

# Snowflakes, Living Systems, and the Mystery of Giftedness

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**Abstract:** The main argument of this article is that human living systems are open, dynamic, intentional systems and, therefore, are capable of building ever more complex behaviors through self-organization and self-direction. This principle underlying general human development is also applicable to the development of gifted and talented behaviors. These behaviors are dynamic because persons demonstrating such behaviors are forming dynamic, functional relations with a specific environment, with unique temporal trajectories capable of engendering emergent properties that feed into further development. This Contextual, Emergent, and Dynamic Model provides an alternative to traditional static, reductionistic, trait-based conceptions of giftedness. The article further elaborates on three dynamic facets of the making of gifted potential: selective affinity, maximal grip, and being at the edge of chaos. These facets allow for dealing with the genesis of talents, developing expertise over an extended period, and developing creative potential.

**Putting the Research to Use:** The practice of gifted education is always guided by one's implicit or explicit theory of what constitutes giftedness or what makes some children gifted. This article attempts to situate giftedness in its functional context and show its dynamic and emergent qualities rather than defining it as a set of traits. If giftedness is a dynamic quality that has a developmental trajectory, then we need to be very specific about interventions. Because of its focus on developmental processes, the Contextual, Emergent, and Dynamic Model can help specify educational programming in terms of goals, tools, and support needed to facilitate specific lines of development for a given child or a group of children at a specific point in time. Assessment (identification) and educational provisions inform each other and thus become an integrated system. The dynamic facets of selective affinity, maximal grip, and being at the edge of chaos elaborated in this article can be readily used as heuristics to frame curricular goals and educational experiences.

**Keywords:** *talent; intelligence; creativity; nature-nurture; domain and context specificity; state versus trait; dynamic systems and organized complexity; Systems 1 and 2 cognitive representations and processes*

Growth is the key ingredient for the generation of snow-crystal patterns. . . . Even the tiniest protruding points will grow faster than their surroundings and thus protrude even more. Small corners grow into branches; random bumps on the branches grow into sidebranches. Complexity is born.

—Kenneth Libbrecht (2004, p. 25)

Complex systems tend to locate themselves at a place we called “the edge of chaos.” We imagine the edge of chaos as a place where there is enough innovation to keep a living system vibrant, and enough stability to keep it from collapsing into anarchy.

—Michael Crichton (1996, p. 4)

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Living in the Northeast, we perennially deal with the “white stuff,” sometimes enjoying its chilling beauty, other times getting annoyed with the hassles it brings to our lives. But how are snowflakes formed, and why do they have various shapes? Libbrecht (2004), a CalTech

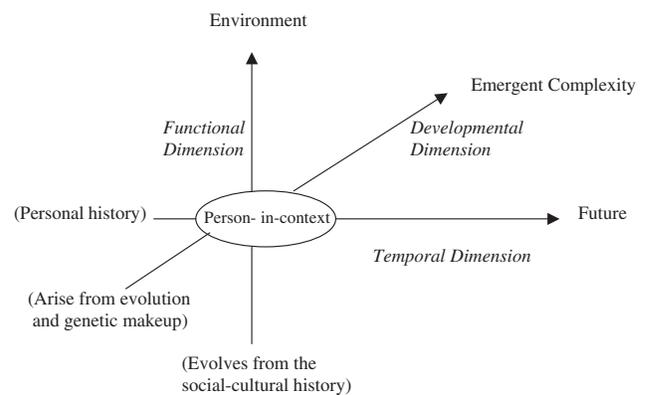
professor of physics, has found snowflakes to be a wonderful example of nonlinear, nonequilibrium systems. It is a tale of how simple structures like water molecules can start with some erratic dance in the air, but with the right temperature and moisture levels, vapor condenses and grows into varied shapes. What is marvelous about snowflakes is that there is no designer or blueprint, no genetic code that gives instruction for the apparently highly orderly construction of hexagon patterns (Libbrecht, 2004). It is a tale of the spontaneous creation of complex patterns. The emergent complexity is largely due to branching instability, a tendency of a nascent snowflake to branch out in an accelerated rate.

Now consider organic forms of complexity—living systems. Living systems share one thing in common with snowflakes: They self-assemble and self-organize. If the shaping of snowflakes reveals much of physics, mathematics, and chemistry, the evolving of living systems allows us to delve into the more complexly organized existence of the biological, psychological, sociocultural nature. Living things have, over millions of years of evolution, developed complex nervous systems, consciousness, language, and shared technology, which enable *homo sapiens* to achieve a maximal fit through learning and development in an unprecedented manner (Dawkins, 1995). An adequate theory of human functioning and development, including a theory of high human potential or accomplishments, needs to consider all those properties bestowed on an individual human living system through phylogeny (i.e., evolution of a species) and ontogeny (i.e., individual development).

There are three basic dimensions of humans as dynamic, open living systems: functional, developmental, and temporal (cf. Ford, 1994).

1. *Functional dimension.* In Figure 1, the vertical line refers to the person-environment functional relations and the nature of an individual as an open, self-directed, adaptive system, constantly exchanging energy and information with its environment, capable of changing itself as well as its environment. Consider a simple example of an infant attempting to reach out and grasp a toy. An infant and a toy here constitute a functional relation: A toy invites grasping, so to speak (technically called *affordances*) but it also poses challenges to an infant (technically called *task constraints*). What we characterize as gifted and talented behavior or performance always involves a unique set of functional relations, particularly the effectiveness of the person's functioning vis-à-vis affordances and demands of a specific task environment.

**Figure 1**  
**A Schematic Representation of Three Critical Dimensions of Human Functioning and Development**



Note: The oval indicates a unit of analysis that intersects the three dimensions. The arrows signify the evolving nature of the three dimensions and do not indicate functional relationships.

2. *Temporal dimension.* The horizontal line indicates the temporal dimension of a dynamic system: transactions and interactions between an individual agent and a task environment take place through time. The temporally evolving nature of these interactions can be represented as a trajectory through a state space. For example, an infant may initially fail to grasp the toy in question, but with improved visual-motor coordination over time, the infant finally succeeds (Smith & Thelen, 1993). The arrow here also suggests the future-oriented nature of human behavior; that is, a self-directed human agent always anticipates future states of an action (even for an infant or toddler, what developmental psychologists call *means-end readiness or sensitivity*) and behaves accordingly (e.g., making self-corrections based on feedback). Thus what we describe as gifted and talented behaviors not only are situated functional relations but also have a temporal trajectory (evolving from the past state and moving toward a future state).
3. *Developmental dimension.* The diagonal line indicates the developmental dimension. We define *development* as incremental or qualitative changes occurring to the developing person, on various timescales, while interacting with a specific task environment. Thus, an infant's engagement in coordinated motor acts promotes the development of coordination skills (to use Piaget's term, a "grasping scheme" is developed). Although biological maturation contributes to growth,

it is contingent on experience, learning, and cultural provisions, which play an indispensable role for much of human competence of the intellectual, artistic, or practical nature. Therefore, development involves orderly changes as a result of adaptive interactions of the individual with an environment (the functional dimension) over time (the temporal dimension).

