts in conventional DT batteries, the evaluation of ideation quality/appropriateness remains at a surface level, e.g., a brick is judged to be an inappropriate instance of square things simply because bricks are usually rectangular (Runco & Charles, 1993).

The lack of creative thinking measurement with sound construct validity may lead researchers to draw plausible conclusions from invalid empirical evidence. Torrance (1968) reported discovery of a fourth-grade slump in creativity, as indicated by the measures of TTCT, and concluded that third-grade students are more creative than fourth graders. Some researchers have even stated that most people harness less of their creativity ability as they mature (Couger et al., 1993). However, this conclusion is contradictory to most people's accepted belief and practice that “creativity is developmental and consistently increases with age and education” (Torrance, 1995, p. 320; Weisberg, 2006). Empirical evidence supporting the contention of consistent development of creativity was found in the domain of art (Baer, 1996). One possible explanation of this conflict is that people adopt more and more moral, ethical, and other standards as they mature, so that they provide fewer original but inappropriate responses, which is misinterpreted by traditional DT inventories.

In all, neglect of appropriateness causes current DT instruments' failure to fully capture the concept of creativity. When an individual is identified as creative, care needs to be taken to make sure that this person not only can generate multiple original, unique responses, but that the ideas generated are also of worth and value (i.e., appropriate). Especially in design of products/services, not only should a design be novel and unexpected, but it also should be of practical and business value so that people would like to purchase the product/service (Horn & Salvendy, 2009; Zeng et al., 2009b; Zeng et al., 2010). Neglect of appropriateness as a vital scoring dimension is where existing creative thinking tests fall short. Those most widely used creativity tests reviewed earlier mainly emphasize novelty and



acknowledge appropriateness as a criterion of creativity only to a limited extent. The TTCT might be more appropriately referred to as measures of fluency and originality, and the WKCT as measures of associational fluency and uniqueness (Crockerberg, 1972). Thus, it is reasonable to expect that design geniuses who can come up with most novel and commercially competitive products may not be those who score highest on current DT tests.

### Not Testing the Integrated General Creative Process

Another major shortcoming of existing creative thinking tests is that there is little relation between subtest activities. Each subtest may evaluate one aspect of creative thinking, but neither a single subtest nor the task activities as a whole assess an examinee's creative potential by taking into account an integration of fundamental phases in the creative process. According to the general creative process discussed earlier, there are four major phases: problem analysis, ideation, evaluation, and implementation (Howard et al., 2008; Zeng et al., 2009b). Most existing creative thinking batteries, as represented by the TTCT, emphasize ideation and, to a rather limited extent, analysis, but the phase of evaluation has received very little attention.

Wakefield's (1991) situational theory of thinking skills suggests that creative thinking is entailed in open-problem, open-solution situations, in which one needs to combine both problem invention and expressive problem-solving skills. The current DT tests mainly represent closed-problem, open-solution situations that only call for problem recognition and expressive problem solving. Consequently, current creative thinking tests "may be better thought of as measures of expressive problem-solving than of creativity per se" (Wakefield, 1991, p. 191).

On the other hand, evaluative skill is also paramount in identifying promising alternatives for further enrichment. Explicit evaluation, with mainly logical and convergent thinking involved, is a crucial constituent of the entire creative thinking process. It is imperative whenever a decision maker selects promising ideas for implementation or determines whether further iteration of the creative process is needed (Plucker & Renzulli, 1999; Runco, 1991). Both DT and logical reasoning play important roles in creative production (De Bono, 1973; Holt, 1982). The latter, i.e., the evaluation phase, is unfortunately neglected in most existing creativity tests. No wonder it is likely that one would list a brick as an instance of square things (Runco & Charles, 1993). In all, evaluation is a vital constituent that operates throughout all stages of a creative behavior sequence (Guilford, 1967). Without taking evaluative skill into account, accurate assessment of creative potential can never be achieved.

