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Object Lessons

SHERRY TURKLE

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In the ongoing national conversation about science education in America, there is a new consensus that we have entered a time of crisis in our relationship to the international scientific and engineering community.[1] For generations we have led; now Americans wonder why our students are turning away from science and mathematics—at best content to be the world's brokers, broadcasters, and lawyers and at worst simply dropping out—while foreign students press forward on a playing field newly leveled by the resources of the World Wide Web (Friedman 2005). Leaders in science and technology express dismay. On this theme, Bill Gates (2005) stated flatly, "In the international competition to have the biggest and best supply of knowledge workers, America is falling behind." He went on: "In math and science, our fourth graders are among the top students in the world. By eighth grade, they're in the middle of the pack. By 12th grade, U.S. students are scoring near the bottom of all industrialized nations."

When the science committee of the House of Representatives asked the National Academies, the nation's leading scientific advisory group, for ten recommendations to strengthen America's scientific competitiveness, the academies offered twice that number. There were recommendations to support early-career scientists and those who plan to become science teachers. There were recommendations to create a new government agency to sponsor energy research and to use tax policy to encourage research and development in corporate settings.

As sensible as these recommendations may be, they deal largely with financial incentives and big institutions. Here I suggest a different tack, one resonant with the philosophy and practice of education I saw as a mentor at the Ross School. In this view, one approaches the teaching of science by looking to how objects, met early in children's lives, enter into the development of a love for science. The Ross philosophy respects the importance of the tactile, the sensuous, and the aesthetic in all aspects of the curriculum, with no exemption for science and technology. It values diversity in approaches to learning, including the learning of science. And it puts science in the closest possible relationship to art.

At the time of my first visit to the Ross School in fall 1997, its beautiful campus had not yet been built. My meetings with students and faculty—I was invited to speak about technology as an intimate partner in daily life—took place in a newly renovated school building that had very recently housed dental and real estate offices. The renovation was elegant, but what I remember most about those early years is how even modest spaces were transformed by art: beautiful reproductions of Asian art, classical and modern European paintings and sculpture, Oriental rugs. And there were computers all around, in every classroom, studio, and laboratory space. At the time of my early visits, it was still common practice for schools to isolate technology in "computer laboratories." At Ross, high technology was not isolated from Persian and Greek pottery. Art and science were considered together, within a curriculum envisaged as a spiral; from every point on the spiral one could see disparate elements of culture as one moved back and forward in time. From every point on the spiral, one could see that the disparate elements of the spiral formed a whole.

A curriculum that considers art and science together, a school environment rich in evocative objects—this is an idea that feels right to many people. Most often, the reason for their approval is intuitive: art and science together is a beautiful thing to believe in. Here I argue that the Ross School's art- and objects-infused scientific culture (and its technology-infused artistic culture) not only feels right but is right.

Objects

There are many paths into science. In one of them, imagination is sparked by an object. Some young people discover objects that can "make a mind," objects that become part of the fabric of their scientific selves. From my very first days at MIT in 1976, I found attachments to objects everywhere. I had students and colleagues who spoke about how they were drawn into science by the mesmerizing power of a crystal radio, by the physics of sand castles, by playing with marbles, by childhood explorations of air-conditioning units. And they spoke of new objects. I came to MIT in the early days of the computer culture. My students were beginning to talk about how they identified with their computers, how they experienced these machines as extensions of themselves. For some, computers were "objects-to-think-with" for thinking about larger questions, questions about determinism and free will, mind and mechanism (See Turkle 1984/2005).