In sum, development of competence is situated in functional contexts, and person-task interactions and transactions have a characteristic temporal trajectory (latency, fluctuation, centralization, stabilization, increasing mechanization, etc), with competence as emergent self-organized complexity of human behavior. From this perspective, manifested gifts and talents are emergent properties of person-task transactions over time. This general principle applies to child prodigies as well as adult eminent accomplishments.

As can be seen in the above brief delineation, we treat gifted and talented phenomena as a special case of human development following the same general principles of the human living system as open, dynamic, and intentional rather than exceptional to these general principles. It is also consistent with the following basic tenets of human development:

1. *The tenet of the flexible agency.* Unlike other animals, which have relatively fixed, preformed developmental pathways, human biology affords individuals neural plasticity and cognitive flexibility in development. This is largely due to the human ability to acquire complex skills through learning and extended periods of development, which maximally enhances effectiveness, individually and collectively. In short, human beings are not just rigid, reactive creatures, but flexible, creative beings.
2. *The tenet of differential development.* Individual human beings have genetically shared and unique predispositions, propensities, and potentialities. However, specific developmental paths and trajectories of a person are contingent on environmental experience and learning, with early upbringing, socially structured activities, and fortuitous encounters all playing a role. Given the same environment, genetic predispositions bias the developing person toward certain directions and pathways, but in and of themselves they do not determine developmental outcomes. Given the same genetic makeup (e.g., identical twins), different opportunity structures and environmental experiences help shape differential developmental pathways and trajectories.
3. *The tenet of self-organization and temporal emergence.* Many aspects of mental functioning show dynamic instability (like snowflakes), capable of

self-engendered adaptive changes (e.g., error detection and self-correction) online and offline to enhance their effectiveness in specific contexts, resulting in emergent patterns of behavioral and psychological complexity. It is important to note that self-organization here is a spontaneous process as the person-environment interaction temporally unfolds: “There is no ‘self’ inside the system responsible for emergent pattern. Rather, under certain conditions, the system organizes itself. There is no ghost in the machine, instructing the part how to behave” (Kelso, 2000, p. 65).

4. *The tenet of self-directedness.* Although there is no *homunculus* inside the head, human beings are capable of regulating and directing one’s own behavior according to one’s intention and determination. Self-directedness is a special law applicable only to intentional living systems. Because of self-awareness, reflectivity, and the capability of reconstructing the past, representing the present, and modeling the future (Edelman, 1989), human beings are unique in their capability of exercising self-direction and self-regulation through feedback control of current goals or feedforward anticipation of future states. It is in this sense that some developmental theorists consider humans as producer of their own development (e.g., Lerner & Busch-Rossnagel, 1981).
5. *The tenet of balancing instability and stability.* This is a challenge any complex, open living system has to face. To be viable and creative, complex living beings have to avoid rigidity on one hand and chaos on the other. They have to be sensitive to new stimuli to make adaptive changes yet stable enough to function appropriately and not get overwhelmed by the bombardment of new information and stimulation. For extreme developmental complexity and novelty to occur (e.g., to be creative), however, “self-organized systems may even tune themselves to stay near critical points” (Kelso, 2000; see also the quote from Crichton, 1996, at the beginning of the article).

Development of exceptional competence in whatever line of human endeavor does not deviate from these basic tenets but highlights them. How do we investigate the development of exceptional competence in a way consistent with these principles? The answer is to explore proper units of analysis and research methodology that allow one to observe these principles in action. Specifically, we need to look at the genesis of exceptional competence in terms of a developmental process involving both the developing person (endogenous) and engaged environment, symbolic, social, and physical (exogenous). This process may take place at the micro level (days and weeks) or

macro level (months and years, or even decades). However, essential facets of this process remain invariant.

### **Three Dynamic Facets of the Making (or Breaking) of Gifted Potential**

In the rest of this article, we explore three critical facets of the making of gifted potential and ultimate achievement: selective affinity, maximal grip, and at the edge of chaos. Note that these metaphorical terms all imply an active state of feeling, thinking, and doing, which can only be observed in behavioral episodes of some length, including experimental conditions (e.g., Kanevsky, 1990). They flesh out the basic tenets of the Contextual, Emergent, and Dynamic Model (CED model) and specify how the unit of analysis we use captures the contextual, dynamic, and emergent character of gifted potential and achievement.

#### **Selective Affinity: The Emergence of Sensibilities and Primary Selection**

A prevalent observation of gifted and talented children is their spontaneous manifestations of specific talents or strong interests, sometimes bordering on obsession (e.g., Feldman, 1986). This observation is often the basis for inferring genetically based abilities, aptitudes, and talents. Although the inference may have some validity, what often gets obscured is that these abilities, attitudes, or talents are relational property of person-object or person-task functional dynamics. We characterize such a pattern of spontaneous, emergent functional relations as *selective affinity*.

*Selective affinity* is a term used frequently in the chemical and biological research to describe a broad array of biochemical phenomena of selective binding of chemical substances. We use the term to refer to an individual's predisposition or propensity for a specific class of activities, objects, phenomena, ideas, or people—what Edelman (1995) called *values* of biological systems or what Panksepp (1998) characterized as the *seeking system* in the brain. Indeed, human selective affinity is evident in play preferences in early childhood, and may also have a biochemical basis, such as dopamine effects (Panksepp). To use Dabrowski's (1964) term, individuals have different kinds of *overexcitability* (see Piechowski, 1991). In this sense we call selective affinity *primary selection* because it indicates some domains of activities are biologically privileged for children, normatively and

differentially. For example, as young children, Darwin and Piaget showed fascination with biological objects. Piaget published his first essay on the albino sparrow when he was 10 (Miller, 1993, p. 31)! Selective affinity also occurs in chance encounters or fortuitous events, depicted as crystallizing experiences (Freeman, 1999; Walters & Gardner, 1986).

*Exogenous and endogenous factors.* There is a spontaneous, microlevel self-organization and patterning of various functional units (e.g., neural circuits) in the brain in the service of producing such an affective binding (see Panksepp, 1998, Chapter 8), a process best called co-incidence (Feldman, 1986). A view of development as determined by physical and mental states does not mean that we cannot map out general control parameters that contribute to these states. In human development, such control parameters necessarily include both exogenous (external) and endogenous (internal) forces in complex interactions. On the exogenous side, there are many environmental factors that determine the probabilistic nature of development. For example, opportunity structure determines what one is exposed to and what choice is available at a specific point in time. Culture determines the relative distinction of a specific line of human endeavor. Selective affinity also takes much social mediation in formative years. For example, Richard Feynman (1999), a renowned physicist, felt indebted to his father for early nurturing in him a passion for finding things out for oneself. Social mediation can also take indirect forms, as in the case of a child who lost a loved one to cancer and aspired to be a cancer researcher. In such a case, early interests may be caused by extrinsic reasons but gradually achieve functional autonomy.

