How to transform schools to foster creativity

R. Keith Sawyer

Morgan Distinguished Professor in Educational Innovations

University of North Carolina at Chapel Hill

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In the 19th century, several educators began to argue that schools should foster creativity. Creativity is an important component of the Kindergarten movement of Froebel, of Pestalozzi's writings, of the Montessori method, and of Dewey's emphasis on inquiry and experience. Scholars have long suggested that artistic activity and children's play are related, that they somehow tap into the same inner source (Freud, 1907/1989). Schiller ([1793/1794] 1968) associated the creative impulse with children's play; Froebel was perhaps the first to argue that play is children's work. In the 19th and early 20th centuries, these writings had tremendous impact on early childhood and primary education. One of the core features of the progressive education movement was an emphasis on student creativity throughout the curriculum.

In the United States, after World War II, many intellectuals emphasized the importance of creativity to individual fulfillment and to society—not only in childhood, but throughout the lifespan. Humanist psychologists (Maslow, 1959; Rogers, 1954) argued that creativity was the fullest realization of the human spirit, a fulfilling peak experience. Abraham Maslow claimed that the most psychologically healthy people are the most creative (1959). Carl Rogers argued that the primary motivation for creativity is "man's tendency to actualize himself, to become his potentialities" (1954, p. 251). The existentialist psychologist Rollo May (1959) agreed with his humanist contemporaries in arguing that creativity is "the expression of the normal man in the act of actualizing himself… the representation of the highest degree of emotional health" (p. 58). Recently, *positive psychologists* have pursued empirical studies inspired by these humanist insights, and have demonstrated that participating in intrinsically motivating creative activities contributes to happiness and well-being (Csikszentmihalyi, 1990; Gilbert, 2006; Haidt, 2006).

Alongside these humanist arguments for creativity, democratic arguments also emerged in the 1950s. By the late 1950s, many U.S. intellectuals were worried that an "age of conformity" had taken hold. Whyte (1956) argued that a regimented and bureaucratized economy was leading to a population of uncreative, identical conformists, and his concern was echoed in similar books through the early 1960s. Burns and Stalker (1961) argued that rigid hierarchical organizations were rarely innovative; instead, creativity came from companies with flat hierarchies, empowered workers, and authority distributed throughout the organization. The research psychologists that studied creativity in the late 1950s and early 1960s were profoundly influenced by these nationwide concerns (as can be seen in transcripts of discussions at the five influential Utah conferences on creativity in 1955, 1957, 1959, 1961, and 1962: Taylor, 1959, 1964a, 1964b; Taylor & Barron, 1963). For these postwar scholars, creativity was essential to a democratic society. Stein (1961/1963) wrote "To be capable of [creative insights], the individual requires freedom—freedom to explore, freedom to be himself, freedom to entertain ideas no matter how wild and to express that which is within him without fear of censure or concern about evaluation" (1961/1963, p. 119). In 1962, Donald MacKinnon advised parents and teachers "to encourage in their children and in their students an openness to all ideas and especially to those which most challenge and threaten their own judgments" (1962, p. 493).

The above short review shows that arguments for creativity in schools are not new. But today, in addition to these longstanding humanist and democratic motivations for more creative schools, a third motivation has emerged: economic competitiveness. The twenty-first century requires schools to foster creativity, the reasoning goes, due to several broad transformations in major industrial economies:

1. Increasingly globalized markets result in greater competitiveness, even for industries that historically had been protected from significant challenge

2. Increasingly sophisticated information and communication technologies result in shorter product development cycles, increasing the pace of innovation and change
3. Increasingly sophisticated information technology is spreading the scope of automation into sectors of the economy that formerly required active human involvement, including increasingly advanced service and knowledge work; thus making obsolete those job categories that do not involve active, daily creativity
4. Global labor market competition has resulted in low-skill, low-creativity jobs moving to extremely low-wage countries such that labor forces in advanced countries can no longer compete
5. Increasing wealth and leisure time in advanced industrialized countries (and beyond) have increased the demand for the products of the creative industries. As of 2007, the creative industries represented over 11% of U.S. GDP (Gantchev, 2007).

International organizations have increasingly emphasized the need for educating for creativity; the Organization for Economic Co-operation and Development (OECD) has published a series of reports on creativity and schools, including *Innovation in the Knowledge Economy: Implications for Education and Learning* (2004) and *Innovating to learn, learning to innovate* (2008). U.S. government and private organizations have likewise emphasized the importance of creativity to the U.S. economy, as exemplified by two high-profile 2005 reports (Business Roundtable, 2005; Council on Competitiveness, 2005). The Council on Competitiveness report led directly to the U.S. America Competes Act of 2007, with bills introduced into both houses of Congress; the bill was passed into law and signed by President Bush. The America Competes Act was reauthorized by both houses of Congress in 2010, and signed by President Obama in January 2011. These reports emphasize the economic demand for creativity, particularly in STEM disciplines, and argue that schools must play an essential role in building a more creative and innovative economy. Schools today should prepare students to go beyond what they have learned and to think creatively with the knowledge they have acquired. Creativity is one of the most important skills needed in the twenty-first century (Partnership for 21st Century Skills, 2007; Trilling & Fadel, 2009).

Thus we have today a historically unique alignment across a broad spectrum of society, and across a broad range of ideological stances. In the United States and in other industrialized countries, there is a broad consensus: we need more creative graduates—for the economy, for a functioning democracy, and for human fulfillment.

Education researchers, with funding from the National Science Foundation, the Institute of Education Sciences, and other sources, must respond by providing national leaders and educators with research-based advice for how to design learning environments that foster creative learning. But we do not yet have a complete understanding of how to design creative learning environments that foster the sort of learning that prepares students to use their knowledge in creative thinking and behavior. This paper is an exploration of what we know about creative learning and about the teaching that fosters creativity. And it is a call to action for the education research community and the agencies that fund their research, a call that identifies a range of unanswered questions that are worthy of a sustained research effort.

I begin by exploring several research traditions that provide us with some guidance as to what a creative learning environment might look like. I conclude that creative learning environments always exist at the balance of a tension that I call *the teaching paradox*. I then describe a case study taken from my own ethnographic research that reveals several challenges presented by the teaching paradox.

Arts Education

For much of the last fifty years, creativity in education has been closely associated with the arts—music and visual arts in particular. Researchers in creativity have traditionally been closely allied with arts education researchers. The teachers who are most receptive to creativity in the classroom are arts educators, because in traditional schools, creativity is rarely found outside of arts, music, and drama classes. Thus, one of the most obvious ways to increase creativity in schools is to strengthen arts education programs.

There are roughly three arguments in support of arts education. The first argument is that the arts are important in and of themselves, and that all educated citizens should have a solid grounding in the arts, as a part of our shared cultural heritage. But the argument of "art for art's sake" tends to lose in the face of tight budgets and hard choices. When financial pressures first began to impact arts programs in U.S. schools in the 1970s and increasingly in the 1980s, arts education researchers developed a second and a third argument in defense of arts education, both based on the argument that arts education provided unique cognitive benefits to the learner—including enhanced creativity--and that these benefits would transfer to other content areas (including math, science, and literacy) and would result in enhanced learning across the curriculum.

The second argument is that education in the arts results in enhanced cognitive skills (including enhanced creativity) that then transfer to other content areas, resulting in enhanced learning in all content areas. For example, it has been hypothesized that music listening enhances spatial reasoning, that classroom drama enhances verbal achievement, and that music enhances mathematic ability. Elliot Eisner (2002b) proposed six distinctive "artistically rooted forms of intelligence": (1) experiencing qualitative relationships and making judgments; (2) working with flexible goals that emerge from the work; (3) form and content are inseparable; (4) some forms of knowledge cannot be represented propositionally; (5) thinking with a medium that has unique constraints and affordances; (6) thinking and work that results in satisfaction and flow that are inherently engaging.

These new arguments emerged at the same time that the cognitive revolution spread through psychology and education research more generally (Eisner, 1982, 2002a; Gardner, 1973). Perhaps the most influential cognition and arts research was that done at Harvard's Project Zero during the 1970s (e.g., Gardner, 1973). The primary impact of Gardner's influential 1983 book, *Frames of Mind*, was to provide academic support for educators who wanted to prevent schools from being narrowly focused on the "rationalist" content areas of math, science, and literacy.

Although these arguments have been prominent since the 1970s, it remains controversial whether or not the arts provide unique cognitive benefits that transfer to other content areas (see Burnaford, 2007 in support, and Hetland & Winner, 2004, and Moga, Burger, Hetland, & Winner, 2000, for a critique). But even some of the strongest critics of transferable cognitive benefits nonetheless argue that arts education results in unique "habits of mind" or dispositions that are valuable in learning other content areas (Hetland, Winner, Veenema, & Sheridan, 2007): the dispositions to observe, envision, express, reflect, stretch and explore, engage and persist, develop craft, and understand the art world.

