imagination conversations

a project of Lincoln Center Institute

Learning to Imagine

by

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Introduction

Lincoln Center Institute (LCI) has identified imagination as the first step in a continuum that leads to Creativity and then Innovation, characterized by many as the key capabilities needed to succeed in the 21st century (see *Imagination First: Unlocking the Power of Possibility,* by Eric Liu and Scott Noppe-Brandon; and *Why Imagination?* by Noppe-Brandon, Madeleine F. Holzer, and Christopher St. Clair [2009, 2008]). We agree with their idea of imagination as the ability to conceive of what is not, and creativity as imagination applied to real issues. Innovation only occurs when what is created has application in the real world and has advanced knowledge or action in a useful way. LCI believes that without a highly developed imagination, neither creativity nor innovation would flourish. In addition, we believe that our schools are critical places in which to foster imagination. The central assumption of this paper is that the course of the future depends on our ability to cultivate the imaginations of young people. Our hope is to provide food for thought—to help you ask, What if imagination were central to education? What issues would it address? What would it look like?

To set the context, we first examine the purposes of education in a democracy such as the United States of America, and the role that nurturing students' imaginations can play. We then take a brief look at the relationship between creativity and imagination, and at general programs incorporating imagination broadly throughout schools. Finally, we focus on two specific programs that cultivate students' imaginations, one grounded in the arts, and the other in the sciences, as examples of the role imagination can play across all subjects.

Imagination and the Purposes of Education in a Democracy

For the purpose of this discussion, we posit that there are essentially four overarching reasons we educate. They are: preparing students for democratic participation, providing access to knowledge and critical thinking, enabling all students to take advantage of life's opportunities, and enabling students to lead rich and rewarding personal lives. None of these can be achieved fully without attention to the role of imagination. While we acknowledge that not all would agree with our definition of purposes, our comprehensive vision, we believe, can serve our children and our society well.

PURPOSE 1. PREPARING STUDENTS FOR CRITICAL DEMOCRATIC PARTICIPATION.

The first purpose of public education we explore is: preparing students to be critical participants in a democratic society. In order to do that effectively, participants must be able to imagine the possibilities in society. Ideally, for this purpose and others, students learn to think critically while examining important concepts through challenging ideas, offering different perspectives, and participating in discussions with others. Learning to think imaginatively as well as critically is essential here. When we engage in critical thinking, we must be able to consider all the possibilities relevant to the judgment we are making and not just the obvious ones. Thinking in a way that opens new doors that are not apparent when we stare at the obvious, defines the essence of imaginative thinking. In a sense, we want students in a democratic society to become participants who are actively skeptical, who do not take things for granted. This is the essence of being an active and critical participant, rather than a passive one, in a democracy. We do not just say "active" participant, because activity can limit itself to the act of voting. We are hoping for more than that—critical analysis of ideas and decisions followed by actions based on that analysis. Robert Kennedy, attributing the quote to George Bernard Shaw, said, "There are those that look at things the way they are, and ask why? I dream of things that never were, and ask why not?" It is a small leap from translating dreaming of things that never were to creative thinking: this is the beginning of imagination in action. If we only look at what is and can't imagine alternatives, we are stuck in the present or the past. Children in schools need to learn to understand important public issues in this light. Whether the issue is equity in education, full employment, segregation, overdependence on fossil fuels, or closing the opportunity gap, we need to be able to imagine the possibilities to move forward.

Closely related to this is the way we treat each other. Imagine a classroom where all these qualities were present all the time:

- **Listening carefully to other points of view**. Careful listening is often a goal in elementary schools, but it is a skill that must be developed throughout

one's education. Listening carefully is related to treating others with respect—it suggests that we take what others say seriously and that we can both imagine and understand the reasons behind their position.

- **Responding to differing points of view with reasoned arguments**. Learning to give reasons and support for our positions is an important intellectual skill and central to our role in a democratic society. Equally important is recognizing specifically how imagination led to the reasons given or to the very formation of the argument. Giving reasons allows for discussion, and the capacity to "visualize"—that is, to imagine another's position—is crucial to our ability to change our own views and work toward a reasonable compromise.
- **Avoiding anger and violence**. One outcome of showing respect, listening carefully, imagining, and giving reasons for a position, is a reduction in dealing with differences through anger or even violence.