On the endogenous side, there is competition for distinction and salience of values within the living system, some inhibited and others played up. For the young Kevin Spacey, motion pictures were not just a pastime but a passion, an enduring interest that bore fruition in his adulthood (IMDb Editors, 2005). Another important endogenous factor is developmental timing. A child may shift his or her selective affinity from one object to another as a result of developmental changes (Shavinina, 1999). For example, Piaget was interested in mechanics, fossils, and birds as a young child but immersed himself in philosophical writings of Kant, Bergson, and many others as an adolescent (Miller, 1993), presumably due to his cognitive maturation. Thus, the process of mutual sampling is time sensitive (D. K. Simonton, 2005) depending on (a) the biological readiness of a specific individual, (b) the nature of a

domain, and (c) the timing of domain experience. For domains that do not heavily rely on social experiences (e.g., math, chess, music), the onset of selective affinity may occur very early and trajectory may be quite stable (e.g., Lubinski, Benbow, & Ryan, 1995). For domains that involve interpersonal skills and social-emotional maturity (e.g., political or organizational leadership), the onset may be later and trajectory less predictable (but see Hatch, 1997).

*Aptitude as an emergent property.* D. K. Simonton (1999, 2005) postulated that a talent in a complex domain is not one thing but a combination of several personal characteristics. However, how do these characteristics come together? Our answer is that the system is self-organizing through selective affinity in that the experiential encounters create new schemata (e.g., for music, or more specific, classic music or jazz) and in that many components of the system are co-opted in the process and gradually become a functional unit or module. For example, tuning into music binds instrumental (perceptions of tonal changes and rhythms) and expressive (emotions and feelings) elements (Sloboda, 1990). The result is an emergent sensibility of some sort.

Sensibility, as a concomitant or result of selective affinity, has perceptual and cognitive underpinnings (e.g., modules, schemata, mental models). The term *sensibility* is used here because, unlike the notion of ability, it retains a perceptual quality of being sensitive to a particular kind of stimulations or situations (e.g., epistemic curiosity or sensitivity to human concerns). In other words, it is perceptual and domain specific. These sensibilities are emergent, rather than innate, properties. To make an analogy with snowflakes, they evolve like tiny protruding points of a snow crystal, quickly growing into specific shapes. Using the two-system framework proposed by cognitive scientists (e.g., Kahneman, 2003; Stanovich & West, 2000), sensibilities are best characterized as System 1 qualities (e.g., perceptions, intuitions, sensitivities), which are fast, effortless, associative, affective, automatic, and consciously inaccessible, compared to System 2 qualities (e.g., thinking, reasoning, problem solving), which are slow, effortful, conative, rule governed, and consciously accessible. We distinguish between sensibility as a nascent form of talent and expertise as full-blown one, systematically developed (Gagné, 2004) because it is still nebulous, not refined and fully articulated.

*Temporal trajectories.* Dynamic system theory and general system theory use the term centralization to describe the extent to which some elements in the

system dominate the course of its developmental trajectory (Wachs, 2000). Situations or activities that yield positive emotions are further sought, and the bond strengthened, not unlike operant or instrumental conditioning. Selective affinity tends to strengthen itself (even self-perpetuating), leading to what Renzulli (2002) called a *romance*, an extended period of deep engagement in a topic or domain (see also Renzulli & Dai, 2001). As human beings are self-directed, intentional agents, selective affinity differentiates the environment for the self (i.e., perceptually structuring the environment in their own ways) and, by so doing, differentiates the self (i.e., perceiving selective affinity as a self-defining moment; see Damasio, 1999). Gibson (1979) put it succinctly: “One perceives the environment and conceives oneself” (p. 127). Thus, the temporal trajectory of selective affinity reflects the tenets of self-directedness as well as self-organization. As a phenomenal (subjective) experience, selective affinity may further evolve into enduring life themes, as the example of Spacey shows.

*Selective affinity as indicative of niche potential.* It is possible that selective affinity may be a false alarm, only to be found ill informed, even illusionary. Indeed, it is a nature’s gambit that can occasionally misfire. However, in most instances, selective affinity indicates a goodness of fit. For example, Kevin Spacey has a set of characteristics that fit well with acting, for example, his flair for mimicking celebrities displayed very early on, his intellect for grasping the essence of a matter, and his precocious sensitivity to human conditions. Even his impulsivity, which caused major troubles during his adolescence, became a plus for a theatrical personality.

*Summary.* Selective affinity is an early indicator of niche potential (Wachs, 2000). An emergent talent can be better seen as a bootstrapping (fitting) process of achieving a maximal fit between a developing person and a task environment. A major difference between our conceptions and traditional conceptions is that niche potential is seen as determined by a set of functional relations rather than specific functional units per se. It is in this sense that we say that giftedness is made, not born.

## **Maximal Grip: The Exercise of Adaptive Control and Secondary Selection**

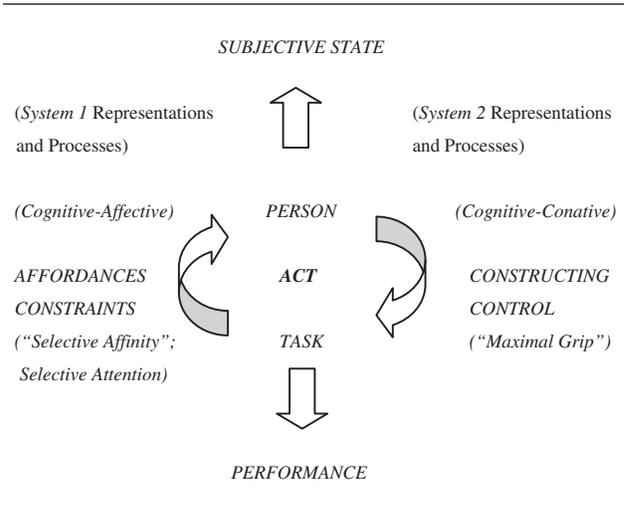
Scientific, artistic, and other human endeavors are inherently challenging even for the most gifted, as they involve internalization of systems that are artifactual or

human made, and semantically rich (Simon, 1969/1981). Natural sensibilities, no matter how refined they are, are still too crude to capture all the intricacies and complexities of physical, social, and cultural worlds. In this sense, even highly gifted children have to learn the hard way. Mozart still had to learn and work very hard for an extended time (more than 10 years) before he was able to produce his first masterpiece (Hayes, 1989).