The third argument in defense of arts education is that when the arts are integrated with instruction in another content area, such as math or science, that other knowledge is learned more effectively (Efland, 2002; Winslow, 1939). The claim is that when the arts are integrated with instruction in other content areas, learners achieve a deeper understanding, acquire an ability to think more flexibly using content knowledge, and develop enhanced critical thinking and creativity; the arts helps teachers engage students more deeply, and reach a broader range of learning styles (Burnaford, 2007). In recent decades, arts educators use the term "interdisciplinary" or "arts integration" to refer to curricula that integrate the arts with other subjects (e.g. Burnaford, 2007; Cornett, 1999; Schramm, 2002; Strokrocki, 2005). Eisner (2002a) identified four possible curricular structures for arts integration: (1) in a unit focusing on a particular historical period or culture; (2) a unit that focuses on similarities and differences among art forms; (3) a unit that is centered on a major theme or idea that can be explored through the arts and other fields too; (4) a unit in which students are asked to solve a problem that has roots in both the arts and another content area.

It has proven to be exceedingly difficult to design studies that support these second and third arguments. The most exhaustive survey of research in support of transfer (argument 2) and arts integration (argument 3) is found in a 2007 report from the Arts

Education Partnership (Burnaford, 2007). The most extensive critique of research in support of transfer is a meta-analysis by Lois Hetland, Ellen Winner, and colleagues (Moga et al., 2000; Hetland & Winner, 2004). The jury is still out on whether arts education enhances creativity in general.

In any case, in recent years, it has become increasingly clear that it is overly simplistic to equate arts education with creativity education. Many contemporary scholars have argued that creative learning should be embedded in all subject areas (e.g., Craft, Jeffrey, & Leibling, 2001; Gardner, 2007). Today's discourse surrounding creativity in education has moved beyond arts education, to argue that creativity is required in all subject areas (e.g., Craft, 2005; Sawyer, 2006b). And contemporary calls for more creative learning are, more often than not, focused on Science, Technology, Engineering, and Math (STEM) disciplines (e.g., Business Roundtable, 2005; Council on Competitiveness, 2005)—because business leaders and politicians generally believe that these disciplines impact economic competitiveness more so than others.

History of creativity and education

There are two ways that one might design creative learning environments. The first way is to design a learning environment that would help students to master creativity relevant skills, skills that would be generally applicable to all subject areas. For example, a school could add a class to their curriculum that would provide students with creativity exercises and techniques, which they would then be encouraged to use in their other classes. I refer to this as a *domain general* approach. This is the implicit assumption made by arguments to justify arts education—that such education results in domain general creativity skills that will transfer to other subject areas.

One of the most influential modern scholars advocating a domain general approach to creativity in education was the late E. Paul Torrance (Sawyer, 2012a). At a conference in 1959, Torrance and Parnes (in Taylor, 1959) reported some results that showed that domain general creativity training could work. These initial findings led to a burst of creative education efforts during the 1960s. In 1972, Torrance identified 142 studies showing that training could enhance creativity (Torrance, 1972). Most of these training programs emphasize the same goals (Davis, 2003):

- Fostering creative attitudes
- Improving understanding of the creative process and of creative people
- Exercising creative behavior and thinking
- Teaching specific creativity techniques

To assess the effectiveness of training, Torrance developed an influential test to measure creative potential, known as the Torrance Tests for Creative Thinking (TTCT: Torrance, 2008). This test was based on J. P. Guilford's proposal that a key component of creativity is *divergent thinking*, the ability to generate a large number of possible solutions to open-ended problems. The Torrance test resulted in several scores. The three most important are *ideational fluency*, the sheer number of ideas generated; *originality*, the number of ideas generated that were not usually suggested by similar-aged students; and *flexibility*, the number of different categories that the ideas fell into. Torrance also developed several different curricular units to teach creativity, with the goal of helping students to increase their scores on the TTCT, such as the Future Problem Solving Program (Torrance, Bruch, & Torrance, 1976).

In the 1970s and 1980s, Torrance's work inspired a variety of creativity training programs designed for use in schools, including:

- *Productive Thinking Program* (Covington et al., 1974): a self-instructional program, packaged in fifteen booklets, designed for use by 5th and 6th graders. Measures of its effectiveness have produced mixed results (Nickerson, 1999).
- *CoRT or Cognitive Research Trust*, founded by Edward de Bono. The program (de Bono, 1973) is composed of six units. There was some evidence of effectiveness in a large-

scale implementation with Venezuelan 10 and 11 year olds (Nickerson, 1999).

- *The Purdue Creative Thinking Program* (Feldhusen, 1983): a set of 32 15-minute audiotaped lessons, each one focused on a famous creator from the past; worksheets, and a teacher's manual.

In the 1990s, an important group of scholars in the United Kingdom began to study creative teaching and learning, based on the broader societal recognition that creativity is required to succeed in the modern world (see the papers collected in Craft, Jeffrey, & Leibling, 2001). First, these scholars emphasized that creativity was not limited to arts classes, but that creativity was important to all subjects, including mathematics and sciences. Second, these scholars argued that creativity was not limited to gifted and talented students, but that creative potential should be nurtured in all students. These scholars studied two distinct, but related, elements of creativity in education: the creativity of teachers, or "creative teaching," and the types of learning environments that foster creativity in students, or "teaching for creativity". Both of these were emphasized in the U.K. report by the National Advisory Committee on Creative and Cultural Education (NACCCE, 1999; Joubert, 2001), which argued that teaching for creativity involves encouraging beliefs and attitudes, motivation and risk taking; persistence; identifying across subjects; and fostering the experiential and experimental. Creative teaching involves using imagination; fashioning processes; pursuing processes; being original; and judging value.

Cremin, Burnard, and Craft (2006) defined creativity as *possibility thinking*, which includes seven habits of mind: posing questions; play; immersion; innovation; risk-taking; being imaginative; and self determination. A report by the UK government's Qualifications and Curriculum Authority (QCA; 2005) mentions quite similar habits of mind: Questioning and challenging; Making connections and seeing relationships; Envisaging what might be; Exploring ideas, keeping options open; Reflecting critically on ideas, actions, and outcomes.

This recent emphasis on creativity is closely related to the "thinking skills" movement in the U.K., and the "twenty-first century skills" movement in the U.S (Partnership for 21st century skills, 2007; Trilling & Fadel, 2009).

Advice for creative teaching

This long tradition of research on creativity and education has produced much advice for teachers about how to encourage creativity (Craft, 2005, pp. 43-45; Cropley, 1997; Feldhusen & Treffinger, 1980, p. 32; Fleith, 2000; Piirto, 1998, 2004; Rejskind, 2000; Sternberg & Williams, 1996; Torrance, 1965, 1970). The teacher behaviors most commonly provided in these eight sources include:

- Openness: respect unusual questions and unusual ideas
- Evaluation: have students do something without being evaluated; connect evaluation to causes and consequences of the idea rather than to quality of the idea; Recognize and reward each child's creativity; Instruct and assess creativity. Make sure that your tests include questions that require creative thinking; Reward creative ideas and products. Your grading should take creativity into account; Delay evaluation of student ideas until they have been fully worked out and clearly formulated
- Surprise: Encounter the unexpected and deepen expectations
- Trust and safety: Maintain a psychologically safe classroom environment
- Build self-efficacy. Tell your students that they have what it takes to be creative; Help students become aware of their creativity
- Help students resist peer pressures to conform. Allow students to be odd; avoid emphasizing socialization at the expense of creative expression.
- Problem finding: Encourage questions, different responses, humor, and risk-taking. Define and redefine problems.

Allow students to choose their own ways to solve problems; give them opportunities to revise and redefine.

- Model creativity: Teachers should be role models, by themselves engaging in creative behaviors. Use profiles of creative people.
- Question assumptions. Encourage students to ask questions about their unstated assumptions. Take students' suggestions and questions seriously
- Encourage idea generation. Don't ask for just one response; give students time to generate multiple responses. Support and reinforce students' unusual ideas.
- Cross-fertilize ideas. Give students opportunities to think across disciplines.
- Allow time for creative thinking and incubation. Schedule ten minutes of thinking time during a class, or a longer period during the week; Allow time for students to develop and think about their creative ideas
- Encourage sensible risks; allow mistakes; use failure as a positive
- Encourage creative collaboration.
- Imagine other viewpoints; encourage the adoption of different perspectives
- Motivate students to master factual knowledge; it's an important basis for creativity. Emphasize that talent is only a small part of creative production, and that discipline and practice are important. Foster the in-depth study of disciplines, to enable children to go beyond their own immediate experience
- Take an inclusive approach where students and teachers collaborate to identify problems and issues, and debate and discuss, together.

True creativity requires specific classroom designs and teacher behaviors; the teacher's role is a facilitator and fellow collaborator, joining the students in a process of knowledge building (Scardamalia & Bereiter, 2006; Sawyer, 2004). Students must be active collaborators and participants in the learning.

Creativity researchers have been studying these topics since the 1950s. But this research has had surprisingly little impact on schools. Most teacher education programs don't mention creativity at all (Mack, 1987), education textbooks don't tell teachers how to foster creativity (DeZutter, 2011), and most teachers use creative teaching techniques rarely (Torrance & Safter, 1986; Schacter, Thum, & Zifkin, 2006). Unfortunately, in too many classrooms, teachers are unable to engage in these creativity-fostering behaviors, due to institutional pressures including the need to cover a large amount of material (resulting in learning that's "a mile wide and an inch deep"), and the need to prepare students to score well on standardized tests that don't assess creativity.

Does creativity training work?