Modeling these behaviors and focusing on the role of imagination in the process is an essential part of democratic living that must be taught to each new generation. Our schools are the main public institutions charged with this responsibility, and carrying it out can be done without diminishing students' attention to the subjects they need to learn.

PURPOSE 2: PROVIDING ACCESS TO KNOWLEDGE AND FOSTERING CRITICAL THINKING FOR ALL CHILDREN.

The next major purpose of education in a democracy is helping all children reach high levels of understanding of the domains of knowledge (the disciplines) and to learn to think critically. This purpose of education comes to mind first for many individuals who see it as the primary concern of education. As you can see from our discussion of the first purpose—preparing students for critical democratic participation—critical thinking is an educational goal that appears as part of more than one purpose of education. Understanding subject matter knowledge means learning to think critically about what we believe we know and to be able to imagine alternative explanations. Living in a democracy means making good judgments through critical thinking. Thinking critically is important to taking advantage of life's opportunities, and is central to the quality of life.

On the surface, providing access to knowledge is a goal all seem to agree on: a major purpose of education is to come to know and understand different subject matter areas. The goal, however, is embedded within a number of contested issues that policy makers and politicians argue over, including:

- **What kinds of knowledge should be taught**? Another way of asking the question is "What knowledge is of most worth?"

- **What form should knowledge take**? Is it a series of facts, concepts, and problems to be solved? Or is knowledge really a process? How does imagination fit into the process of forming and understanding knowledge?
- **How is knowledge created**? Can knowledge be created without the application of imagination? How do students think of themselves with respect to knowledge? As potential creators? Recipients? Are they encouraged to imagine alternatives?

There is another important point embedded in this purpose. We use the phrase "for all children" very purposefully. Our expectations for children's ability to imagine, to be creative, and to learn the critical ideas embedded in the disciplines cannot be tempered by race or social class. Some studies show that teacher expectations differ for different groups of children often distinguished by race or socioeconomic status. High expectation is essential for strong learning by all children. Developing the expectation that all children can imagine, create, and learn at high levels must be central to how we prepare teachers, and evident in how they implement the new Common Core Standards.

PURPOSE 3: HELPING STUDENTS HAVE FULL ACCESS TO LIFE'S CHANCES

Many would state this purpose more simply: to help students get a good job, or to assure their place in the economy. The connection between better schools, better education, and better jobs is perhaps justifiably important to many policy makers. Many of the national reports on education in the 1970s through the 1990s focused on the tie between the economy and education, although some recent studies have questioned it (Condron, 2010; Roschelle et al., 2011).

We believe that conceiving of schools as preparing students for integral roles in the economy is important, but too narrow a goal. At one time in our history, job preparation meant vocational tracking and vocational schools, a movement which is seeing a resurgence. Liberal arts and science education, where imagination and problem solving were most likely to be emphasized, were seen as a luxury for the elite, and specific job preparation was available for students who did not achieve high academic standards. It can be argued that this is still the case through the differing expectations teachers have for children and the variations in the quality of education. All children deserve an education that gives them the opportunity to enter respected professions where problem solving and imagination are essential.

Meeting the purpose of helping students have full access to life's chances, requires preparing students to consider all the options open to them, to understand what it takes to pursue one option or another and to embrace the chances—the opportunities—that life provides. Maxine Greene, one of our best-known philosophers of education, has often said, "We can't become what we can't imagine"

(2001). Preparing students for the economy includes having them imagine themselves as physicians, artists, business leaders, lawyers, actors, dentists, architects, poets, media workers, computer specialists and, of course, as teachers. Providing deep knowledge about subject matter and the opportunity to imagine the possibilities are how this public purpose of education in a democracy should be pursued.

If we accept that helping students to imagine all the possibilities for their place in society, to pursue those of their choice, and to have full access to life's chances are together important purposes of education in a democratic society, we argue that:

- All students must be exposed to the wide range of possibilities in their lives.
- Students cannot become what they cannot imagine, so imagination is an important part of helping students think about possible occupations.
- Learning academic knowledge and critical, imaginative thinking skills enables students to perceive and use the full access to life's chances.
- All students should have access to teachers who are committed to providing opportunities to develop students' imagination and creativity.
- There is a need to be careful about "tracking" students into particular careers or levels of employment too early in their lives.