These facts may explain why most present assessments of creative thinking only have moderate validity, as other important components are not taken into account (Runco & Vega, 1990). The research on testing creative thinking abilities is occupied almost exclusively with measuring and enhancing ideational productivity. Because ideation is only one aspect of the entire creative process, "its predominance devalues the integral role of creativity in the solving of problems" (Plucker & Renzulli, 1999, p. 41).

Furthermore, there are interactions among individual phases within the creative process (Runco & Vega, 1990). Performance of problem-finding is significantly related to problem-solving, and more highly correlated with criteria of creativity than is problem-solving (Chand & Runco, 1993). In addition, problem-finding significantly explains additional variance in predicting creative achievements (Runco & Vega, 1990). Problem-finding and formulating is closer to the heart of scientific and design creativity than problem-solving, as better identified and formulated problems are often half-solved (Wakefield, 1991). On the other hand, ideational productivity and evaluative skill are significantly correlated with each other. These two constituents are interrelated but not redundant, and there may be a functional relation between them (Runco, 1991). Individuals who are highly capable of DT may have a better appreciation for novel ideas (Runco & Vega, 1990).

Solely testing the original and divergent thought process alone does not fully account for people's ability in generating creative breakthroughs (Kilgour, 2006). In real-life problem contexts, the four fundamental phases of the creative process should all function to produce highly creative (i.e., novel and workable) solutions. Numerous creativity researchers have pointed out that DT should not be treated as synonymous with creative thinking. Apparently, the task activities that make up the current creativity tests are not conducive to high-level creative responses (Crockerberg, 1972).

As Torrance (1966a) argued when developing the TTCT, one would measure an athlete's jumping potential by measuring the highest level she or he could jump. The same rationale should apply to assessing an individual's creative potential. Because the four fundamental phases are indispensable and conducive to high-level creativity, one's creative thinking ability should be measured at its peak when the individual has gone through the entire creative thinking process. Therefore, a desirable instrument for assessing creative thinking should consider all important phases of the creative process in each subtest or in the test as a whole. We suggest that tasks used in DT testing should include problem contexts that can help one first identify basic goals so that the individual can then conduct goal-oriented creative thinking by proceeding through problem analysis, DT,

and convergent thinking recursively to produce innovative and valuable products. It may be challenging to integrate our expanded conceptions of creativity (i.e., problem analysis and evaluation) into psychometric investigation instruments. However, upon this very effort, more realistic models and theories can be developed and tested (Plucker & Runco, 1998).

### Domain Specificity and Expertise

Existing creative thinking measurement tools have been criticized for overreliance on content generality and failure to consider the role of domain-specific expertise in creative productions. Gardner (1988) argued that the assumptions that a creative proclivity in one domain can predict that in another domain and that creative products resemble one another across domains are both quite vulnerable. Theoretical and empirical evidence accumulates to support the notion that creativity is domain specific (Plucker & Runco, 1998). Throughout history, people's significant creative works are almost entirely restricted to a single domain. Although the general creative process is the same across domains, content-specific knowledge is a prerequisite for most creative advances and such domain-specific expertise cannot be easily transferred across domains (Proctor & Van Zandt, 2008). Therefore, most people can only make appreciable creative contributions to the domains in which they have cutting-edge expertise (Smith et al., 1995).

Domain-specific expertise has been found to be closely tied to creativity (Weisberg, 2006). Creative individuals rely on their content-specific knowledge to reason about the immediate problem situation and produce creative solutions accordingly. In addition, domain-specific expertise lays the foundation for transfer of knowledge to new situations. Expertise does not just represent mindless, automatic processing. Rather, it helps the problem-solver build rich, complex mental models to represent and reason about various situations. Only by expertise (i.e., deliberate practice and extensive experience) can an individual construct a detailed and appropriate mental model of a situation needed to support adaptive processing and creative thinking. Deliberate practice, the basis for expertise, in turn, is responsible for consistent superior performance that can be considered as creative (Ericsson, 1998, 1999; Weisberg, 2006).