To demonstrate effectiveness, one must test participants' creativity both before and after the training, and then demonstrate an increase in the assessed level of creativity. Some studies have used this method and have found that training raises scores on creativity tests. A 2004 meta-analysis (Scott, Leritz, & Mumford, 2004) of 70 prior studies found that certain creativity training programs work: those that focus on the development of cognitive skills and the heuristics involved in skill application, and those that used realistic exercises appropriate to the domain at hand. The eight cognitive skills that they identified explained about half the variance in increased performance (R = .49). They found that a focus on more analytic methods (including critical thinking and convergent thinking) was more effective than a focus on unconstrained exploration.

Sternberg and Williams (1996) divided 86 gifted and nongifted children into two groups. All children took pretests on insightful thinking, then half of the children received instruction on insight skills. Then, all children took a posttest. Children taught how to solve insight problems gained more than children who were not (Davidson & Sternberg, 1984). In a related study, Ansburg and Dominowski (2000) demonstrated that very short training on verbal insight problems can improve performance on other insight problems; people that received training solved 14% to 24% more problems than a control group. Their training instructions were short (only about 400 words), and simply warned not to focus on the first or the most obvious interpretation of the problem, and emphasized the importance of looking for alternative interpretations. Cunningham and MacGregor (2008) redid this study, this time including analogous puzzle versions and realistic versions of each problem, and added in spatial problems; they found that training enhanced performance on puzzle versions, but not on real-world versions, and that training was effective with spatial puzzles but not verbal puzzles. Those who received training solved 67% of spatial puzzles, compared to a control group that only solved 27%.

In sum, there is some limited evidence that creativity training works to enhance creativity. The most successful programs are those that focus on cognitive skills and their application, and those that focus on the domain of interest. This suggests that creative learning may require something more than general creativity training: it may require a modification of instruction in the content areas.

A second approach: Domain specific creativity

A second way to foster creative learning would be to alter the design of learning environments in the content areas, so that the knowledge that students acquire better prepares them to engage creatively with that knowledge. For example, math class could be redesigned so that students are prepared to think creatively with mathematics, rather than simply to demonstrate their mastery of existing mathematics. Science class could be redesigned so that students are better prepared to identify good research questions, to propose a broad variety of plausible hypotheses, or to design experiments that would be appropriate to a specific question. I refer to this as a *domain specific* approach.

The general consensus among creativity researchers is that creativity is largely domain specific (Sawyer, 2012a)—that the ability to be creative in any given domain, whether physics, painting, or musical performance, is based on long years of study and mastery of a domain-specific set of cognitive structures. These studies are consistent with research showing that creativity requires a person to become an extremely knowledgeable expert in his or her domain of activity—investing approximately ten years (Gardner, 1993) or 10,000 hours (Ericsson, 2006). If so, then learning how to be creative in one subject would not transfer to being creative in other content areas. This is consistent with the above findings by arts education researchers that arts education does not result in transferable cognitive benefits to other content areas, such as science and math.

Research shows that creativity training is more effective when it focuses on a specific domain. Mayer (1989) found that when students were taught learning strategies that encouraged them to identify relational statements and to extract generalizations from texts and problem statements, they displayed greater creativity. His research suggests that schools should "teach creative learning skills within specific content domains rather than as a separate course in general learning skills" (p. 204). Jay and Perkins (1997) found that training in problem finding, in a specific domain, worked. Dow and Mayer (2004) found that the most effective training was domain-specific. Baer (1998) found that training enhanced creativity, but only in the domain used in the training. He asked subjects ranging in age from 7 to 40 to create stories, poems, collages, and math word problems. Training on any one of those four areas increased the creativity of work in that area, but not in the other three areas. Dow and Mayer (2004) found that creativity training on insight problems enhanced performance only on insight problems in the same domain (verbal, mathematical, spatial, and verbal/spatial combined).

So then how to explain those studies that found measurable benefits to general creativity training? Baer (1998) argued that they might actually be providing a variety of domain-specific creativity training, in multiple contexts and task materials, and the positive results are due to learning how to be more creative in specific domains.

Creativity researchers have concluded that real-world creative performance depends both on domain-general creativity skills, as well as domain specific knowledge and skills. Although we don't yet know the exact balance, and although that balance probably varies across domains, the implications of this research are that creativity involves both general creativity skills and also domain specific skills.

Consistent with this research, many contemporary scholars have argued that creative learning should be embedded in all subject areas (e.g., Craft, Jeffrey, & Leibling, 2001; Gardner, 2007). An international consensus has developed that schools should use curricula in all subjects that result in cognitive outcomes that support creative performance (OECD, 2008). Ultimately, if our goal is more creative education, we must teach content area knowledge in ways that prepare students to be more creative using that knowledge. This requires us to redesign learning in the content areas so that the knowledge students acquire is of a different sort: the kind of knowledge that supports going beyond, creative thinking, adaptive expertise.

The consensus among creativity researchers is that although there are domain-general creative strategies, creativity is primarily domain specific. The implication of domain specific creativity research is that we can't hope to produce more creative graduates simply by adding creativity enrichment activities to the curriculum. If math and science continue to be taught in a way that doesn't foster creative thinking and problem solving, then no amount of creativity training or arts education can help. Rather, it will be necessary to transform the ways that each subject area is taught, so that the knowledge that students acquire is of the sort that fosters creative thinking and behavior.

The challenge: The tradition of instructionism

The above history, and contemporary research, suggest that creative learning will require us to transform teaching in the content areas. The learning sciences are providing us with an increasingly rich knowledge base for how to do that (Sawyer, 2012b). Unfortunately, schools today are designed around common-sense assumptions that are opposed to creative learning:

- Knowledge is a collection of *facts* about the world and *procedures* for how to solve problems. Facts are statements like "The earth is tilted on its axis by 23.45 degrees" and procedures are step-by-step instructions like how to do multi-digit addition by carrying to the next column.
- The goal of schooling is to get these facts and procedures into the student's head. People are considered to be educated when they possess a large collection of these facts and procedures.
- Teachers know these facts and procedures, and their job is to transmit them to students.
- Simpler facts and procedures should be learned first, followed by progressively more complex facts and procedures. The definitions of "simplicity" and "complexity" and the proper sequencing of material were determined either by teachers, by textbook authors, or by asking expert adults like mathematicians, scientists, or historians—not by studying how children actually learn.
- The way to determine the success of schooling is to test students to see how many of these facts and procedures they have acquired.

This traditional vision of schooling is known as *transmission and acquisition* (Rogoff, 1990), the *standard model* of schooling (OECD, 2008), or *instructionism* (Papert, 1993). Instructionism emerged in the industrialized economy of the early 20th century. But the world today is much more technologically complex and economically competitive, and instructionism is increasingly failing to educate our students to participate in this new kind of society. Economists and organizational theorists have reached a consensus that today we are living in a knowledge economy, an economy which is built on knowledge work (Bereiter, 2002; Drucker, 1993). In the knowledge economy, memorization of facts and procedures is not enough for success. Educated graduates need a deep conceptual understanding of complex concepts, and the ability to work with them creatively to generate new ideas, new theories, new products, and new knowledge. They need to be able to critically evaluate what they read, to be able to express themselves clearly both verbally and in writing, and to be able to understand scientific and mathematical thinking. They need to learn integrated and usable knowledge, rather than the sets of compartmentalized and decontextualized facts emphasized by instructionism. They need to be able to take responsibility for their own continuing, life-long learning. Instructionism is particularly ill-suited to the education of creative professionals who can develop new knowledge and continually further their own understanding; instructionism is an anachronism in the modern innovation economy.

The research emerging from the new sciences of learning is in direct contrast to instructionism; this research suggests that effective learning occurs in learning environments that share the following characteristics (see Table 1):

- *An emphasis on deeper conceptual understanding*. Scientific studies of expertise demonstrate that expert knowledge includes facts and procedures, but simply acquiring those facts and procedures does not prepare a person to work creatively with that knowledge. Factual and procedural knowledge is only useful when a person knows which situations to apply it in, and exactly how to modify it for each new situation. Instructionism results in a kind of learning which is very difficult to use outside of the classroom. When students gain a deeper conceptual understanding, they learn facts and procedures in a much more useful and profound way that transfers to real-world settings.
- *The importance of building on a learner's prior knowledge*. Learners are not empty vessels waiting to be filled. They come to the classroom with preconceptions about how the world works; some of them are basically correct, and some of them are misconceptions. The best way for children to learn is in an environment that builds on their existing knowledge; if teaching does not engage their prior knowledge, students often learn information just well enough to pass the test, and then revert back to their misconceptions outside of the classroom.
- *The importance of reflection*. Students learn better when they express their developing knowledge—either through conversation or by creating papers, reports, or other artifacts—and then are provided with opportunities to reflectively analyze their state of knowledge.