Trained as a humanist and social scientist, I began to ask, What is the role of objects in the creative life of the scientist? What makes certain objects good-to-think-with? What part do objects take in the development of a young scientific mind? So, for over twenty-five years of teaching at MIT, I have taken a question as my first class assignment: "Was there an object you met during childhood or adolescence that had an influence on your path into science?" Over the years, assigning a paper on childhood objects has sometimes provoked surprise, even anxiety. Students ask: "Why write about an object? Will I be able to find one?" I reassure these students that if they have trouble fixing on an early object, together we will find something appropriate for them to write about. No one will do poorly on this assignment. But then, once students begin to work, there are calls to parents to check their memories. There are conversations with siblings. My students go home for vacation and return to MIT with an object in tow. I typically devote one or two class sessions for reports on the objects of childhood; students have trouble keeping to their allotted times, so we schedule extra meetings. Over the years, it has become clear that this assignment stirs something deep.

By the early 2000s, I had collected over 250 student essays, twenty-five years of student writing (see Turkle 2008b). I began to study them in detail, looking for patterns that might inform science education. Inspired by the essays, I asked several dozen working scientists (I refer to them as "mentors") to reflect on the same question I had asked my students: Was there an object that had led them into science, technology, and design? Predictably, many spoke of chemistry sets, crystal radios, and Lego blocks. But less predictably, and against prevalent stereotypes, they also spoke of cameras, colored crayons, lengths of straw. These objects, too, were described as integral to the development of scientific passions.

My use of the word *integral* is deliberate. In the stories I have collected, when students and working scientists speak about art or art materials, it is not to refer to such things as the beauty of cells or how the transcendent regularities of physics can be represented in aesthetically pleasing images. Instead, students and mentors focus on how the experiences of working with such things as clay, paints, and musical instruments (including tin whistles and music boxes) become woven into a scientific identity.

Art materials become "objects-to-think-with" for thinking about technical ideas even as they are indissociably linked to emotionally charged narratives of self-discovery. Recollections about the birth of scientific curiosity are romances. Young people fall for science, but science, in its turn, catches them, offers them something personally and intellectually sustaining. Putting children in a rich object world is not just a theoretically good idea. It is essential to giving science a chance. Giving science its best chance means guiding children to objects they can love, without prejudice that only an artist will attach to paint or only a sculptor will attach to clay. In rich object worlds, children make intimate connections that they need to construct on their own; what educators can provide are the conditions for their doing so.

Art and Science

As a child, the biomedical researcher Donald Ingber was drawn to visual arts: "Patterns and forms caught my attention and made my heart pulse more than sounds or music," he says (Ingber 2008). Ingber's interest in how things work (and his talent for disassembling and reassembling bicycles and broken televisions) caused family and friends to see him as a young scientist and shower him with what he calls "science toys." But Ingber ignored these. To him, chemistry sets and junior physics laboratories represented a side of science in which one just followed rules. Ingber was looking for something else. He turned to objects that gave him the feeling of "mak[ing] something my own." Above all, he turned to a Venus Paradise Pencil-by-Number Coloring Set: "It wasn't that science didn't interest me, but these kits all seemed to require that I follow rigid rules in order for their experiments to be successful. This was not as interesting as exploring what I could build without rules. I loved to see whether or not structures would hold their shapes when I released my hand, or what pictures I could draw by filling in numbered spaces with my vibrant colored pencils, often ignoring the pre-printed numbers" (255).

Ingber was colorblind, counted out of the game in art class. The Venus Paradise pencils taught him that "limitations can be circumvented. . . . The numbered pencils and the drawing templates allowed me (when I so wished) to circumvent the terror I experienced when a teacher asked me, for example, to paint something green, and I had no idea which paint cup to select" (255). The pencils provided more than a sense of competency; when Ingber ignored the preprinted numbers, they were a way to defy authority. And the pencils carried ideas. Ingber speaks appreciatively of "the school of Venus Paradise," where he learned "that there is structure to pattern and that function follows form, rather than the other way around. From Venus Paradise I learned that there can be simplicity in complexity, and that art and science are one and the same. . . . My Venus Paradise Coloring Set conveyed to me that everything has underlying structure, so even life can have architecture" (258–59).