We use *maximal grip* to denote a tendency or action (mental or physical) toward mastery of knowledge, skills, and dispositions to an optimal level. In other words, the person strives toward a maximal grip on task constraints and demands of a domain. If selective affinity reflects a more evocative cognitive-affective process, maximal grip can be seen as more of an intentional and deliberate mental action in response to the impinging demands and challenges. Maximal grip is a self-directed effort toward a future state of mastery. This motivational tendency is captured by concepts such as effectance motivation (White, 1959), self-efficacy as an exercise of control (Bandura, 1997), volition or will to implement an intention and resist distractions (Kuhl, 1985), task commitment (Renzulli, 1978), the rage to master (Winner, 1996), and deliberate practice (Ericsson, 1996). Cognitively, it is a distinct System 2 quality (Kahneman, 2003). Figure 2 shows a dynamic person-task interaction that involves both evocative (cognitive-affective) and self-directed (cognitive-conative) processes. Subjective State in Figure 2 indicates valence or value of the person-task transaction (e.g., interest-iness, importance, or excitement vs. frustration with respect to the task affordances and demands). Performance, on the other end, is an output, the result of the interplay of both System 1 and System 2 representations and processes.

Maximal grip implies more than motivated thinking and reasoning. It indicates a tendency of human living systems to coordinate and harness many aspects of inner and outer resources to meet new challenges and achieve mastery. Inner resources may include perceptual and intuitive (i.e., System 1 resources such as sensibility, intuitive grasp of meanings), cognitive (i.e., System 2 resources, such as forming effective internal representations, reasoning about task requirements), and emotional and motivational (e.g., affective excitability and intensity, approach vs. avoidance tendency) ones. Besides, maximal grip also includes seeking outer resources such as enlisting social and technical support as well as seeking opportunities and learning experiences to enhance competence and optimal development (Zimmerman, 1995).

**Figure 2**  
**Dynamic Person-Task Interaction That Involves**  
**Both Evocative (Cognitive-Affective) and**  
**Self-Directed (Cognitive-Conative) Processes**



*Learning as an exercise of adaptive control (i.e., maximal grip).* Ericsson (see Ericsson, Nandagopal, & Roring, 2005) distinguished between everyday learning and deliberate practice toward high-level expertise. In everyday learning, one typically stops when one's competence or effectiveness is good enough. In deliberate practice, good enough is not enough; one is striving for what is humanly possible (i.e., maximal grip). Deliberate practice is most evident in sports and music. What about academic subjects? How does a person start with limited knowledge as a novice and move gradually to high levels of expertise (Yan & Fischer, 2002). For any complex or semantically rich task, performance bottleneck is not basic information processing capacities (e.g., processing speed) but limited knowledge (Matthews, 1999); namely, the lack of proper response components (modules, schemata, situation models, etc.) specifically tuned to task constraints. Learning in these domains takes two basic forms: top down and bottom up.

In the top-down learning approach, response components are initially constructed declaratively and are gradually relegated to unconsciousness through mechanization (Anderson, 1987). The function of this top-down process is to relegate System 2 cognitive representations and processes to System 1 perceptions and intuitions so as to maximally develop efficiency of the system functioning. Consider the example of how a medical student, who has to sort

through all she or he has learned about a disease, gradually grows into a sophisticated doctor, who can formulate educated hypotheses instantaneously by taking a glimpse of manifested symptoms. In this way, experts only need to deal with novel or anomalous aspects of the presenting problem.

In contrast to top-down relegation, the bottom-up process starts with behavioral mastery and implicit learning and then gradually makes them more articulate and more flexible. In essence, bottom-up learning elevates System 1 response components to more articulated, formalized System 2 properties, such as conceptual systems and theories that have generalizing power. The function of bottom-up elevation is to ensure cognitive (or metacognitive) control and flexible use of knowledge. N. M. Robinson, Zigler, and Gallagher (2000) provided a fine example of such an approach. When a 6-year-old boy was asked to define a series of words, he replied by asking, "Do you want me to tell you the complicated way or just the simple way?" (p. 1417). His reply displayed metacognitive insights (there are many ways words can be defined and used) as well as the adaptive control he has exercised. Such metacognitive insights in development of expertise can evolve into a personal epistemology of a domain or discipline (e.g., Wineburg, 1991).

The bottom-up process of adaptive control is distinct in domains that involve much implicit learning, such as language and music. If the top-down relegation leads to efficiency, the bottom-up elevation ensures functional flexibility, which is the essence of intelligent behavior. It is this functional flexibility that makes transfer of knowledge and skills, or even creativity, possible (Karmiloff-Smith, 1992).

*Endogenous and exogenous factors.* On the exogenous side, Bloom (1985) found that access to the best training resources was necessary to reach the highest levels of competence. Much of education is meant to provide tools, resources, and aids necessary to facilitate maximal grip. The importance of technical support is most evident in the historical improvement of performance in sports and music, as some music compositions deemed too difficult to play in the 19th century have become part of the standard repertoire as more sophisticated techniques have been developed to help deal with the challenges (Ericsson et al., 2005).

On the endogenous side, we look at how individuals differ in adapting to new learning challenges. A major difference between a view of learning and performance as an exercise of adaptive control and the

traditional intelligence-correlation or intelligence-component approaches (see Gustafsson & Undheim, 1996) is that the former emphasizes the person as an enactive agent vis-à-vis a task environment, and the latter attempts to reduce performance to a set of fixed cognitive parameters. From a dynamic perspective, observed individual differences in intraindividual variations in adaptive control are emergent patterns from complex person-task interactions and, thus, cannot be reduced to one putative control parameter such as Intelligence Quotient (IQ), granted that IQ may be a stable trait of the developing child. Cognitive ability measured by IQ tests constrains but does not determine performance, to the extent that the task in question entails similar performance components tapped by specific IQ measures involved (Sternberg, 1998). We suspect that this is also why correlations between measures of general intelligence and learning of complex tasks in a laboratory-controlled setting were relatively low (explaining about 10 to 15% of the performance variance; see Ackerman, 1988). In contrast, the CED model would argue that individuals always function as a whole vis-à-vis task demands and constraints, and emergent patterns necessarily involve cocognitive attributes, such as task commitment (Renzulli, 2002), as maximal grip or adaptive control implicates, and thus cannot be reduced to static cognitive traits. Thus, cognitive learning (or performance) and motivation are inextricably intertwined (see Dai & Sternberg, 2004). As Clark (1997) pointed out, "The internal representations the mind uses to guide actions may thus be best understood as action-and-context-specific control structures rather than as passive recapitulations of external reality" (p. 51).