Traditional classroom practices (instructionism)	**Learning knowledge deeply (findings from cognitive science)**
Knowledge is a collection of static facts and procedures	Knowledge involves facts and procedures, but embedded and integrated in deeper conceptual understanding
The goal of schooling is to get these facts and procedures into students' heads	The goal of schooling is to prepare students to build new knowledge
Teachers know these facts and procedures; their job is to transmit them	The role of teachers is to scaffold and facilitate collaborative knowledge building
Curriculum should be designed so that simpler facts and procedures are learned first	Curriculum should emphasize integrated and contextualized knowledge
To evaluate learning, assess how many facts and procedures have been acquired	Assessment should be formative and authentic, and focused on deeper conceptual understanding

==TABLE 1 contrasting two learning approaches==

In instructionism, creativity is not necessary for learning, because learning is equated with mastery of what is already known. But within the newer understanding of learning that is emerging from the learning sciences, the conceptual understanding that underlies creative behavior emerges from learning environments in which students build their own knowledge (Scardamalia & Bereiter, 2006) through exploratory talk (Mercer, 2000) and sustained argumentation (Andriessen, 2006). The constructivist view emerging from learning sciences research is that learning is always a creative process (Sawyer, 2003a).

Creativity and learning as emergent

Creative learning will require a change away from the instructionist model that is dominant in schools today. Such a change faces immense institutional, administrative, and political challenges. But my primary argument in this paper is that designing creative learning environments is inherently challenging, both theoretically and conceptually, and would be a challenge even if the institutional, administrative, and political climate were completely supportive. This is because creative learning necessarily involves *emergence*; the theoretical and conceptual challenges of creative learning are, ultimately, challenges that must be understood using a theoretical framework based in emergence.

Emergent phenomenon are observed in many complex systems—systems with many components that interact in complex system configurations. In certain complex systems, the interactions of components gives rise to system-level patterns that often seem to be centrally controlled and planned. A classic example of an emergent phenomenon is the V-shape of a migrating bird flock. The birds are not aware of the V shape, and the bird at the front of the V is not chosen as the leader. Instead, each bird is only aware of his or her immediate neighbors, and each bird follows rather simple rules based on the position relative to these immediate neighbors. Because the V shape is not planned or intended, and because it is not caused by any one single bird, it is said to *emerge* from the flock.

Emergent phenomena have been found throughout nature. They are characterized by several features:

- A higher-level system pattern or property is observed, and the pattern or property must be explained in terms of the components of the system and their interactions.
- Emergent systems are difficult to explain using scientific methods based on *reductionism*, the explanatory approach that first decomposes a system into component parts, then analyzes and explains the parts, and then works upwards to explain the entire system.
- Emergent phenomena are *novel*: they are not observed at the level of analysis of the system components. The flock's V shape was not intended, and is not perceived, by any of the birds.
- Emergent phenomena are unpredictable before they occur, even given a fairly complete knowledge off the system components and how they interact.

In the early 20th century, philosophers defined "emergence" as the creation of something new that was unpredictable, even given a full and complete knowledge of the world prior to its emergence. The concept was originally developed to address issues in the theory of biological evolution. In this section of the paper, I argue that both learning and creativity are emergent processes, and that their emergent nature leads to a range of unavoidable challenges facing the design of creative learning environments.

Theories of emergence have influenced psychology since its beginning in the late 19th century (Sawyer, 2002). The 19th century was characterized by a preoccupation with evolution, and Darwin's theory posited that new species emerged over time. Theories of emergence and evolution were the focus of an influential group of British philosophers and evolutionary biologists just after World War I, a group that has been called the "British emergentists" (McLaughlin, 1992). Influential figures from this period include Broad (1925), Morgan (1923), and Whitehead (1926). The emergentism of both Broad and Morgan involved several related claims (Kim, 1992; Teller, 1992):

- Emergence is a process that occurs through time.

- When aggregates of basic entities attain a certain level of structural complexity, properties of the aggregate emerge.
- What emerges are new "levels" of reality, corresponding to evolutionary or historical stages.
- Because these properties are properties of complex organizations of matter, they emerge only when the appropriate lower-level material conditions are present.
- What emerges is novel; it did not exist before the process of emergence.
- What emerges is unpredictable, and could not have been known analytically before it emerged.
- Emergent properties are irreducible to properties of their lower-level parts, even though they are determined by those parts.

When groups of individuals engage in free-flowing and unstructured conversation, one often observes what I call *collaborative emergence*: The flow of the conversation emerges from the successive individual contributions of the participants (Sawyer, 2003b). Like emergent phenomena more generally, the emergent outcomes of group interaction cannot be explained through reduction to the individual mental states and decisions of the participants. They are unpredictable before they occur, and they can only be explained by analyzing the temporal unfolding processes of emergence, using methodologies designed to analyze communicative interaction (Sawyer, 2006a).

In my empirical studies of collaborative emergence, including in improvisational theater groups, business teams, and student learning groups (Sawyer, 2003c; Sawyer, Scribner, Watson, & Myers, 2005; Sawyer & Berson, 2004), I have identified several characteristics of groups that are more likely to result in collaborative emergence:

- *Moment-to-moment contingency*. At each moment, the possible appropriate actions are constrained to varying extent by the prior flow of the conversation. But there is always a wide range of possible appropriate actions, and each one could result in very different future paths to the conversation.
- *Retrospective interpretation*. Each participant's contribution only acquires meaning after it is responded to by the others. In some cases, the interactional meaning of a particular statement ends up being very different from what the speaker might have intended at the time.
- *Equal participation*. There is no group leader who establishes the topic and flow of the collaboration; everyone contributes equally, so that collective phenomena such as topic, topic shifts, and decisions emerge from the conversation.

Empirical studies of exceptional creativity throughout history have demonstrated that creativity emerges from a complex interactional and social process that is characterized by collaborative emergence (Sawyer, 1999, 2012a). An influential theory of creativity, the *systems model* (Csikszentmihalyi, 1988; Gardner, 1993), proposes that creativity emerges from a collaborative process that includes three components. First, the creative individual completes a creative product and then attempts to disseminate it to the broader community, or *field*. For example, a scientist may submit a manuscript to a journal to be considered for publication. The editors of the journal may decide to reject the manuscript, or they may send it to two or three scholars for peer review. This review process could also result in the rejection of the article. If the article—the individual's creative product—is rejected by this group of "gatekeeper" individuals, then it will never enter the *domain*, the shared body of accepted scientific knowledge. The systems model proposes that the analysis of creativity requires not only a psychological focus on the creative individual, but also a consideration of the social system. All creativity is an emergent process that involves a social group of individuals engaged in complex, unpredictable interactions (Sawyer, 1999).

In sum, contemporary empirical and theoretical studies of the creative process correspond quite closely to theories of emergence:

- Creativity is theorized as a process through time, rather than a static trait of individuals or of certain creative products.
- The creative product is novel.
- The creative product emerges from the combination of lower-level elements, in combination in a complex system: ideas contributed by many different individuals brought together through collaboration and conversation.

Learning as emergent

Creative learning involves emergence at both the individual level and the group level. At the individual mental level, new conceptual structures emerge within an individual's mind. At the group level, the collaborative conversations that contribute to creative learning are characterized by collaborative emergence. Creative learning requires unpredictability, irreducibility, and novelty (according to the basic tenets of constructivism: Sawyer, 2003a), and creative learning is more likely with collaborative emergence—with moment-to-moment contingency and retrospective interpretation (Sawyer, 2004).

A theory of learning as emergent is intermediate between two potential alternative explanations. The first is the top-down, passive learner model associated with instructionism. In instructionism, there is no emergence, because learning is simply the transfer and acquisition of knowledge—iconically internalized and represented.

A second alternative to emergentism explains learning by arguing that the final state of the system is determined by the environment of the organism. This position is associated with the radical empiricism of behaviorist psychology. Instead, emergentism holds that an explanation of the final state of the system requires an examination of the step-by-step interaction between learner and learning environment, as it passes from stage to stage, because the state of the learner changes along the way. Thus the environment is not directly imposed on or internalized by the learner; rather, learning results from a constructivist process of learner-environment interaction.

In Piaget's constructivism, learning and creativity are both emergence processes. In describing his lifelong effort to understand stage transitions during development, he said: "The real problem is how to explain novelties. I think that novelties, i.e., creations, constantly intervene in development" (Piaget, 1971a, p. 192). The crucial assumption of Piaget's theory of intellectual development is that new schemas are constructed by the child, and that these schemas are not simply continuous accumulations of new knowledge, but represent complete reorganizations of thought. Piaget acknowledged that he had no good explanation for how these reorganizations occur, referring to it as "the great mystery of the stages" (1971b, p. 9) and noting that "the crux of my problem…is to try and explain how novelties are possible and how they are formed" (1971a, p. 194). In his seminal 1974 study of Darwin's creative process, Gruber explored the relation between Piagetian universal thought structures and Darwin's highly original ones, and he suggested that Darwin's thought structures were transformed through a Piagetian constructivist process (cf. Feldman, 1980).

Instructionist models of learning do not require a theory of emergence. Learning is a straightforward internalization or acquisition of the information that is delivered by the instructor. In such an environment, the learning process has none of the characteristics of emergence—no unpredictability, no novelty, and no issues with irreducibility. Behaviorist models of learning do not require a theory of emergence. Learning can be fully explained by reference to features of the learning environment. But creative learning, based in constructivist learning theory, is differentiated from these two alternatives primarily due to the central presence of emergence processes.

The paradox of creative learning

Learning sciences research has demonstrated the importance of well-designed learning environments that scaffold learners through an optimal learning trajectory, from their existing state of understanding to the desired outcome state (Confrey, 2006). And research on teacher expertise shows that all good teaching involves structuring elements (Sawyer, 2011b). For creative learning to occur, learning environments must be designed that address *the teaching paradox*: to find the balance of creativity and structure that will optimize student learning (Sawyer, 2011a). Great teaching involves many structuring elements, and at the same time requires improvisational brilliance. Balancing structure and improvisation is the essence of the art of teaching.