Ingber identifies a moment with the pencils when a stroke on paper brought him to a "powerful idea" that organized experience and provoked new thought (see Papert 1980). For Ingber, this was the idea of the Gestalt: "After coloring in multiple scattered spaces, I was elated when I penciled in that key space that caused all the other colored tiles to merge into a single coherent image. The moment always came suddenly, a surprise I learned to anticipate with great expectation. It was in this way that I came to understand the power of the Gestalt, that the whole is greater than the sum of its parts, and that the overall arrangement of the parts can be as important as the properties of these components" (Ingber 2008, 255–56).

Ingber knew that the coloring set had its limitations; the drawings might provide material for thinking about the Gestalt, but his final products were not beautiful. He entered college as a science student and sought out "opportunities to better understand what was missing in those pencil drawings." This turned out not to be so easy. At Yale College, says Ingber,

> It was nearly impossible for a science major to take studio art. I nearly gave up after an unsuccessful midnight interview for entry into a painting course. But I became intrigued when I saw students walking around campus carrying polyhedral sculptures made of folded cardboard that were very similar in form to the viruses that I was studying in my science class on molecular biophysics. . . . I found a way to talk myself into this sculpture course and it was there that I had my first "Aha Moment," one that launched me on a path that I follow to this day. (256–57)

Ingber's "Aha Moment" opened him to thinking about sculpture and molecular biology at the same time. Ultimately, it was sculpture that brought him to "tensegrity," the idea that mechanical forces alter cell structure and have a determinative effect on cell functions. Tensegrity gave Ingber a lifetime of intellectual direction. Ingber notes that "the shape of cells turns out to be as important for biological relationships as are chemicals and hormones, an art-inspired insight with implications for cancer research, embryological development, and even understanding the sensation of gravity. [Tensegrity] has contributed to the development of anti-cancer therapies and nanotechnologies. Most amazing to me, it has led to a new way of thinking about the origins of life on this planet" (258).

Ingber's story is exemplary in many ways. What seemed a mismarriage of disciplines to Yale curricular planners was alchemy to Ingber. He was able to create a new kind of space in which the division between art and science was not relevant to creative practice. While it is a cliché to speak of beauty in the eye of the beholder, it is not cliché to think about what it takes to nurture a beholder able to bring the hues of art into his science. Ingber shows us a moment in which this happened: once invited to follow his instincts, once permitted to respect his intuition, he was able to see.

Ingber's experience with his pencils recalls how mathematician and science educator Seymour Papert (1980) describes the gears on a childhood toy car that awakened his interest in science and mathematics. Papert acknowledges the intellectual contribution of the gears: "I became adept at turning wheels in my head and at making chains of cause and effect. . . . I remember quite vividly my excitement at discovering that a system could be lawful and completely comprehensible without being rigidly deterministic" (vi–viii). But while the gears on the toy car brought Papert to mathematics, more than an intimation of mathematics brought Papert to the gears. They may have symbolized a connection to his entomologist father who gave him the car. Papert's father was a romantic but distant figure who spent much of his time doing fieldwork in the South African bush. Papert's facility with gears might have been the first thing his father took pride in, and once this connection was made, Papert's object choice was overdetermined. We cannot know. What is certain is that thinking with and about things is not a cold, intellectual enterprise but is charged with eros. Papert says: "I fell in love with the gears" (viii).

As in Papert's story, Ingber's objects brought him close to ideas and to emotions. Papert saw the differential in his gears and used them to identify with an absent father. Ingber saw the Gestalt in the Venus Paradise drawings and used the pencils for youthful rebellion against the conventionality of his suburban childhood. Growing up in Long Island, Ingber saw himself as destined for other things and other places. The pencils became a way to express his sense of difference as he deliberately used the wrong colors and painted outside the lines. Yet even as a child he knew that as a scientist he would have to temper rebellion with discipline. In Venus Paradise language, he would have to paint both within and outside the lines. The Venus Paradise Pencil-by-Number Coloring Set provided rich material for working through such issues.