*Emergent properties and temporal trajectories of maximal grip.* We identify several emergent properties of maximal grip:

1. First is emergent expertise, in terms of stable and consistent task performance at a designated level of proficiency, with all its psychological underpinnings (Fischer & Biddell, 1998). Ericsson et al. (2005) showed a rapid steep growth in expertise between 10 and 20 years of age when deliberate practice is maintained, and then the growth gradually reaches a plateau.
2. Adaptive control not only involves cognitive transformations of various sorts, indicated by the top-down and bottom-up processes, but it also includes subtle changes in personal characteristics as adaptations. For example, an extroverted young musician may

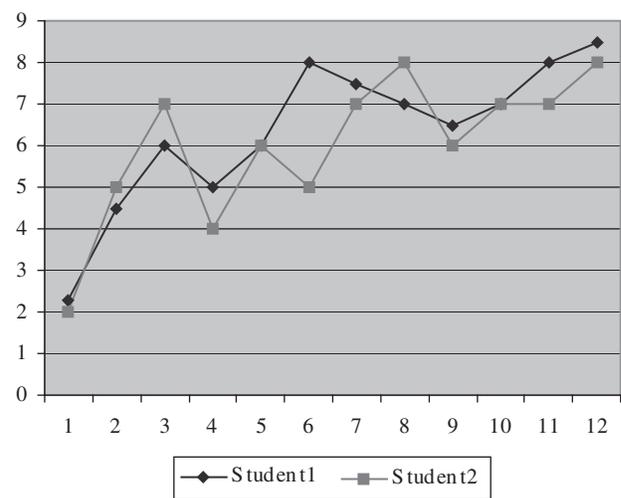
adopt a more introverted mode to facilitate solitary practice on a daily basis (Kemp, 1996). Task persistence or the lack of thereof may also become evident. Of course, repeated failures can also lead to lowered self-efficacy and self-doubt, leading to ultimate disengagement. Inevitably, many will opt out of the process of reaching high-level expertise as it gets increasingly challenging; their niche potential is ultimately tested here.

- There are also emergent aspirations, sometimes related to perceived capacity or self-appraisal of efficacy (Bandura, 1997) and sometimes related to what one can become or envisioned possible selves (Markus & Nurius, 1986). If selective affinity is intrinsic, or autotelic, maximal grip is fundamentally instrumental, or telic—that is, developing expertise over an extended period of time (see Apter, 2001, for the distinction between autotelic and telic motivation). High aspirations are needed to sustained prolonged efforts that do not yield much short-term reward.

In terms of developmental trajectory, systematic development of expertise occurs at both micro (e.g., day-to-day or minute-to-minute changes) and macro levels (e.g., year-to-year or month-to-month changes). At the macro level, Ericsson et al. (2005) delineated developmental trajectories of expertise up to world-class performance. At the micro level, trajectories of skill development as novices are unstable. Figure 3 shows two hypothetical persons attempting to achieve maximal grip on a complex task over a period of one year. Instead of linear growth, skill development typically fluctuates first and gradually becomes consolidated before more complex tasks introduce another round of dynamic instability (Fischer & Biddell, 1998); in other words, it demands new learning or self-directed, adaptive control (see Figure 3). Then the cycle repeats itself, propelling performance to the next level.

*Maximal grip and secondary selection.* As Lohman (2005) suggested, when a student moves to higher grades, task complexity of curriculum tends to increase, imposing more performance demands and constraints. Lohman cited evidence that given the correlation of .71 (a very high correlation!) found between the third-grade and eighth-grade math test scores in a longitudinal, 70% of those in top three percent at the third grade will lose their achievement status at the eighth grade. This shift of achievement status over a 5-year span indicates intraindividual variations in terms of emergent patterns of maximal grip (or lack of thereof) vis-à-vis new challenges as a result of macrolevel development, with some individuals losing maximal grip, so to speak, and others

**Figure 3**  
**Two Hypothetical Students' Developmental Trajectories During 12 Months of Learning and Practice of a Specific Skill**



Note: High and low points represent a range of fluctuations in performance within a year.

catching up. Along with the process, there is a self-selection process we call *secondary selection* in contrast to primary selection indicated by selective affinity. We call such self-selection secondary in a sense that it involves social-evaluative feedback, social comparison, and conscious self-evaluation as well as one's decision to stay or leave. With increasing cognitive sophistication, children will come to differentiate themselves from others by forming self-concepts or self-perceptions, and they will act accordingly (Harter, 1999; Marsh, 1990). In accordance with the tenet of self-directedness, children tend to select task environments that maximize their chance of success. On the other hand, perceived social barriers to talent development and expressions may also thwart personal aspirations (Ambrose, 2003). One's secondary selection may or may not coincide with one's primary selection, just as one's niche potential does not always materialize in a corresponding career path. A person who has a passion for music may nevertheless opt to pursue a career (say, practicing accounting) that is less intrinsically rewarding.

### At the Edge of Chaos: Critical States and Creative Potential

At a certain juncture of mastering a body of knowledge or a particular trade, many will experience a psychological tension between the known and unknown,

the old and the new, or at a marginal state between two systems of thoughts, cultures, or artistic expressions (see Runco, 1994, for an extensive discussion). Darwin, for example, was at the edge of chaos when he found the traditional theological explanations unsatisfying in the face of much biological evidence he accumulated (Gruber, 1986; Fischer & Yan, 2002).

Most people tend to settle down with a version of reality they have created (i.e., reaching a cognitive closure) and gradually lose an innovative edge. For example, once psychoanalytic theory was established, Sigmund Freud became highly dogmatic and intolerant to any deviations from his orthodox. However, deviations from Freud's orthodox (i.e., moving to the edge of chaos) by his students (e.g., Alfred Adler, Erik Erikson, Erich Fromm, Karen Horney, Carl Jung) produced important advances in the history of the psychoanalytic tradition (see Corey, 1996).

We should not consider such critical states to be experienced only by great scientists, philosophers, artists, and writers or that a person needs to achieve very high levels of expertise before he or she can experience such critical states. In a guided inquiry middle-school science class, a student who ventures a hypothesis (albeit incorrectly) about the mechanisms for the transmission of HIV (Brown & Campione, 1994) is also experiencing such a critical state. We should also not assume that the psychological tension described above represents a critical state because it is a state of uncertainty associated with an intense search for solutions to the tension or conflict involved.

*Exogenous and endogenous forces that sustain critical states.* Social-contextual underpinnings of such critical mental states are subtle but recognizable. It is reasonable to assume that the *zeitgeist* of the Renaissance period that produced so many monumental works can be characterized as such a critical state of the transition from the medieval to the modern in the history of the Western consciousness. At a more familiar level, the quality of everyday teaching may have a bearing on such critical states. As Feynman (1999) pointed out, to nurture an inquisitive mind, "it is necessary to teach both to accept and to reject the past with a kind of balance that takes considerable skill" (p. 188).