To best conceptualize and negotiate the paradox presented by creative learning, I argue that teaching is an *improvisational* activity (2011b). In group improvisational genres—such as jazz and improv theater—the group's performance is a collectively generated product that collaboratively emerges from the successive creative contributions of each performer (Sawyer, 2003b). Conceiving of teaching as improvisation highlights the collaborative and emergent nature of effective classroom practice, helps us to understand how curriculum materials relate to classroom practice, and shows why teaching is a creative art. The best teaching is *disciplined* improvisation because it always occurs within broad structures and frameworks (Sawyer, 2004, 2011b).

Creative learning environments face three variants of the teaching paradox that must be negotiated by schools and by teachers who wish to foster creative learning (Sawyer, 2011b):

The teacher paradox: teacher expertise must weave together a large knowledge base of plans, routines, and structures, within improvised classroom practice that responds to the unique needs of the moment.

The learning paradox: in effective creative classrooms, students are provided with scaffolds—loose structures that are designed carefully to guide the students as they improvise towards content knowledge, skills, and deeper conceptual understanding.

The curriculum paradox: good curricula and lesson plans are necessary, to guide teachers and students down the most effective learning trajectory toward desired learning outcomes. Yet, the most effective curricula are those designed to foster improvisational learning within the curricula.

Today most education scholars are committed to the use of constructivist, inquiry-based, and dialogic teaching methods. Contemporary research in the learning sciences has repeatedly shown the superiority of constructivist methods for teaching the kinds of deeper understanding needed by knowledge workers in the innovation economy (Sawyer, in press); constructivist methods result in deeper understanding among learners (Bereiter, 2002; Palincsar, 1998; Rogoff, 1998; Sawyer, 2004, 2006b). Learning scientists have repeatedly demonstrated that constructivist learning proceeds more effectively in the presence of *scaffolds*, loose structures that guide students (Mayer, 2004; Sawyer, in press). Thus, creative learning—like all constructivist learning—involves improvisation and creativity that is guided by structures.

In the most effective classrooms, all three variants of the teaching paradox are balanced through improvisational processes. To address the teacher paradox, teachers constantly improvise a balance between creativity and constraint. To address the learning paradox, teachers create and adapt structures of just the right sort to scaffold students' effective learning improvisations. To address the curriculum paradox, teachers adapt textbooks and develop lesson plans that enable students to participate in classroom improvisations. For students to learn creatively, all three teaching paradoxes must be carefully balanced, and the direction of the class emerges from collaborative improvisation between the teacher and the students.

Case study: Emergent innovation at the Exploratorium

In science education, there is a growing body of research on how to foster creative learning (Sawyer, 2012b). One prominent line of research focuses on introducing *inquiry-based science* into classrooms (Kind & Kind, 2007). "Inquiry based science" has many variations, but the core of the approach is to present students with real-world problems and data, and to allow them to formulate hypotheses, design experiments, gather data, and marshal evidence in support or against the hypotheses. These educational efforts are based on the belief that learning is more creative when learning activities mimic the real-world creative processes of scientists. The problem, according to Kind and Kind (2007), is that real inquiry almost never happens in the classroom; teachers ending up framing the children's investigative pathway, providing a high degree of guidance and preventing the students from engaging in creative, emergent learning. Teachers tend toward this strategy because children's naivety as learners makes real inquiry difficult to achieve in practice.

We still do not know how to best address the teaching paradox. With the goal of exploring this issue, in the summer of 2009 I spent a month at the San Francisco Exploratorium, an influential interactive science center that has long been associated with innovative approaches to inquiry learning. Founded in 1969, the Exploratorium was the first interactive science center. It was founded by Frank Oppenheimer, based in a democratic vision that everyone should know and participate in science (Cole, 2009). The Exploratorium has been an influential science center for over forty years. As of 2009, the Exploratorium has 350 employees, a $30 million annual budget, and 400,000 visitors each year. It has a strong web presence, and offers a range of teacher professional development programs.

The Exploratorium is known for its innovative interactive exhibits; many of their best-known exhibits have been replicated and can be found in science centers around the world. By 2009, the exhibit development group had a staff of seventy. They include PhD scientists, former educators, people who have worked at game design companies, and successful artists. Another division of the organization is responsible for building replicas of exhibits and selling them to other science centers.

The continued success of exhibit development is based on a few core values. First, the exhibits focus on a *phenomenon* and give the visitor an opportunity to directly experience the phenomenon. As one exhibit developer told me, "If it's too small or too big or too fast or too slow, we don't do it." The prototypical Exploratorium exhibit is one that captures a phenomenon in a way that reveals an aesthetic quality, the beauty of nature; one that presents a human-scale phenomenon that can be experienced in a minute or two.

Second, an exhibit should provide the visitor with an opportunity to *interact* with the phenomenon. The term "hands-on" was first coined in the early 1970s to describe the Exploratorium's then-new approach to exhibit design. If the exhibit captures the phenomenon in a compelling way, then the visitor will want to explore the phenomenon, by changing or modifying some aspect and watching the result. Thus an ideal exhibit begins by capturing a phenomenon in a compelling way that leads the visitor to wonder and to pose questions; then, hands-on interactivity enables the visitor to engage in a process of exploration and inquiry.

An exhibit idea originates with a developer, as they explore phenomena, and engage in their own process of inquiry, looking to identify potential exhibit ideas. This process is improvisational and collaboratively emergent. As one senior developer said, "Part of the real fun of exhibit developing for me is that you have an idea about something to do, but along the way, you'll notice something else and go in a different direction. That's what's really thrilling about being an artist, or a scientist or an exhibit developer - the idea that, if you start along this path, something cool is going to happen that you never thought of" (Hunt, 2009, p. Q14).

The ideal exhibit should engage a visitor in a similar process of exploration and inquiry. The developers are aware that different visitors may have different experiences, and thus may learn different lessons from a given exhibit. They embrace this uncertainty, and explicitly welcome the possibility that a visitor may learn something that the exhibit developer did not intend. After all, they reason, this is also the process of inquiry that working scientists pursue.

An example of a recent exhibit will demonstrate how new exhibit ideas emerge from the developers' collaborative and creative processes. This example took place in an exhibit development group called *Playful Invention and Exploration (PIE)*; their task is to develop activities where visitors can build their own devices, using inexpensive materials bought cheaply at the local hardware store. One successful PIE exhibit was *Cardboard Automata* (http://www.exploratorium.edu/pie/library/cardboard1.html). On a table on the exhibit floor, visitors were provided with recycled cardboard boxes, masking tape, sheets of thin foam board, and long wooden sticks, and then given with some basic tips for how to build a box that contains a series of gears, wheels, and mechanical linkages so that turning a crank on the side would cause objects at the top of the box to move (see Figure 1).

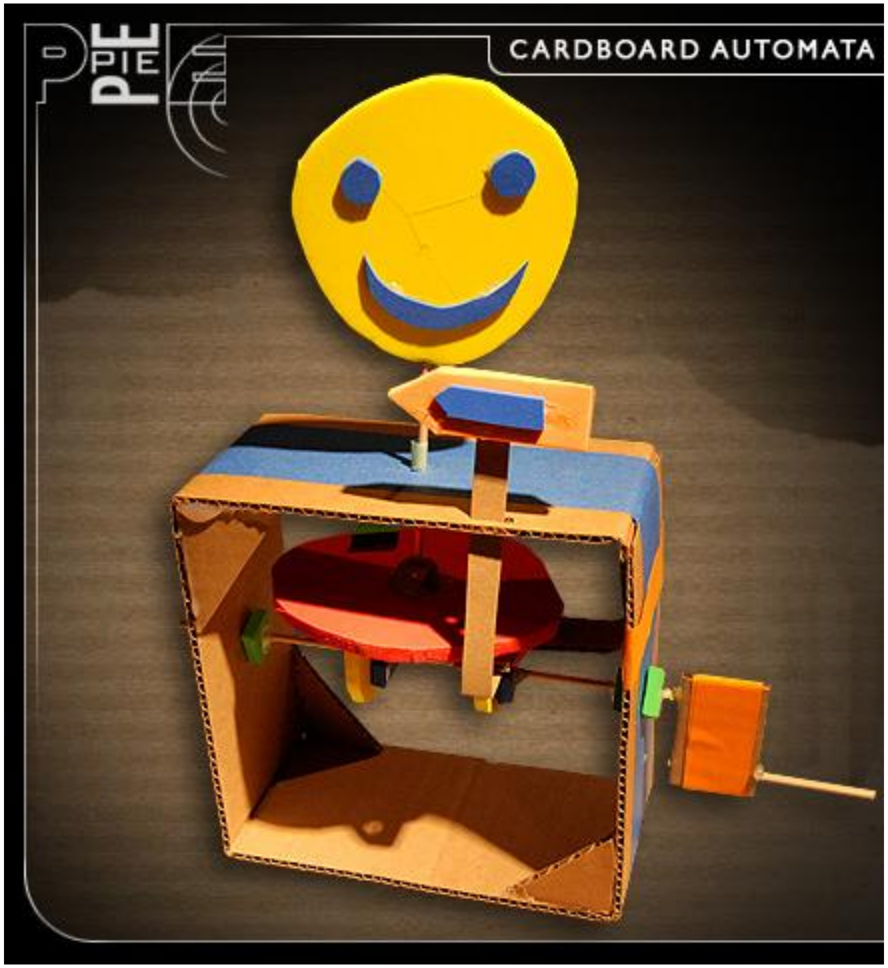

FIGURE 1. Cardboard automata from the Exploratorium. From http://www.exploratorium.edu/pie

The idea originated when the exhibit developers learned of an artist's collaborative in England that called themselves "The Cabaret Mechanical Theatre" and had become known for making mechanical boxes that, due to their craftsmanship and aesthetic qualities, rose to the level of art objects. The developer's first insight was that this seemed to represent a compelling phenomenon: gears, levers, and cams were relevant to science content knowledge, and the mechanical box had the potential to present an experience of this phenomenon in a compelling way. The next challenge was to somehow make the phenomenon more interactive. The developers decided that simply turning a crank on a completed mechanical box wasn't interactive enough to provide a true inquiry experience. The solution was to give the visitor a few basic tips, and then to have them build their own cardboard automata.