PURPOSE 4: PREPARING STUDENTS TO LEAD RICH AND REWARDING PERSONAL LIVES

Do schools have an obligation to think about how rich and rewarding the lives of their students will be? We think they do. The "pursuit of happiness" is one of the basic rights promised by the founders of the United States of America, and experience and knowledge are conducive to the fulfillment of one's potential. What kind of experiences? What kinds of knowledge? In addition to the ways that reading, writing, and arithmetic are related to rewarding lives, we posit that the arts, physical education, health education, and technology education, as well as social skills developed in schools, are all central to leading rich and rewarding personal lives. All of this learning requires the presence and nurturing of imagination.

For Maxine Greene, and for us, leading rich and rewarding personal lives means breaking through dailyness, passivity, and boredom and seeing the world fully, and understanding the problems we face. And it means fostering imagination. Facing problems may not sound like happiness, but in the long run it is a way to have control over our lives and see ourselves as able to solve problems. Trying to find solutions is a constant reminder of the essential nature of imagination in this process. We want all children to understand this. In her book *Variations on a Blue Guitar*, a collection of her lectures at Lincoln Center Institute, Greene writes:

> *We are interested in education here, not in schooling. We are interested in openings, in unexplored possibilities…. For us, education signifies an initiation into new ways of seeing, hearing, feeling, moving. It signifies the nature of a special kind of reflectiveness and expressiveness, a reaching out for meanings, a learning to learn.*
>
> *…we do not regard [this] in any sense a fringe undertaking, a species of "frill." We see it as integral to the development of persons—to their cognitive, perceptual, emotional, and imaginative development. We see it as part of the human effort (so often forgotten today) to seek a greater coherence in the world. We see it as an effort to move individuals (working together, searching together) to seek a grounding for themselves, so that they may break through the "cotton wool" of dailyness and passivity and boredom and come awake to the colored, sounding, problematic world.* (2001)

Attending to the quality of the health of students is also an important part of education. One cannot pursue "the good life" if one does not have the health to do so. Growing evidence suggests that good health is correlated with high school graduation and we believe that compelling programs that foster imagination and critical thinking have a positive impact on helping students understand the meaning of education and reduce their rejection of education as useless. Students must learn to make choices based on good information, and while many educators think of critical thinking only in relation to traditional academic subjects, it is a matter of life and death in making choices about drug use and unsafe sexual behavior. Children caught in a web where drug use and unsafe sexual behavior are part of their peer culture must imagine how it could be otherwise. Educators are instrumental in this cause.

We must underscore that not all of these aims of education can be measured by standardized tests and, in fact, some very important ones cannot. While we understand, of course, the role of standardized tests as a measure of education—we would say one of the measures—they are not why we educate. Developing appropriate ways, beyond the scope of current measures, to assess imaginative skills is essential.

Imagination and Creativity—A Brief Review

When we think about the first part of the continuum defined at the beginning of this paper—from imagination to creativity and then to innovation—it is interesting to note that while there are many books and studies on creativity or its measurement, there are many fewer on the imagination. Writings on imagination seem to fall more in the philosophical and theoretical realms, or are included as part of larger conceptions of creativity. The major center for writings on imagination and education is the Imaginative Education Research Group, at Simon Fraser University in Canada. Founded by Kieran Egan and his colleagues, this group has published a number of books and articles focused solely on imagination in education settings (see, for example, *Teaching and Learning Outside the Box: Inspiring Imagination Across the Curriculum,* Egan, Stout and Takaya, 2007). In addition, a number of creativity books, chapters, and articles mention imagination briefly, or appear to subsume imagination under the concept of "creative ideas," giving imagination itself little or no special attention (see, for example, Sternberg and Lubart, in Sternberg, 1999; Baer and Garrett in Beghetto and Kaufman, 2010; and Sawyer, 2006).