Papert and Ingber's stories are unique, but the "overdetermination" of their object choices is not. Object choices are mobilized by the particularities of a life. So, for example, in my collection of MIT student narratives, the computer scientist Timothy Bickmore (2008) recalls a fascination with lasers that offered emotional support. Performing with the circus after his parents' divorce, Bickmore wanted to put a wall between himself and the audience.

He became an artist, using laser shows as his medium. The lasers provided a way to perform "in which the audience's attention was not focused on me but on an artifact of my construction. It felt safer" (145). As a young child, the media scientist Jennifer Beaudin (2008) developed a fear that she would have to leave her house as she grew up. Specifically, she had an anxiety of scale: she feared she would become too big for her house. She tried to master her fear by moving *closer* to her house as an object. Turning to pencils and drawing, she made detailed maps of the house, a child's version of architectural plans.

These examples make it clear how right the psychoanalyst Erik Erikson (1964) is when he says that play is children's work (222). Children use play to separate from adults and develop their own identities. Separation and individuation are the work of childhood, and children choose play objects that help them do this work. From this perspective, play, object work, is deeply motivated; the emotion that fuels the investigations of young scientists taps into this intensity.

What brought troubled midnight meetings at Yale would never happen at the Ross School. There, art is not adjunct but integral to the teaching of science. Children become comfortable with the idea that falling in love with technical objects, like falling in love with art, is something their teachers expect of them. Simple distinctions between art and science fall away, just as simple divisions between what is constraining and what is liberating fall away in the school of Venus Paradise. For Ingber, its constraining diagrams and rules helped him break out—from his town, from rigid disciplinary definitions, and from ways of thinking that divided art, science, and technology. What nurtures most are fertile confusions in thinking: we come to see colored pencils as doors to science; we find it natural to introduce the periodic table as a form of poetry and circuit boards as a form of art.

This perspective brings us to a very different place than we would get to with a question such as "What objects should children encounter to learn science?" The object that brings you to science doesn't have to be a "science toy." It has to be an object that speaks to a particular child. And it has to be an object that children are free to make their own in their own way.

Styles of Science/Styles of Art

At the Ross School, respect for individual styles is a deeply held value. The psychologist Howard Gardner is a longtime school mentor; his work on multiple intelligences informs how the school approaches individual children's paths to learning. Gardner's perspective looks for diversity where others have imposed uniformity (see, for example, Gardner 1983/1993). When you apply Gardner's ideas to science teaching, they challenge received wisdom about what constitutes a "scientific" style of work.

Stereotypes about scientific work would have scientists and engineers thinking through problems in a "planner's style," a top-down, "divide and conquer" approach that keeps objects at a distance. Of course, some scientists do use this style, and some use it most of the time. Others employ a hybrid style that moves back and forth from top-down planning to a more fluid, "artistic" method. I have described this second style as bricolage or "tinkering" (Turkle and Papert 1990).[2] Yet the "planner's" style has long been frozen in the public imagination (and to some degree, the science education community's as well) as *the* way one does things in science and, even more broadly, what it means to think like a scientist.

For the historian of science Evelyn Fox Keller (1983, 1985), a close look at scientists' practice calls into question the universality of this canonical style.[3] She insists that any description of scientific practice that puts scientists at a distance from their objects of study cannot stand alone. It needs to be complemented by descriptions that explore intimacy and presence. In other words, Keller describes a way of doing science that we associate with art.

The geneticist Barbara McClintock offers such a description of scientific practice when she writes of seeing herself "down there" among the chromosomes she studies. McClintock says: "I actually felt as if I were right down there and these things, they become part of you and you forget yourself" (quoted in Keller 1983, 117).[4] I hear echoes of McClintock's sentiments when the computer science student Austina De Bonte describes imagining herself as a piece of straw as she tried to build three-dimensional objects with structural integrity. These were *siaudinukas*, a Lithuanian folkcraft made by threading straw on pieces of knotted string.