The Exploratorium has a culture of innovation that fosters improvisational collaboration (Sawyer, 2007): an organic culture with low boundaries; a relatively flat organizational structure; weak formal authority; an emphasis on rapid prototyping of exhibit ideas; and an emphasis on remaining aware of what is happening in the scientific and artistic communities, where new ideas—like the cardboard automata—often originate.

Challenges of emergent innovation

The success of the Exploratorium demonstrates the strengths of an environment that draws on collaborative emergence to generate educational innovation. But the Exploratorium's approach also demonstrates how the teaching paradox presents itself to learning environments that aim for creative learning through collaborative emergence. When other science centers design exhibits, they take a more top-down approach: they start with the environment, gallery, theme, and desired educational outcome, and then they design a series of exhibits to align with these overall goals (Serrell, 1996). The bottom-up approach of the Exploratorium leads them to start with the exhibits. The risk is that a purely bottom-up approach can result in a series of distinct exhibits that fail to cohere, and fail to provide a natural flow of experience for the visitor. The improvisational model of collaborative emergence found at the Exploratorium risks omitting several educationally valuable elements:

- Pedagogical expertise is not applied to integrate visitor experience across exhibits. This risks a less effective visitor learning experience.

- An exhibit does not have explicit learning outcomes; it is thought that visitors could learn a wide range of lessons from any given exhibit. However, establishing explicit learning outcomes could lead to effective assessment that would support a cycle of continuous improvement.
- Connections across exhibits do not naturally result from the development process, and they are not made explicit by gallery design or signage. Yet, such connections could enhance visitor experience by ensuring coherence across exhibits and connected learning.

Each of these three neglected elements could be enhanced with the introduction of some top-down organizational structures. Yet, the introduction of such top-down structures would come into tension with bottom-up collaborative emergence process. In one form or another, this tension is faced by all creative organizations (Sawyer, 2007): How to retain collaborative emergence and innovation, and at the same time design organizational structures and processes that scaffold and facilitate organizational creativity? As schools reinvent themselves as creative learning environments, they will increasingly face organizational challenges similar to those faced by innovative organizations that have moved beyond top-down, command and control models of organization, toward more organic and participatory models of organization that are designed to foster collaborative emergence.

Conclusion: Facing the teaching paradox

In today's knowledge societies, schools need to teach content knowledge in a way that prepares students to use that knowledge creatively; and, they need to impart thinking skills, 21st century skills, to students. Most schools have not yet become creative learning environments. Most schools continue to be largely based on an instructionist model of teaching and learning.

There are many challenges ahead for schools that hope to foster creative learning. Many educational leaders and policy makers have focused on the institutional, administrative, and political challenges that make it difficult for schools to explore more innovative organizational forms. These are *external* forces that make creative teaching and learning difficult. In contrast, in this paper I have chosen to discuss *internal* forces that make creative teaching and learning difficult. In sum, my argument has been:

- Creative learning requires that students create their own knowledge, a constructivist process that involves *emergence*.
- Creative learning requires *collaborative emergence*, with teacher and students working together to build new knowledge.
- Collaborative emergence occurs in the presence of unavoidable tensions that I have called *the teaching paradox*.
- Negotiating the teaching paradox requires that teachers and classrooms engage in *disciplined improvisation*.
- Disciplined improvisation allows for the creative benefits of collaborative emergence, yet guided by teacher practices, curricular structures, and learning goals that guide and aid students in their own process of creative learning.

My case study, the San Francisco Exploratorium, suggests that the teaching paradox cannot be avoided by educators who hope to design creative learning environments. The Exploratorium represents a solution to the teaching paradox that is in many ways directly opposed to the solution represented by instructionist classrooms: Whereas instructionist classrooms are almost completely top down, with no room for emergence or creativity to occur, the Exploratorium is almost completely bottom up. The Exploratorium is an exciting case study because its strengths are exactly in those places where instructionism is weak: Creative learning requires collaborative emergence and creativity on the part of the student, and visitors to the Exploratorium constantly experience creativity and emergence.

Yet, collaborative emergence may result in more effective learning if the process is guided appropriately. The best way to foster creative learning is not to allow learners complete freedom to improvise their own path through disciplinary knowledge; it is, rather, to guide them in a process of disciplined improvisation. Schools are complex organizations with many structures and constraints; these structures serve important functions and cannot simply be abandoned.

Effective creative learning involves teachers and students improvising together, collaboratively, within the structures provided by the curriculum and the teachers. But this collaborative emergence, a bottom up group process, must be guided effectively by (at least) four top-down structures—(1) curriculum, (2) assessments, (3) learning goals, and (4) teacher practices. In too many schools today, these top-down structures are overly constraining, and do not provide room for the disciplined improvisation that results in collaborative emergence. And yet, effective learning environments will always need curriculum, assessments, learning goals, and teacher practices. To transform schools to foster greater creativity in students, these four top-down structures need to change:

1. The curriculum should provide opportunities for multiple learning trajectories that could result from a creative inquiry process.
2. Assessments should incorporate and reward the sort of deeper conceptual understanding that results from creative learning, and they should accommodate potential differences in learning sequence and outcome
3. Learning goals should explicitly incorporate creative learning. Schools and districts should ensure that the expected learning outcomes do not emphasize breadth over depth.
4. Teacher professional development should be based in creativity research, and in research in the content areas—for example, science education research that explores the appropriate role of guiding scaffolds in the unavoidably unpredictable and emergent process of creative learning.

Thus, my call to action: Education researchers should respond by providing research and practical recommendations for how to teach for creativity. We need research efforts that can help teachers, administrators, and curricular developers negotiate the teaching paradox. Potential research questions include:

- What is the optimal balance between scripts, routines, and activities on the one hand, and creative improvisation on the other? What is the best way to educate preservice teachers to prepare them to optimally negotiate the teaching paradox?
- Decades of research on constructivism in education have demonstrated that the most effective learning occurs when the learners' discovery and exploration are guided by scaffolds—structures put in place by the teacher. What is the right degree and type of scaffolds, that result in the most effective creative learning? Answering this question will require substantial research in the content areas, because the appropriate scaffolds will change with the nature of the content knowledge and with the level of the learner.
- What is the optimal balance of general creativity education, and domain-specific creative learning?
- What role can the arts play in domain general and domain specific creative teaching and learning?
- Designed instruction always has a desired learning outcome. The term "curriculum" represents the structures that are designed to ensure that learners reach those learning outcomes—whether textbooks, lists of learning objectives, or lesson plans. What lesson plans and curricula will guide learners in the most optimal way, while allowing space for creative improvisation?

These research questions are becoming increasingly central to the interdisciplinary field known as the learning sciences (Sawyer, 2012b), a group of education researchers that are exploring the fundamentally constructivist observation that effective learning requires the learner to create their own knowledge. Constructivist learning theory has always presented a challenge to educators: What learning environment can best support learners as they engage in their own creative and constructivist process of learning? In this sense, the teaching paradox is not new; it has always been at the core of attempts to work out the implications of constructivism for teachers and curriculum developers.

In this paper, I have connected these foundational constructivist issues to the contemporary challenge to foster more creative learning in students. I have argued that the cognitive processes underlying creativity and learning are essentially identical—they both involve the emergence of the new in the mind of the individual. Further, I have argued that creative learning environments are those that foster *collaborative emergence*, improvisational group processes where the outcome cannot be predicted from the individual mental states and goals of the participants, and where all members of the group—teacher and students alike—participate in the unfolding flow of the encounter. I concluded by using the case study of the Exploratorium to demonstrate some challenges presented by the teaching paradox.

I have presented a vision of the school of the future, one that begins with the claim that creative learning requires collaborative emergence and improvisation. All schools aspire to be institutions that provide students with learning environments that foster the most effective learning. To accomplish this goal, these learning environments should be based on learning sciences research. This research is beginning to provide suggestions for how to foster creativity in the face of the teaching paradox (e.g., Sawyer, 2011a). My call to action is a call for education researchers and funding agencies to invest more resources in the study of creative teaching and learning. Teacher professional development should build on this research, to help teachers understand how to foster creative learning through disciplined improvisation.