The 460-page *Handbook of Creativity* (Sternberg, 1999), which includes some thirty authors, has only four citations for "imagination" in its index. Nonetheless, one of these actually articulates the idea of imagination as part of a creative continuum. Policastro and Gardner define imagination as an important part of a generative cognitive style, which is involved in what they call "creative talent" (in Sternberg, 1999). They further see imagination as a "…form of playful analogic thinking that draws on previous experiences, but combines them in unusual ways, generating new patterns of meaning." Importantly, they distinguish between imagination and fantasy, with the former denoting the generation of patterns of meaning that serve as an adaptive function toward reality; and the latter denoting a subjective expression of needs, conflicts, and wishes. They see imagination potentially generating creative ideas, whereas fantasy generates illusions. This echoes, and lends credence to, the first part of the Imagination, Creativity, Innovation continuum described above.

Others, too, allude to the imagination as part of a continuum in their discussions of creativity. Sir Ken Robinson, well known for his books and lectures on creativity, also includes imagination. For him, creativity is, in fact, "imaginative processes with outcomes in the public world" (Robinson, 2001). Renzulli and De Wet, in their article *Developing Creative Productivity in Young People* (2010) cite Phil Phenix, who, some forty years ago, argued for the importance of imagination in selecting and creating curricular materials that would appeal to the learner. And over a century earlier, the Italian Giovanni Antonio Colozza tried to define something called the "constructive imagination" (Antonietti and Cornoldi in Kaufman and Sternberg, 2006). According to Antonietti and Cornoldi, Colozza states:

> *The constructive imagination, involved in scientific discovery and in the solution of ill-defined problems, allows people to formulate new hypotheses on the basis of the overall consideration of the elements of a given situation and of the relations among them, and it allows them to evaluate and criticize the generated hypotheses. The constructive imagination is characterized not only by cognitive qualities, but also emotional and motivational qualities: It is accompanied by an increase in arousal and curiosity* (p. 132).

While these few examples of theories about the relationship between imagination and creativity are far from exhaustive, they are important because they support the argument that imagination is critical to creativity. If this is so, how can we make the skills and capacities that lead to cultivating the imagination an important and valued part of an education that leads to creativity and innovation?

IMAGINATION AND EDUCATION

Schools that focus on cultivating imagination as a primary goal are few in number. Some current examples include: Reggio Emilia (Italy), with its focus on studio arts and imagination in early childhood education; the pre-K-12 Waldorf schools, founded by Rudolf Steiner, which have a similar focus; and schools that incorporate the work of Kieran Egan of Simon Fraser University on imaginative education. Many mainstream reforms that focus on cultivating Habits of Mind often incorporate the imagination either implicitly or explicitly. There are still schools that follow the Progressives basing their work on philosopher John Dewey. But few of these efforts have had lasting and wide-scale impact on current education systems in the United States.

To some, this may not seem surprising. The current emphasis on standardized tests (mentioned earlier) has narrowed the curriculum in many schools to include only those items that relate directly to achievement as measured by those tests. It is surprising, on the other hand, given the widely accepted view that fostering imagination, creativity, and innovation is essential for supporting children's development of 21st-century skills.

Nonetheless, in specific subject areas, especially the arts and the sciences, there is movement. What follows is a description of two different approaches to education that develop children's capacities and understanding of imagination and creativity in order to engage in learning and innovation. The first approach, from Lincoln Center Institute, focuses on the development of the Capacities for Imaginative Learning that are applicable across all subject areas and are grounded in the arts. The second, from Exploratorium, a San Francisco museum and laboratory for learning about learning, focuses on imagination as a driver of science learning.

Lincoln Center Institute: From Aesthetic Perception to Imaginative Learning

For over 35 years, Lincoln Center Institute has grounded its work in education by exploring the idea that cultivating aesthetic perception releases the imagination. The idea is rooted in the philosophies of John Dewey and Maxine Greene, the latter of whom has been the Institute's philosopher-in-residence from its inception. Building on Greene's stance that "informed engagements" with the arts are the most likely mode of releasing our students' (or any person's) imaginative capacity and giving it play (2001), Institute staff and teaching artists have designed ways to nurture this type of engagement. Over time, this work has evolved into a sophisticated, embodied inquiry process grounded in the arts.