Endogenously, a creative person has to be able to maintain both the sensitivity to new information and the stability of the system functioning along with sufficient freedom and playfulness to explore the new and enough discipline and seriousness to remain committed to valuable parts of the tradition (Csikszentmihalyi, 1996). We

**Table 1**  
**Dialectical Interplay of Experience-Producing and Experience-Organizing Characteristics**

Experience Producing, Differentiating	Experience Organizing, Integrating
Intellectual curiosity	Intellectual cautiousness
Excitability	Independent judgment
Sensitivity to changes, variations, and nuances	Sensitivity to regularities, patterns, and discrepancies
Situational interests	Individual (personal) interests
Risk taking	Prudence
Open mindedness (maintaining naïvety)	Cautiousness and skepticism
Divergent	Convergent
Playfulness	Seriousness
Imagination	Reflective
Perceptive and intuitive	Analytic
Autotelic, expressive	Telic, instrumental

identify two sets of seemingly contradictory systemwide characteristics: one is experience producing, the other is experience organizing. They alternate in expression in a dialectical manner and complement each other, and thus help achieve maximal fit with the equally dynamic, complex world (see Table 1).

*Emergent novelty.* Creative images, ideas, and expressions can be considered as forms of developmental novelty (Feldman, Csikszentmihalyi, & Gardner, 1994). There are several distinct emergent processes, psychologically.

1. There are novel combinations of ideas, images, and theories or dynamic reorganization of existing systems of knowledge. The process may be fundamentally connectionistic (System 1 processes), representing a constrained stochastic (random) process (D. K. Simonton, 2003). Novel ways of perceiving (e.g., Picasso) or thinking (e.g., Piaget) reflect truly emergent properties out of old elements in new combinations or permutations (see Sawyer, 2003, for a discussion).
2. At a more intentional level, there is an emergent motivation to follow through with these images, ideas, or visions to fully articulate and justify them (System 2 processes). This is what Renzulli (2002) called a *sense of destiny*. It may take the form of personal visions, some gradually crystallized personal convictions about the truth and possible transformations (e.g., Charles Darwin).
3. There is also an emergent desire to communicate such visions and make an impact on an audience or

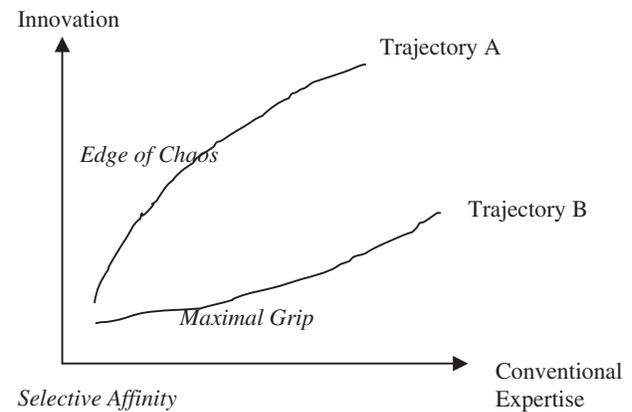
community (Renzulli & Reis, 1997). This social dimension of creative motivation is often neglected in the creativity literature.

*Temporal trajectories.* Trajectories of creative productivity can be mapped along two orthogonal dimensions: innovation and conventional expertise (Figure 4). Trajectory A shows innovation much earlier than does Trajectory B, which shows more loyalty to the existing system. There are critical points along these trajectories where a person has to decide how much innovation is too risky, as being innovative also means stepping into the world of uncertainty, with high likelihood of many failures. For example, according to Feynman (1999), a fundamental condition for scientific creativity is “the freedom to doubt” (p. 141). But doubt is a force of instability, destabilizing from within. Therefore, the trajectories of maintaining a delicate balance can be extremely precarious, walking a fine line between accepting and rejecting, creating and conserving. Those who play safe will follow more conventional pathways. Those who prefer to stay at the edge of chaos are natural risk takers. By virtue of that, they will have to endure certain degrees of conflict, chaos, and ambiguity within themselves and experience more fluctuations in development, more tipping points and phase transitions. Such dynamic instability partially explains why some gifted individuals are prone to what Dabrowsky (1964) called *positive disintegration*.

From a social-emotional point of view, alienation from the mainstream society is not unusual for the gifted, sometimes producing valuable inspirations for others (e.g., David Henry Thoreau), other times leading to downright criminal deviations (e.g., Ted Kaczynski). There is also an intimate relation between living at the edge of chaos intellectually or spiritually and mental illness (e.g., Nietzsche); the direction of causality can go either way. In an evolutionary scheme of things, it is nature’s gambit to produce variations that may or may not serve the human individual or collective good or teleological ends. The temporal trajectories of staying at the edge of chaos can be either failure or success (accepted or rejected by the society), productive or destructive (benefiting or harming the society). Therefore, ethical considerations are an inevitable part of understanding and promoting human creativity and gifted and talented education (Gardner, Csikszentmihalyi, & Damon, 2002; Renzulli, 2002).

In contrast to Trajectory A, which likely leads some to become makers of new systems, ideas, and expressions, people more or less following Trajectory B are more likely to become masters (Gardner, 1997;

**Figure 4**  
**A Schematic Representation of Two Contrasting Temporal Trajectories of Developing Proficiency and Expertise (Maximal Grip) in a Conventional Domain While Maintaining an Innovative Edge (at the Edge of Chaos)**



Note: The arrows indicate degrees in trajectory toward innovation versus conventional expertise.

see also a similar distinction made by Tannenbaum, 1997, between high-level proficiency and creativity). They can also be creative in their own ways. Using the taxonomy of creative products created by Sternberg’s (1999) propulsion model, we can infer that people with Trajectory A are more like to make creative contributions that are redefinition or redirection in nature and people with Trajectory B are more likely to make creative contributions that are forward incrementation or integration in nature. They show different kinds as well as different degrees of creativity.

### A Synthesis of the Three Dynamic Facets of Gifted Potential

As shown in Figure 4, with selective affinity as the onset of a developmental pathway, there are many possible trajectories, some gravitating toward conventional expertise and others toward more innovation. For some, the tension between the two may build up over time, eventually leading to creative combinations, restructuring, and transformations. Ideally, one would hope that the three facets be cyclically self-optimizing in that selective affinity leads to maximal grip, which, in turn, reciprocally enhances selective affinity. Likewise, maximal grip might lead

**Table 2**  
**Processes and Products Involved in Three Different Phases of Talent Development**

	Selective Affinity	Maximal Grip	At the Edge of Chaos
Cognition and learning	Intuition based (implicit), informal and thematic	Analytically based (explicit), formal and technical	Implicit and explicit
Motivation	Intrinsic (autotelic)	Instrumental (telic)	Intrinsic and instrumental
Development	Sensibility, acquired modules	Technical proficiency, internalized conceptual systems	Creativity
Developmental windows (years of age)	6 to 16 (varying with domains)	10 to 30 (varying with domains)	16 to 40 and beyond (varying with domains)
Developmental milestones	Early demonstrated talents and strengths	Outstanding achievement in specific areas of study	Early demonstrations of creativity and actual creative contributions

the person to the edge of chaos as one might find conventional ways restricting or otherwise unsatisfactory and, therefore, pursue innovative paths. We also speculate that a particular sensibility (which always has an idiosyncratic component) associated with selective affinity may also build up a tension between individual insights and conventional wisdom (see Table 2).