In creative schools, students learn content knowledge; but in contrast to the superficial learning that results from instructionism, they learn a deeper conceptual understanding that prepares them to go beyond and build new knowledge. They learn collaboratively, in ways that help them externalize their developing understandings and fosters metacognition. They learn to participate in creative activities based on their developing knowledge—how to identify good problems, how to ask good questions, how to gather relevant information, how to propose new solutions and hypotheses, and how to use domain-specific skills to express those ideas and make them a reality. The school of the future will be filled with creative learning environments that result in deeper mastery of content knowledge, and the ability to think and act creatively using that knowledge.

References

Andriessen, J. (2006). Arguing to learn. In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 443-459). New York: Cambridge University Press.

Ansburg, P. I., & Dominowski, R. L. (2000). Promoting insightful problem solving. *Journal of Creative Behavior, 34*(1), 30-60.

Baer, J. (1998). The case for domain specificity. *Creativity Research Journal, 11*(2), 173-177.

Bereiter, C. (2002). *Education and mind in the knowledge age*. Mahwah, NJ: Erlbaum.

Broad, C. D. (1925). *The mind and its place in nature*. New York: Harcourt, Brace & Company.

Burnaford, G. (2007). *Arts integration frameworks, research, & practice: A literature review*. Washington, DC: Arts Education Partnership.

Burns, T., & Stalker, G. M. (1961). *The management of innovation*. London: Tavistock Publications.

Business Roundtable. (2005). *Tapping America's potential: The education for innovation initiative*. Washington, DC: Business Roundtable.

Cole, K. C. (2009). *Something incredibly wonderful happens: Frank Oppenheimer and the world he made up*. New York: Houghton Mifflin Harcourt Trade.

Confrey, J. (2006). The evolution of design studies as a methodology. In R. K. Sawyer (Ed.), *Cambridge handbook of the* *learning sciences* (pp. 135-151). New York: Cambridge University Press.

Cornett, C. E. (1999). *The arts as meaning makers: Integrating literature and the arts throughout the curriculum*. Upper Saddle River, NJ: Merrill.

Council on Competitiveness. (2005). *Innovate America: National innovation initiative summit and report*. Washington, DC: Council on Competitiveness.

Covington, M. V., Crutchfield, R. S., Davies, L., & Olton, R. M. (1974). *The productive thinking program: A course in learning to think*. Columbus, OH: Merrill.

Craft, A. (2005). *Creativity in schools: Tensions and dilemmas*. New York: Routledge.

Craft, A., Jeffrey, B., & Leibling, M. (Eds.). (2001). *Creativity in education*. London: Continuum.

Cremin, T., Burnard, P., & Craft, A. (2006). Pedagogy and possibility thinking in the early years. *Thinking Skills and Creativity, 1*, 108-119.

Cropley, A. J. (1997). Fostering creativity in the classroom: General principles. In M. A. Runco (Ed.), *Creativity research handbook (Vol. 1)* (Vol. 1, pp. 83-114). Cresskill, NJ: Hampton Press.

Csikszentmihalyi, M. (1988). Society, culture, and person: A systems view of creativity. In R. J. Sternberg (Ed.), *The nature of creativity* (pp. 325-339). New York: Cambridge University Press.

Csikszentmihalyi, M. (1990). *Flow: The psychology of optimal experience*. New York: HarperCollins.

Cunningham, J. B., & MacGregor, J. N. (2008). Training insightful problem solving: Effects of realistic and puzzle-like contexts. *Creativity Research Journal, 20*(3), 291-296.

Davidson, J. E., & Sternberg, R. J. (1984). The role of insight in intellectual giftedness. *Gifted Child Quarterly, 28*, 58-64.

Davis, G. A. (2003). Identifying creative students, teaching for creative growth. In N. Colangelo & G. A. Davis (Eds.), *Handbook of gifted education (3rd edition)* (pp. 312-324). Boston, MA: Pearson Education.

de Bono, E. (1973). *CoRT thinking*. Blanford, England: Direct Educational Services.

DeZutter, S. (2011). Professional improvisation and teacher education: Opening the conversation. In R. K. Sawyer (Ed.), *Structure and improvisation in creative teaching* (pp. 27-50). New York: Cambridge University Press.

Dow, G. T., & Mayer, R. E. (2004). Teaching students to solve insight problems: Evidence for domain specificity in creativity training. *Creativity Research Journal, 16*(4), 389-402.

Drucker, P. F. (1993). *Post-capitalist society*. New York: HarperBusiness.

Efland, A. D. (2002). *Art and cognition: Integrating the visual arts in the curriculum*. New York: Teachers College Press.

Eisner, E. W. (1982). *Cognition and curriculum: A basis for deciding what to teach*. New York: Longman.

Eisner, E. W. (2002). *The arts and the creation of mind*. New Haven, CT: Yale University Press.

Eisner, E. W. (2002). What can education learn from the arts about the practice of education? In *The encyclopedia of informal education (available online at http://www.infed.org/biblio/eisner_arts_and_the_practice_or_education.htm).*

Ericsson, K. A. (2002). Attaining excellence through deliberate practice: Insights from the study of expert performance. In M. Ferrari (Ed.), *The pursuit of excellence in education* (pp. 21-55). Hillsdale, NJ: Erlbaum.

Feldhusen, J. F. (1983). The Purdue creative thinking program. In I. S. Sato (Ed.), *Creativity research and educational planning* (pp.

41-46). Los Angeles, CA: Leadership Training Institute for the Gifted and Talented.

Feldhusen, J. F., & Treffinger, D. J. (1980). *Creative thinking and problem solving in gifted education*. Dubuque, IA: Kendall/Hunt.

Feldman, D. H. (1980). *Beyond universals in cognitive development*. Norwood, NJ: Ablex.

Fleith, D. d. S. (2000). Teacher and student perceptions of creativity in the classroom environment. *Roeper Review*, *22*(3), 148-157.

Freud, S. (1907/1989). Creative writers and day-dreaming. In P. Gay (Ed.), *The Freud reader* (pp. 436-443). New York: Norton. (Paper originally presented December 6, 1907).

Gantchev, D. (2007). *Assessing the economic contribution of creative industries: WIPO's experience*. Paper presented at the WIPO International Conference on Intellectual Property and the Creative Industries. Retrieved.

Gardner, H. (1973). *The arts and human development: A psychological study of the artistic process*. New York: Wiley.

Gardner, H. (1983). *Frames of mind: The theory of multiple intelligences*. New York: Basic Books.

Gardner, H. (2007). *Five minds for the future*. Boston, MA: Harvard Business School Press.

Gilbert, D. T. (2006). *Stumbling on happiness*. New York: Knopf.

Haidt, J. (2006). *The happiness hypothesis: Finding modern truth in ancient wisdom*. New York: Basic.

Hetland, L., & Winner, E. (2004). Cognitive transfer from arts education to non-arts outcomes: Research evidence and policy implications. In E. W. Eisner & M. D. Day (Eds.), *Handbook of research and policy in art education* (pp. 135-162). Mahwah, NJ: Erlbaum.

Hetland, L., Winner, E., Veenema, S., & Sheridan, K. M. (2007). *Studio thinking: The real benefits of visual arts education*. New York: Teachers College Press.

Hunt, M. E. (2009, November 1). Experimental Exploratorium activities awe at 40. *San Francisco Chronicle*, p. Q14.

Jay, E. S., & Perkins, D. N. (1997). Problem finding: The search for mechanism. In M. A. Runco (Ed.), *Creativity research handbook (Vol. 1)* (Vol. 1, pp. 257-293). Cresskill, NJ: Hampton Press.

Joubert, M. M. (2001). The art of creative teaching: NACCCE and beyond. In A. Craft, B. Jeffrey & M. Leibling (Eds.), *Creativity in education* (pp. 17-34). London: Continuum.

Kim, J. (1992). "Downward causation" in emergentism and nonreductive physicalism. In A. Beckermann, H. Flohr & J. Kim (Eds.), *Emergence or reduction? Essays on the prospects of nonreductive physicalism* (pp. 119-138). New York: Walter de Gruyter.

Kind, P. M., & Kind, V. (2007). Creativity in science education: Perspectives and challenges for developing school science. *Studies in Science Education*, *43*, 1-37.

Mack, R. W. (1987). Are methods of enhancing creativity being taught in teacher education programs as perceived by teacher educators and student teachers? *Journal of Creative Behavior*, *21*, 22-33.

MacKinnon, D. W. (1962). The nature and nurture of creative talent. *American Psychologist*, *17*(7), 484-495.

Maslow, A. H. (1959). Creativity in self-actualizing people. In H. H. Anderson (Ed.), *Creativity and its cultivation* (pp. 83-95). New York: Harper & Row.

May, R. (1959). The nature of creativity. In H. H. Anderson (Ed.), *Creativity and its cultivation* (pp. 55-68). New York: Harper & Row.

Mayer, R. E. (1989). Cognitive views of creativity: Creative teaching for creative learning. *Contemporary Educational Psychology, 14*, 203-211.

Mayer, R. E. (2004). Should there be a three-strikes rule against pure discovery learning? The case for guided methods of instruction. *American Psychologist, 59*(1), 14-19.