Dewey's definition of aesthetic perception, in *Art as Experience*, forms the basis for this inquiry:

> *…to perceive, a beholder must create* [sic] *his own experience. And his creation must include relations comparable to those which the original producer underwent. They are not the same in any literal sense. But with the perceiver, as with the artist, there must be an ordering of the elements of the whole that is in form, although not in details, the same as the process of organization the creator of the work consciously experienced. Without an act of re-creation, the object is not perceived as a work of art. The artist selected, simplified, clarified, abridged and condensed according to his interest. The beholder must go through these operations according to his point of view and interest. In both, an act of abstraction, that is of extraction of what is significant, takes place. In both, there is comprehension in its literal signification—that is, a gathering together of details and particulars physically scattered into an experienced whole.* (1934, p. 54)

Specifically, the Institute's process of preparing people for perceiving works of art starts with a generative question called the "line of inquiry," whereby the instructor (teaching artist or teacher) tries to imagine and re-create the process or processes a specific artist used to create a particular work of art. Building on this question, the instructor creates experiential lessons that include art making, questioning, reflection, and the use of multidisciplinary and multimedia resources. Some of these lessons purposely occur before the actual experience with the work of art to help initiate perception; others occur afterward to deepen reflection. All set the stage for the possibility of what is called by John Dewey "an experience"* which can lead to what we have come to call Imaginative Learning.

* By "an experience" Dewey implies an event where there is a sense of coherent parts leading toward a feeling of closure and wholeness.

This kind of learning can be connected to other subjects through the capacities it seeks to develop in students, regardless of the subject matter being taught.

THE CAPACITIES FOR IMAGINATIVE LEARNING

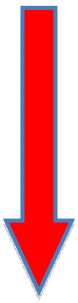
In 2004, as part of a proposal to create a small high school in New York City, the Institute was asked to articulate what students would learn in an LCI-guided school that might be different from what they could learn at any other school. LCI focused on what its foundational work in the arts taught students, introducing what has become the *Capacities for Imaginative Learning*. (Holzer, 2004). Building on LCI's philosophy and practice for cultivating perception through the study of works of art as a way of releasing imagination, the Capacities became: Noticing Deeply, Embodying, Questioning, Making Connections, Identifying Patterns, Exhibiting Empathy, Living with Ambiguity, Creating Meaning, Taking Action, and Reflecting/Assessing. While the Capacities are never linear in how they are applied, the first three seem most closely related to perception and cultivating imagination, and the next five to seven are related to creativity (or creative problem solving) and innovation. Reflecting and Assessing occur throughout the perception, problem-solving, and action phases.

The Institute has discovered that as these capacities were introduced to its partnering educators, Pre-K-18, teachers instantaneously saw connections between them and the modes of thinking they were teaching in other subject areas. Indeed, they saw the potential for the Capacities to become a common language across subject areas, akin to Habits of Mind. Nonetheless, it is important to understand that while there is a kinship among the modes of thinking in the subject areas, the Capacities are not the scientific method, nor are they totally the way historians, social scientists, or mathematicians think. Rather, they have similarities to patterns of thought in these disciplines, and to Colazzo's concept of the constructive imagination, mentioned earlier. Importantly, they also add something different—those aspects of perception in the arts that validate embodying, empathizing, and ambiguity as ways of knowing.

TEACHING FOR IMAGINATIVE LEARNING

If it is agreed that embodying, empathizing, and living with ambiguity as a part of inquiry are important for all students, how do we teach these skills? As a result of a two-year study of the Capacities in action at seven of the Institute's Focus Schools funded by the Ford Foundation (Palmer Wolf, 2010), a theory of action has been articulated for LCI's work that includes what can happen after students and teachers have become familiar with cultivating perception through the study of works of art.

LCI'S THEORY OF ACTION



- Stimulated by complex and evocative objects of study such as paintings, films, illustrated books, and plays, along with inquiries led by skilled teaching artists, classroom teachers and students can engage in sustained and nuanced inquiry that is both highly motivating and highly rewarding.

- In turn, these interactions build an appetite for tackling big ideas, comprehending texts with multiple meanings, and engaging in spirited discussions.