This conception, of course, uses an optimal process criterion (Ziegler & Heller, 2000). In reality, less optimal functioning and development may be more prevalent for either exogenous or endogenous reasons. Selective affinity may not evolve to maximal grip at the right time due to the circumstances, or maximal grip is geared exclusively toward conventional expertise at the cost of unique individuality and innovation. Moreover, one may experience selective affinity in multiple domains and pursuing expertise in different directions. Trajectories of such complex development in terms of differentiation and integration are even more complex than described here. Whether one can manage multiple interests and pursuits (i.e., multipotentialities) may depend on inner resources and the ability to manage system instability and even chaos. Organization of purpose, a phrase Gruber used to characterize Darwin's intellectual enterprise (see Gruber & Wallace, 1999, p. 106), may be crucial for holding different pieces together and achieving creative synthesis.

In sum, creative potential entails adapting to the current systems of thought and practice in a field yet still maintaining the edge of an innovative spirit, resisting the temptation of settling down and being entrenched in established points of view (Frensch & Sternberg, 1989).<sup>1</sup> As mentioned earlier, being at the edge of chaos introduces a delicate balance between sensitivity and stability, between freedom and discipline, between unfettered imagination and principled ways of

thinking. However, the balance may be tilted either way, producing various developmental trajectories.

### A Recurrent Issue in a New Light

Renzulli (1986) asked a set of related questions 20 years ago that still have relevance to the way we conduct gifted education:

Is giftedness an absolute or a relative concept? That is, is a person either gifted or not gifted (the absolute view) or can varying kinds and degrees of gifted behaviors be displayed in certain people, at certain times, and under certain circumstances (the relative view)? Is gifted a static concept (i.e., you have it or you don't have it) or is it a dynamic concept (i.e., it varies both within persons and within learning-performance situations)? (p. 62)

The CED model answers these two questions unequivocally. First, the CED model is simultaneously contextual, differential, and developmental. The three dynamic concepts (selective affinity, maximal grip, and at the edge of chaos) are all situated in specific functional contexts. Different kinds and degrees of selective affinity and sensibilities will be displayed, given the right timing and the right circumstances. Various kinds and degrees of maximal grip will be evident in terms of rates, trajectories, and asymptotes (i.e., peak performance) of the development of expertise in a variety of domains and socially structured activities, each having its own unique affordances and constraints. Different kinds and degrees of creativity will be produced (Sternberg, 1999) as a result of various trajectories that are pulled between the forces of achieving proficiency in conventional expertise and deviating from that path.

In the context of formal education, the tension between innovation and conventional expertise is the same as between schoolhouse giftedness and creative productive giftedness (Renzulli, 1986). Some may display trajectories that follow conventional pathways but others may show trajectories that strongly lean toward innovation (see Figure 4). In short, there is no single benchmark, such as IQ, that can capture the complexity and diversity of the phenomena.

To answer the second question, the CED model views gifted manifestations as fluid states (i.e., dynamic quality) rather than traits (i.e., static quality). This argument is in line with the view that a dynamic system is state determined and has its own trajectory and emergent properties that feed into its further development, based on the tenets of flexibility, niche potential, self-organization, self-direction, and dynamism. Gifted potential, in terms of sensibility, adaptivity, and creativity, is dialectically shaped by social-cultural (nurture) and biological forces (nature), evolving through learning and development, with latencies, fluctuations, and dynamic instability. A system that is highly sensitive to new information and uncharted territories is more likely to be perturbed, thus less stable in its functioning. There will be more fluctuations as one undergoes self-organization and phase transition. Thus, by nature, gifted potential has a precarious character. A gifted program that only identifies high achievers in a conventional manner (relying on standardized achievement or aptitude tests) as gifted is destined to miss a big chunk of the innovative side of gifted potential. Finally, a creative person can also exhaust his or her own means and become stagnant or suffer burnout. To use D. K. Simonton's (2005) words, people can lose their giftedness in development.

### **Utility of the Contextual, Dynamic, Emergent Perspective on Gifted Potential**

We might think of several criteria against which the validity and viability of a new model can be assessed compared to competing models: (a) how well it addresses key theoretical issues; (b) how well it helps explain a diverse array of phenomena under the gifted-and-talented rubric and generates new research questions and new theoretical predictions; (c) how well it points to new directions in research methodology; and (d) how well it provides new thinking, principles, and tools for practice.

### **Addressing Key Theoretical Issues**

As Lohman (2001) pointed out, "Early theories of human intelligence were not able to move beyond a belief in innateness because they lacked a cognitive theory of learning and development" (p. 92). While retaining the premise of individual differences, the CED model emphasizes the irreducibility of the emergent organization of complexity and novelty undergirding behaviors that we celebrate as gifted and talented. It addresses in its own way three key issues in the psychology of giftedness and talent development: the issues of nature-nurture, of domain-specificity-generality, and of trait-state.

*The nature-nurture issue.* The CED model refutes any notion of the preordained or innate nature of gifts and talents. In that sense, the CED model is distinctly nonreductionistic (see Dai, 2005, for a discussion of the distinction between reductionism and emergentism). Rather, it stresses self-organization of competence via interaction with the environment (including cultural provision), resulting in emergent sensibility, adaptivity, or creativity. It also attaches fundamental importance to the timing of certain experience and exposure as crucial for developmental pathways and trajectories. Indeed, it entertains the possibility of sensitive periods, when certain environmental experience tend to have the most impact. Instead of considering nature and nurture as separate, independent forces, the CED model considers relatively endogenous and exogenous forces jointly produce specific developmental outcomes, which feed into further development (see Dai & Coleman, 2005).

*The domain-specificity-generality issue.* Whether intelligence and creativity are domain specific or domain general is a lingering issue that affects how we define giftedness. Multiple intelligences theory (Gardner, 1983) conveys a strong domain-specific view, and the triarchic theory of intelligence (Sternberg, 1985) emphasized domain-general processes. The CED model suggests both domain-specific and domain-general processes are involved. First, sensibility through selective affinity is modular or module-like; that is, it functions as a special device dedicated to a specific class of information or stimuli. However, in the CED model, a talent is an acquired module through turning domain-relevant components into domain-specific ones. An example is co-opting pitch perception, which is relevant but not specific to music, as a key ingredient of the module for music perception. Second, goal-directed adaptive

behavior (maximal grip) reflects flexible, adaptive agency, and thus it has a distinct domain-general flavor; that is, it is particularly meant to cope with novelty and complexity that one has never encountered or with cultural artifacts that one cannot form proper responses to without extended learning experiences. In general, we can view top-down learning as using domain-general resources (System 2 representations and processes) to produce domain-specific products, and we can view bottom-up learning as elevating domain-specific implicit processes (System 1 representations and processes) to a level of consciousness that affords flexible use and transfer (Karmiloff-Smith, 1992). Third, creativity via staying at the edge of chaos entails some deep domain-specific knowledge and insights, yet the process of creating something new cannot be fully domain-specific. Rather, some domain-general or weak methods are used to produce creative products (Klahr & Simon, 1999; D. K. Simonton, 2003), and even some level of naivety is desirable. Creativity, by nature, is venturing into novelty or something that cannot be mentally prespecified.