Weisberg (2006) conducted case studies of world-renowned creative elite and their works in multiple disciplines: music (Mozart and the Beatles' masterpieces), art (Picasso's *Guernica*, Calder's mobiles, and Pollock's poured paintings), and science (Watson and Crick's discovery of the double helix, the Wright brothers' airplanes, and Edison's light bulb). His research provided solid evidence to corroborate that (a) expertise is

necessary for creativity, and (b) the 10-year rule for developing expertise also holds in the development of creative thinking. In all, innovation depends on domain-specific expertise, and deliberate practice plays a vital role in the development of that expertise.

There is still debate about under what conditions creativity will be domain general or specific (Plucker & Runco, 1998). Empirical evidence in natural contexts has indicated that creative thinking occurs in complex and information-rich contexts that entail the use of domain-specific expertise. In contrast, problem-solving activities in laboratory contexts are much simpler and bare of information, and thus general expertise by itself can suffice (Weisberg, 2006).

Experts in one domain typically perform no better than novices when they encounter problems in another domain. Hence, creativity cannot be apprehended exclusively from a multidisciplinary perspective. Thereby, the extent to which standard DT tests can predict creative potential in different domains is questionable. Studies have shown that at the amateur, nonprofessional levels, DT ability is positively correlated with creativity in everyday life. However, the relations have been too weak to state that enhancing performance in DT tests would affect real-world creativity, let alone foster creativity in different domains (Mansfield, Busse, & Krepelka, 1978). Some studies found that the TTCT measures of students from elementary and high schools do not provide reliable prediction of nonacademic achievements, and that TTCT lacks predictive validity in identifying creative scientists or artists (Feldhusen & Goh, 1995). So, to sum up, relevant research in expertise should call attention to the lack of valid and reliable creativity assessment tools in professional fields. We suggest that the tasks used in creative thinking measurement should incorporate testing of domain-specific expertise according to the specific application area of interest.

### Predictive Validity

Given the weaknesses previously discussed, there is little surprise that the predictive validity of existing DT inventories has been criticized. Longitudinal studies showed that the correlations between creative abilities as measured by DT tests and prediction of later creative achievements typically range from 0.2 to 0.3 (Sternberg & Lubart, 1996). Although Torrance reported significant correlations between TTCT measures and later self-reported and documented creative performance, many researchers have failed to find such desired relations. Consequently, there is widespread doubt of DT instruments' power in predicting consensually-validated creative accomplishments (Gardner, 1988). Additionally, DT tests have proved inconsistent with other measures

of creativity, because individuals who rank highly on one instrument do not necessarily rank highly on others (Hocevar, 1981).

With an emphasis on real-life creativity, Kogan and Pankove (1974) conducted research to examine the predictive power of the WKCT in terms of nonacademic achievement. Measures of fifth-grade DT performance was of little prognostic value for nonacademic creative achievement in high school, yet that of tenth-grade ideational productivity was of marginally significant predictive power. Because extracurricular attainment was argued to be a joint function of divergent and convergent productions, Kogan and Pankove concluded that research on DT can be faulted due to lack of evidence for predictive or concurrent validation of test performance against real-world criteria. In a recent investigation, Brougher and Rantanen (2009) reported that the measures given by conventional DT tests (i.e., TTCT and remote association tests) are not significantly correlated with design performance and concluded that creativity measures by prevalent DT tests do not appear to relate to design ability.

A number of assessments of the predictive validity of existing DT batteries have been negative and pessimistic (Plucker, 1999). More than any other factor, the perceived lack of predictive power of DT instruments has dissuaded researchers and educators from employing them (Plucker & Runco, 1998). This fact calls for the critical need to improve current instruments so that they are able to better predict real-world creative accomplishments.

### Ecological Validity

Conventional DT tests that use abstract tasks have been criticized for their low correlations with real-world creative performance across different domains (Feldhusen & Goh, 1995; Mansfield et al., 1978; Okuda, Runco, & Berger, 1991). This lack of ecological validity is probability due to the artificial and limited format of standard DT batteries. The traditional DT measures are more highly correlated with performance in creative writing than other domains. Therefore, researchers have suggested that one should not equate measures of conventional DT tests with real-life creativity, and that real-world problems should be used to assess creativity in a certain domain (Okuda et al., 1991).