Young people develop a set of dispositions or capacities (e.g., noticing deeply, questioning, creating meaning, etc.) which they can and will use across settings and subjects.

Classroom teachers and schools develop an understanding of the importance of imaginative learning and increasingly support this kind of inquiry.

This theory of action makes the argument that skills of perception/imagination will set the stage for creative problem solving across subject areas, and that teachers and school administrators will support Imaginative Learning across schools and school systems because of its value in achieving 21st Century Skills through the Common Core Standards.

The study also begins to point out the kinds of teaching strategies, or moves, that either teachers or teaching artists use to support students' Imaginative Learning. According to Palmer Wolf, these strategies include such actions as

- Inviting: teacher or teaching artist requests or assigns students to engage in imaginative activity, setting up structures or processes that support it;
- Modeling/Entering: Teacher or teaching artists responds imaginatively on his/her own as a way of modeling or extending imaginative learning for students;
- Connecting: Teacher or teaching artist connects the current teaching and learning to other moments or types of learning, in other formats, times, or subject matters;
- Extending: Teacher or teaching artist asks questions, probes, or otherwise encourages students to take their imaginative activity further;
- Acknowledge/Praise: Teacher or teaching artist points out what's strong about the student's work or responses, or uses a student's work as a model for imaginative learning;
- Content/Information: Teacher or teaching artist supplements, enriches, or supports imaginative learning with added information or context (from subject matter, work of art, etc.);
- Protect/Support: Teacher or teaching artist protects or supports imaginative learning by setting rules or procedures that create a safe environment for providing new things, sharing early drafts of work, or generating ideas, etc. (more than is habitual in schools at present); and
- Partnering: Teacher and teaching artist collaborate closely, building on or supplementing what each does or says to make the imaginative experience richer or more challenging and engaging for students.

It is important to note that Palmer Wolf posits that these strategies support Imaginative Learning, whether it occurs through the study of a work of art or of another object that is rich with meaning. To recall, the core practices LCI has developed to study works of art are experiential lessons that include art making, questioning, reflection, and the use of multidisciplinary and multimedia resources. In disciplines other than art, the core becomes a hands-on in-depth experience with an object important to that discipline, followed by the other three. But it is the combination of the other parts of inquiry with this *experience with an object of study* that differentiates this teaching practice that fosters imaginative learning from other teaching practices. It is the experience (in Dewey's terms, mentioned earlier) with an object that initiates the process. Without it, there might only be superficial ways to notice, hone perceptive skills, imagine, and create.

Exploratorium: Imagination, Creativity, Innovation in Science Learning

Many scientists have commented on the central role that imagination plays in the production of scientific knowledge. Einstein famously said that imagination was more important than knowledge. In his examination of the history of science, Thomas Kuhn wrote about the centrality of imagination for the advancement of science as an enterprise and as a body of understanding: Imagination compels the asking of new questions, the crossing of old boundaries, and the breakthrough interpretations of novel or unexpected findings (1962/1966).

So why do students, on the whole, find science to be so boring, so alienating, and so irrelevant to their social worlds? Why is imagination perhaps the last word many students would use to describe science and what it takes to be a scientist? And how might this disparity relate to trends that show that U.S. students are less and less interested in studying and pursuing science?

As is well documented, science in school is notoriously taught as a received body of facts and a scripted process of investigation (the "scientific method"). But we know that this representation of science bears only a distant relationship to the active practice of science. Every day, in the field and in the lab, scientists bring their personal and their social imaginations to the job of wondering, noticing, questioning, investigating, and making sense of the natural world. They go back and forth; they are circular; they make huge leaps of understanding. Of course, they undertake and verify their work using specific disciplinary-based ways of knowing (observing, comparing, analyzing, etc.) and particular standards of evidence. But sometimes, as in the case of Einstein's theory of general relativity, not only does imagination drive the questions and the observations, but even scientific evidence must be imagined and then conjectured until technologies are developed that allow experimentation that can test claims. One might say that imagining itself is a scientific practice, as integral to scientific investigation as is questioning or analyzing, but you are unlikely to find it in the state or local frameworks for science standards.