McLaughlin, B. P. (1992). The rise and fall of British emergentism. In A. Beckermann, H. Flohr & J. Kim (Eds.), *Emergence or reduction? Essays on the prospects of nonreductive physicalism* (pp. 49-93). Berlin: Walter de Gruyter.

Mercer, N. (2000). *Words and minds: How we use language to think together*. London: Routledge.

Moga, E., Burger, K., Hetland, L., & Winner, E. (2000). Does studying the arts engender creative thinking? Evidence for near but not far transfer. *Journal of Aesthetic Education, 34*(3/4), 91-104.

Morgan, C. L. (1923). *Emergent evolution*. London: Williams and Norgate. (Originally presented as the 1922 Gifford lectures at the University of St. Andrews.).

NACCCE (National Advisory Committee on Creative and Cultural Education). (1999). *All our futures: Creativity, culture and education*. London, UK: DFEE.

Nickerson, R. S. (1999). Enhancing creativity. In R. J. Sternberg (Ed.), *The handbook of creativity* (pp. 392-430). New York: Cambridge.

OECD. (2004). *Innovation in the knowledge economy: Implications for education and learning*. Paris: OECD Publications.

OECD. (2008). *Innovating to learn, learning to innovate*. Paris, France: OECD.

Palincsar, A. S. (1998). Social constructivist perspectives on teaching and learning. In J. T. Spence, J. M. Darley & D. J. Foss (Eds.), *Annual Review of Psychology* (Vol. 49, pp. 345-375). Palo Alto, CA: Annual Reviews.

Papert, S. (1993). *The children's machine: Rethinking school in the age of the computer*. New York: BasicBooks.

Partnership for 21st Century Skills. (2007). *The intellectual and policy foundations of the 21st century skills framework*. Tuczon, AZ: Partnership for 21st Century Skills.

Piaget, J. (1971a). Comment on Beilin's paper. In D. R. Green, M. P. Ford & G. B. Flamer (Eds.), *Measurement and Piaget* (pp. 192-194). New York: McGraw-Hill.

Piaget, J. (1971b). The theory of stages in cognitive development. In D. R. Green, M. P. Ford & G. B. Flamer (Eds.), *Measurement and Piaget* (pp. 1-11). New York: McGraw-Hill.

Piirto, J. (1998). *Understanding those who create (2nd edition)*. Dayton, OH: Ohio Psychology Press.

Piirto, J. (2004). *Understanding creativity (Revised edition of Understanding those who create 2nd ed 1998)*. Scottsdale, AZ: Great Potential Press.

Qualifications and Curriculum Authority (QCA). (2005). *Creativity: Find it, promote, promoting pupils' creative thinking and behaviour across the curriculum at key stages 1 and 2, practical materials for schools*. London: Qualifications and Curriculum Authority.

Rejskind, G. (2000). TAG teachers: Only the creative need apply. *Roeper Review, 22*(3), 153-157.

Rogers, C. R. (1954). Toward a theory of creativity. *ETC: A review of general semantics, 11*(4), 249-260.

Rogoff, B. (1990). *Apprenticeship in thinking: Cognitive development in social context*. New York: Oxford University Press.

Rogoff, B. (1998). Cognition as a collaborative process. In D. Kuhn & R. S. Siegler (Eds.), *Handbook of child psychology, 5th edition, Volume 2: Cognition, perception, and language* (pp. 679-744). New York: Wiley.

Sawyer, R. K. (1999). The emergence of creativity. *Philosophical Psychology, 12*(4), 447-469.

Sawyer, R. K. (2002). Emergence in psychology: Lessons from the history of non-reductionist science. *Human Development, 45*, 2-28.

Sawyer, R. K. (2003a). Emergence in creativity and development. In R. K. Sawyer, V. John-Steiner, S. Moran, R. Sternberg, D. H. Feldman, M. Csikszentmihalyi & J. Nakamura (Eds.), *Creativity and development* (pp. 12-60). New York: Oxford.

Sawyer, R. K. (2003b). *Group creativity: Music, theater, collaboration*. Mahwah, NJ: Erlbaum.

Sawyer, R. K. (2003c). *Improvised dialogues: Emergence and creativity in conversation*. Westport, CT: Greenwood.

Sawyer, R. K. (2004). Creative teaching: Collaborative discussion as disciplined improvisation. *Educational Researcher, 33*(2), 12-20.

Sawyer, R. K. (2006a). Analyzing collaborative discourse. In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 187-204). New York: Cambridge.

Sawyer, R. K. (2006b). Educating for innovation. *The International Journal of Thinking Skills and Creativity, 1*(1), 41-48.

Sawyer, R. K. (2007). *Group genius: The creative power of collaboration*. New York: BasicBooks.

Sawyer, R. K. (Ed.). (2011a). *Structure and improvisation in creative teaching*. New York: Cambridge University Press.

Sawyer, R. K. (2011b). What makes good teachers great? The artful balance of structure and improvisation. In R. K. Sawyer (Ed.), *Structure and improvisation in creative teaching* (pp. 1-24). New York: Cambridge University Press.

Sawyer, R. K. (2012a). *Explaining creativity: The science of human innovation (2nd edition)*. New York: Oxford.

Sawyer, R. K. (Ed.). (2012b). *The Cambridge handbook of the learning sciences*. New York: Cambridge University Press.

Sawyer, R. K. (in press). Introduction: The new science of learning. In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences*. New York: Cambridge.

Sawyer, R. K., & Berson, S. (2004). Study group discourse: How external representations affect collaborative conversation. *Linguistics and Education, 15*(4), 387-412.

Sawyer, R. K., Scribner, J. P., Watson, S. T., & Myers, V. L. (2005). Talking leadership: Conversation analysis and distributed leadership. In W. K. Hoy & C. Miskel (Eds.), *Educational leadership and reform* (pp. 169-185). Greenwich, CT: Information Age Publishing.

Scardamalia, M., & Bereiter, C. (2006). Knowledge building. In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 97-115). New York: Cambridge University Press.

Schacter, J., Thum, Y. M., & Zifkin, D. (2006). How much does creative teaching enhance elementary students' achievement? *Journal of Creative Behavior, 40*(1), 47-72.

Schiller, F. (1968). *On the aesthetic education of man, in a series of letters*. New York: Oxford University Press. (Originally published as über die aesthetische Erziehung des Menschen in einer Reihe von Briefen, 1793/1794.).

Schramm, S. L. (2002). *Transforming the curriculum: Thinking outside the box*. Lanham, MD: Scarecrow Education.

Scott, G., Leritz, L. E., & Mumford, M. D. (2004). The effectiveness of creativity training: A quantitative review. *Creativity Research Journal, 16*(4), 361-388.

Serrell, Beverly. 1996. *Exhibit labels: An interpretive approach*. Walnut Creek, CA: Alta Mira Press.

Stein, M. I. (1961/1963). Creativity in a free society. *Educational horizons, 41*, 115-130. (Reprinted with minor changes from the October 1961 issue of Graduate Comment at Wayne State University, Detroit, MI).

Sternberg, R. J., & Williams, W. M. (1996). *How to develop student creativity*. Alexandria, VA: Association for Supervision and Curriculum Development.

Strokrocki, M. (Ed.). (2005). *Interdisciplinary Art Education: Building Bridges to Connect Disciplines and Cultures*. Reston, VA: National Art Education Association.

Taylor, C. W. (Ed.). (1959). *The third (1959) University of Utah research conference on the identification of creative scientific talent*. Salt Lake City: University of Utah Press.

Taylor, C. W. (Ed.). (1964a). *Creativity: Progress and potential*. New York: McGraw-Hill Book Company.

Taylor, C. W. (Ed.). (1964b). *Widening horizons in creativity: The proceedings of the fifth Utah creativity research conference*. New York: John Wiley & Sons.

Taylor, C. W., & Barron, F. (Eds.). (1963). *Scientific creativity: Its recognition and development*. New York: John Wiley & Sons.

Teller, P. (1992). A contemporary look at emergence. In A. Beckermann, H. Flohr & J. Kim (Eds.), *Emergence or reduction? Essays on the prospects of nonreductive physicalism* (pp. 139-153). Berlin: Walter de Gruyter.

Torrance, E. P. (1965). *Rewarding creative behavior: Experiments in classroom creativity*. Englewood Cliffs, NJ: Prentice-Hall.

Torrance, E. P. (1970). *Encouraging creativity in the classroom*. Dubuque, IA: W. C. Brown.

Torrance, E. P. (1972). Can we teach children to think creatively? *Journal of Creative Behavior, 6*, 114-143.

Torrance, E. P. (2008). *The Torrance tests of creative thinking: Norms-technical*

manual. Bensenville, IL: Scholastic Testing Service.

Torrance, E. P., Bruch, C. B., & Torrance, J. P. (1976). Interscholastic futuristic creative problem solving. *Journal of Creative Behavior*, *10*, 117-125.

Torrance, E. P., & Safter, H. T. (1986). Are children becoming more creative? *Journal of Creative Behavior, 20*, 1-13.

Trilling, Bernie and Charles Fadel. 2009. *21st century skills: Learning for life in our times*. San Francisco, CA: Jossey-Bass.

Whitehead, A. N. (1926). *Science and the modern world*. New York: Macmillan Company.

Whyte, W. H. (1956). *The organization man*. New York: Simon and Schuster.

Winslow, L. (1939). *The integrated school art program*. New York: McGraw-Hill.