It has been found that real-world problem-finding performance is more reliable and predictive of creative achievements than standard DT tasks that do not involve real-life problems. The correlations between standard DT measures and other assessments of creativity seldom exceed 0.30, yet the correlations between the real-world problem-finding performance and creative activities are all significantly greater than 0.30, with an

average of 0.49. In addition, real-world problem-finding measures correlate significantly with creative performance across domains, including science, crafts, music, writing, and public performance (Okuda et al., 1991). Furthermore, it is suggested that the perceived relevance of testing tasks to real-life activities may affect one's motivation and test performance (Kilgour, 2006). So far, little research has been conducted employing real-world problems to assess creative potentials in certain domains, which implies appreciable room for further improving conventional DT tests.

### Discriminant Validity

Another issue related to construct validity is the discriminant validity of the scoring criteria. A good many of studies demonstrated that the scoring factors of current DT tests are dependent on contents of subtests (i.e., task sensitive) rather than the claimed four scoring dimensions of creativity (i.e., fluency, flexibility, originality, and elaboration; Kilgour, 2006; Plucker, 1999). Furthermore, these four dimensions lack mutual independence (i.e., discriminant validity). It was found in Guilford's (1967) DT tests that when fluency subscores are partialled out, the originality subscores become unreliable. In the TTCT verbal test, when fluency submeasures are partialled out, both flexibility and originality subscores become unreliable. In the TTCT figural test, one general factor can adequately explain an examinee's task performance. It is suggested in these studies that fluency is the major dimension measured in both Guilford's DT tests and the TTCT (Clapham, 1998). The TTCT scoring mechanism has been criticized for its lack of discriminant validity. Subscales are so highly intercorrelated (0.74 to 0.80) that each of them does not provide meaningfully different information (Almeida et al., 2008; Clapham, 1998; Feldhusen & Goh, 1995; Kim, 2006; Mansfield et al., 1978). It has even been contended that "the evidence of consistently different meaning for the fluency, flexibility and originality scores is almost vanishingly small" (Heausler & Thompson, 1988, p. 466).

## CONCLUSION

Our evaluation of DT research has led to the following insights:

1. Novelty and appropriateness should be the two predominant criteria in assessing creative thinking products. Measurement tools that fail to involve either of these two criteria do not have sound construct validity.
2. An individual's creative potential would be more validly and reliably measured based on the final

productions resulting from the integrated creative thinking process, instead of the individual products from separate, segmented cognitive phases.

3. Although the general creative thinking process can be domain general, creative endeavors in the natural world rely on the development of domain-specific expertise. Thus, a creativity test employing problems in a certain domain of interest will have better face validity and may be more predictive of an individual's creative potential in that specific field than a standard assessment instrument.

In light of the preceding discussion, no creative thinking test can purport to represent a comprehensive and adequate assessment of people's creative potential across multiple domains (Treffinger, 1985). Although conventional, standard creative thinking tests can be used for many different domains and purposes, they have not proved satisfactory in terms of measurement validity and reliability. Such tests might be better suited for testing children's creativity in educational settings where domain-specific expertise is not yet developed and required. The merit of an instrument specifically designed for a professional domain of interest is that it may do a better job in measuring and predicting creativity when specialty plays a critical role. It may be effort-demanding to tailor creativity tests to different domains, but such effort will be worthwhile if the quality of measurement is of a serious concern in some major domains. For example, in the industry of product/service development, creativity is deemed to be an exceptionally desirable characteristic of designers (Brougher & Rantanen, 2009), and thus reliably and validly measuring the designer's creative potential is important for forming productive research and development teams and evaluating the effectiveness of creativity training programs. Due to our interest in measuring the designer's creative potential in real-life product/service innovation, we aim to develop and evaluate a creative thinking test for this application domain in our future studies.

Our general conclusion is that researchers need to devote more effort to broadening assessment tools by integrating into them expanded conceptions of creativity. By doing so, the psychometric approach to studying creativity will not only rise from its rumored sick bed but also begin to thrive again (Plucker & Runco, 1998).

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