The absence of imagination in the science classroom is not a trivial matter; it is a matter of equity, critical to expanding students' access to participation and futures in science. Too few students today find science to be a field of study that involves them as imaginative, creative, and social beings, and too few can imagine themselves as scientists. There is a long history of science reform efforts that have identified lists of concepts that children need to know. There is a more recent history (though it references the work of Dewey from over 100 years ago) that emphasizes the ways in which science is best experienced as processes of investigation, driven by authentic questions, entailing scientific practices, and leading to the development of canonical conceptual understandings found on state and local lists. But 20 years after such views of science were presented in the National Standards for Science

Education, the AAAS Benchmarks, and the NSTA Frameworks, we have less interest and uptake in science than ever. What is missing in this picture of science?

What might be missing is an image of the learner her or himself, what science means to that learner, and how the learner sees her or himself with respect to science. Indeed, there is a growing body of research that supports the notion that engagement with science involves not only knowing the facts of science, and not only mastering the practices of science, but also developing a personal and social imagination with respect to how science can become a tool for satisfying questions, needs, and goals for one's self and one's social community. In this body of research, science is taken up to pursue genuine questions of consequence, where answers are not known. Scholars have long argued that science must be made more relevant to students, but frequently these arguments are made without elaborating on the ways in which such engagement builds on and develops the social imagination of the individuals who are part of the learning group.

IMAGINATION—CREATIVITY—INNOVATION: THE ROLE OF MAKING

A specific example of incorporating imagination into the science classroom can be found in the Exploratorium's Making work. Making, in an educational context, references the national grassroots Makers Movement, which is made up of people who use their hands, and a range of tools from high to low tech, to design and create systems, objects, or ideas. Making communities include welders, crocheters, computer hackers, inventors, artists, and garage scientists. The Makers community has a journal, *Make* Magazine, a website, and also stages Maker Faires in cities throughout the U.S. and in other countries. Maker activities are highly imaginative, creative, and innovative, often infused with the unexpected, the fantastic, and a mix of 21st- and 16th-century technologies and aesthetics. For example, at a Makers Faire held at the New York Hall of Science in 2010, a group of Makers conducted chariot races between elaborately ornamented foot-powered chariots and equally ornamented solar-powered mopeds. Other presenters at the Faire included home-made laser cutting machines, a three-dimensional printer that worked with sugar-based materials, and a two-axis plotter that drew tessellating vector patterns on hard boiled eggs and light bulbs. Making has attracted the attention of the White House as an important medium for engaging people in creative processes.

In an educational context, Making activities incorporate key features of what drives *making* in the real world—the learner's imagination, interests and ideas; access to a variety of tools; processes of bricolage and tinkering. But in a science education context, these features are employed in such a way that scientific processes, concepts, and tools become instrumental means for engaging in the acts of design and creation. For example, an Exploratorium Makers activity called *Cardboard Automata* requires learners to work with, adapt, refine, and master the science of simple machines. They work with such components as cams, axles, and levers, and study structure and scale as well as cause and effect, in order to build toaster-sized, hand-cranked automata made of cardboard and other materials.

With the goal of sparking imagination as a means of beginning engagement, the activity takes place in a physical space constructed entirely of cardboard and stacked with past collections of whimsical cardboard automata representing all kinds of objects and phenomena: leaping dogs, setting suns, baton-playing conductors. Inspired by the fanciful setting and accessible materials, learners begin to imagine what they can contribute to the collection.

In a multi-year study, Exploratorium has identified and tested design features of the making environment, activity, and facilitation that operate to engage learners, to help them to develop intentionality, solidarity, and to innovate. Imagination is at the core of these processes. Sparking imagination, a function of the environment, is central to inviting in and orienting learners. Developing imagination, a function of the activity design, is central to building a sense of intentionality, creativity, and ultimately innovation. A shared social imagination, a function in part of facilitation, is central to developing a sense of solidarity that leads to learners sharing strategies, borrowing ideas, and building on the work of one another.