*The trait-state issue.* A distinct feature of the CED model is that it is a process or state model, not a trait model. It should be noted that trait and state differences are not inherent different qualities of the nature but reflect how we observe the phenomenon in question. Indeed, any traits under microscopic scrutiny will reveal dynamic qualities (Tannenbaum, 1997). Developmentally, one may observe a stable trait on a scale of macrolevel development (e.g., correlations of IQ performance at the ages of 8 and 18); yet, put on a scale of microlevel development, it may reveal sharp fluctuations (e.g., innumerable changes and many phase transitions in intellectual functioning occurring between the ages of 8 and 18). Dynamic systems theory views any dynamic system as a state-determined system in that it is the current state of the system that determines its future behavior (van Gelder & Port, 1995). Translating it in the context of this exposition, any process (e.g., selective affinity) or product (e.g., newly formed sensibility or interest) that occurs in real time has the power to influence future developmental trajectory. A specific manifestation of gifted potential, then, can be seen as a functional state engendered or materialized in a specific context that has direct consequences for its future development. Changing the context, this potential may be obscured or expressed differently. In short, the CED model is more concerned with explicating developmental processes than with individual trait descriptions; the two may have differing theoretical interests and practical utilities.

## **Explanatory Power and Generative Heuristics**

Although the CED model portrayed in this article is still a normative framework rather than a testable theory, it has the potential to explain a diverse array of data, positive as well as negative. It is particularly suited to explain longitudinal patterns from early studies (e.g., Goertzel & Goertzel, 2004; Terman, 1925) to those most current (e.g., Gottfried, Gottfried, Cook, & Morris, 2005; Subotnik & Arnold, 1994). Postdictively, it is consistent with the research findings on talented youths in mathematics, science, and music (Bloom, 1985). It can explain, for example, why most high-IQ children in Hunter Elementary School (Subotnik, Kassin, Summers, & Wasser, 1993) grew up to be good professionals but did not attain eminent accomplishments: The trajectories of many of them seemed to lean toward conventional expertise rather than creative contributions; furthermore, the IQ-based definition and identification may have already preempted the outcomes. Predictively, the three dynamic concepts can be used separately or combined to frame a research project. One can predict who would be most likely to succeed given a set of exogenous and endogenous factors, how specific timing facilitates what types of talent development, or what are some make-or-break moments in talent development at critical junctures (in other words, success and failure in phase transition). Using the CED model as a framework, specific new research questions, theories, and hypotheses can be generated.

## **Methodological Implications of the CED Model**

The gifted and nongifted causal-comparative research paradigm has dominated the field for decades (see A. Robinson & Clinkenbeard, 1998, for a review). This paradigm is predicated on an understanding of giftedness as traits or a constellation of traits. It is also designed to generate a generalizable image of the gifted child (intellectually or otherwise). The CED model provides an alternative vision for research. The dynamic view of gifted and talented emergence calls for innovative research methodology that can (a) identify a relational property of person-task interaction in all its richness of meaning and cognitive and affective underpinnings, (b) track temporal trajectories at a micro or macro level to show how and when development occurs, (c) identify emergent properties and how they feed into the process of further development, and (d) show differential developmental pathways and trajectories. In short, it takes a developmental approach.

Historically, there have been two alternative research traditions regarding the development of exceptional competence. Nomothetic approaches (e.g., Goertzel & Goertzel, 2004; D. K. Simonton, 1999) attempt to identify universal patterns, laws, and regularities; ideographic approaches (e.g., Gardner, 1993; Gruber, 1986) focus on unique individuality and experience that give rise to creative contributions. They represent two ends of a methodological continuum, with one end involving isolating variables (e.g., love of learning; Goertzel & Goertzel, 2004) that presumably contribute to optimal development and the other end focusing on the unique individuality of the person in question. There is, of course, middle ground. For example, analysis of latent classes and changes in latent classes (Muthén & Muthén, 2000) allows researchers to identify homogeneous subgroups within a population that have different profiles of characteristics or developmental changes, such as trajectories toward science versus toward humanities.

In terms of tracking developmental changes, duration of engagement in a specific domain, and timing of developmental events, there are a host of methods and analytic techniques using microgenetic approaches, survival analysis, latent growth modeling, and more (see Singer & Willett, 2003). Innovative methodologies and designs in the research on the emergence and evolution of talent, intelligence, and creativity are crucial to implement and substantiate claims based on the CED model.

### **The CED Model as Guiding Principles for Gifted Education**

Although the CED model is developed to elucidate the genesis and development of gifted and talented behaviors, it is nevertheless use inspired. We believe that the CED model has a distinct advantage in guiding practice compared to trait-based models. From an educational or practical point of view, it is less important to determine whether a child is truly gifted than to make an assessment or prognosis of the developmental trajectory of the child based on all available information about the child to facilitate educational planning and interventions, given the identified educational needs. In other words, service models of gifted education are a better alternative to status models (Renzulli & Dai, 2003). Gifted students are as diverse among themselves as they differ from the rest of their peers. Because of its focus on developmental processes, the CED model can help specify programming in terms of goals, tools, and support needed to facilitate specific kinds of development for a given child or a group of children at a specific point in

time. In static models of gifted education, assessment (identification) and educational provisions are separate processes, but in dynamic models of gifted education, they inform each other and thus become an integrated system. The framework of selective affinity, maximal grip, and being at the edge of chaos can be readily used as heuristics to frame curricular goals and educational experiences.

## **Concluding Words**

The CED model as presented here is still a preliminary attempt to conceptualize the dynamic interplay of many forces jointly shaping gifted and talented behaviors and performances and their developmental trajectories. Many details need to be spelled out, and empirical research that adheres to the contextual, emergent, and dynamic principles need to be pursued. However, precisely because the model is relatively new, we are hopeful that it will help improve the way we think about gifted development, the way we conduct research on them, and the way gifted education can be delivered to facilitate their optimal development.

### **Note**

1. One reviewer commented that age consideration and, for that matter, educational acceleration may be important for a trajectory toward creative contributions because it protects students from the “dulling repetition that squelches new insights.” Further evidence can be obtained from the history of science that many creative ideas were actually germinated in adolescent years of these creators, before they received formal or higher education (Holton, 1981).

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