Features of the cardboard automata activity, which are also found in other making activities, include multiple pathways in, materials that invite curiosity, increasingly complex possibilities and combinations, and unexpected or whimsical challenges and materials. The Making environment itself is designed to help learners slow down and dig in as they become oriented to and begin to explore the surrounding set of

ideas. This patina of past exploration provides a history, an archaeology, and a sociology that helps learners to begin. Past projects, positioned on walls, shelves, ceilings, and work tables, create an immediate picture for the new visitor, allowing the environment to speak for itself, and providing building blocks—either conceptually, in terms of ideas, or literally, in terms of a project to add on to—for newcomers to take up and work with. In this way, the environment scaffolds learners to move from initial imagination (what can I do here?) to creativity (how do I do it?).

Materials are centrally located so that learners can dive in and begin to create, often building on what they have observed among existing creations. They develop ideas through seeing the work of others, trying something, observing results, refining designs, and perhaps, as in the real world of science, switching experiments when compelled by an unexpected finding, and starting the design and experimentation process anew. The array of materials and open-endedness of the activity allow room for new intentions to develop and for innovations to emerge.

Science Making activities provide a limited palette of materials and phenomena with which learners work, but they do not limit particular endpoints that result in a production of an identical set of constructions. In this context, it is critical that science Making facilitators allow mistakes and dead ends to occur. These moments, which may be fleeting, can help learners to the next step, or to a new set of experiments. The principles identified in this work include the following:

TENTATIVE INFORMAL SCIENCE PROGRAMS DESIGN PRINCIPLES (Short Version)

ENVIRONMENTAL CHARACTERISTICS	ACTIVITY DESIGN	FACILITATION APPROACHES
Ideas and **inspiration** are seeded by models, prior work, activities in the setting	Goals/tasks relate to and **build on prior interests** and knowledge	Spark interest through **modeling**, inviting, welcoming
Organized to support **initiative** and **autonomy**	**Materials** invite inquiry (demand to be touched, explored, etc.)	Sustain engagement with questions, and **what-ifs**
Organized to allow for **cross-pollination** of ideas	STEM is a **means, not ends,** to engagement	Deepen understanding and purpose through **complexification** and **reflection**
Organized to enable and allow **collaboration**	Multiple **pathways** in and through the activity	
	Ability to **complexify** choices, directions, and tools	

What we find powerful and engaging about Making activities, when intentionally designed along the principles described above, is the power of the learning experience to engage and release the imagination in ways that lead to learners digging in, experimenting, and committing to their ideas and imagination. This level of engagement and persistence leads in time to innovation. It is the hallmark of science, as described at the beginning of this section, where "what-ifs" both spark and sustain investigation. This way of experiencing science is much closer to, if not actually, the day-to-day working lives of all scientists, at least to the driving passion that leads them to choose science as a pursuit, and to come to imagine themselves as scientists. It is such a vision of learning, with imagination as the centerpiece, that we seek to support in our educational designs.

Conclusion

While acknowledging that effective schools and successful education depend on many components, one that must be emphasized for all of the critical purposes of education is fostering imagination as a precursor to creativity, innovation, and success in school and life. To emphasize this premise, we reiterate several essential points in the conversation about the role of education in fostering imagination.

1. We must recognize the broad purposes of education in a democracy, and support its success by attending to the role of imagination.
2. It is important to think of imagination's role in all disciplines, not only the arts, as the example from the sciences indicates.
3. When imagination is included in education, it is not at the expense of accountability. For example, through the use of Lincoln Center Institute's Capacities for Imaginative Learning, meaningful assessment and research are possible.
4. We must take advantage of the Common Core Standards as a way of helping to cultivate imagination in schools. These standards contain many connections to imaginative learning. We should articulate these.
5. The kind of education we describe is mostly available to privileged students. We must make every effort to assure equity in access to imaginative learning.

   and

6. To achieve these ends, we must carefully prepare teachers to be effective in understanding imagination and promoting it in their instruction.

We firmly believe that the introduction of imagination in classrooms, in the ways we have described, will enhance traditional learning and those things most easily measured by standardized tests, and not have a negative effect on those outcomes. In fact, we argue the outcome is likely to be a more effective and productive system that places us with strength in education among the nations of the world.

Images on pages 14, 15, 16: courtesy of Exploratorium. All other images: Jane Hoffer.

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