Once De Bonte put herself in the place of the straw, she built her *siaudinukas* in an experimental, "painterly" style. She tried something, stood back, evaluated, tried something else, made small adjustments. A classic bricoleur, De Bonte (2008) played with her materials. "Sometimes I would just start stringing some straws together, looking for ideas; once something took shape, it was easy to find ways to extend or elaborate on it. Often I wouldn't be able to tell for sure whether a complicated structure would be solid until putting in the very last piece" (138). It was through this way of working that De Bonte looked for the rules behind what she calls "stable structure," structure that is, as she puts it, "rigid, reasonably strong, and structurally complete" (139). "I discovered, mostly by example and through trial and error, that I couldn't make a solid structure that wasn't based fundamentally on triangles. I also found that every 'link' in the *siaudinukas* was vitally important—the structure was often fully collapsible and foldable right up until the very last straw was secured. Furthermore, I discovered that this was actually the mark of a good structure" (139).

De Bonte had friends at camp who predesigned their straw structures. These classical planners did not do better work than she. They simply had a different style.

The year she wrote her essay on straws, I watched De Bonte run a small workshop on how to build *siaudinukas*. She brought straws and thread and Lithuanian snacks. One rapt five-year-old was always pleased when she could get an early-stage structure to stand on its own; this made it easier for her to thread the straws. De Bonte was gentle and firm in her rebuke that if it looked ready too soon, it wasn't ever going to stand on its own. The lesson needed to be repeated three times. Each time it seemed to have a wider meaning. In the end I was moved by what seemed its most general meaning: suppleness is the precursor to what is ultimately most secure.

The Physical and the Virtual

De Bonte's story, like any construction narrative, raises a question that was always present at the Ross School when teachers dealt with questions of design: When should materials be presented physically and when should they be presented on the computer? When should students be manipulating physical models and when should they be exploring powerful virtual realities?

Imagine an educational computer program to build virtual *siaudinukai*. A user manipulates physical dowels represented in collaboration with the machine. When a builder makes a simple structure, the computer transforms it into thousands of alternate configurations. The lesson of "seeming solidness" emerges from thousands of iterations of the program as robust structures pop up from the many configurations developed in collaboration with the computer. For some students, such multiple iterations of geometric possibilities would facilitate learning. And of course, thus programmed, building *siaudinukai* could take place on a vastly wider scale.

Contrast all of this power with how De Bonte learned the lessons of the *siaudinukai*—through her fingers and in community with her peers—as part of her contact with Lithuanian culture. For some people, when you take this away, what might have been magical about the straw shapes is lost in their digital variant. Otherwise put, in a digital world, children may get the point, but that may be all that they get. And for some people, it is the body-work of physical manipulation that makes all the difference in connecting to one's work. As one architect lamented when contemplating the movement of design pedagogy from pencil and paper to the world of computer-assisted design: "You love things that are your own marks. In some primitive way, marks are marks. . . . I can lose this piece of paper in the street and if [a day later] I walk on the street and see it, I'll know that I drew it. With a drawing that I do on the computer . . . I might not even know that it's mine. . . . People do analyses of their plan [on the computer] but they only fall in love with the marks they make themselves" (quoted in Turkle 2009, 15]). There are possibilities in digital media that should be pressed into the service of more effective education in science and design, and there are things we learn from the physical that are worth fighting for.

Awash as we are in new digital teaching materials, object play, distinctly old-fashioned, is not something to which today's teachers are particularly attuned. It is natural, in a time of crisis—and science educators do see their field as in crisis—to avidly pursue the next new thing. In contemporary educational circles, that thing has of course been the computer, seen for decades as a scarce and exotic commodity. The Ross School made a special contribution to this conversation about the physical and virtual. For at Ross, from the very start, computers were not a scarce resource. Teachers felt free to explore every subject using them, which meant they were also free to not use them. Ross was a testing ground for what pedagogical practice could be when computers were assumed as part of basic infrastructure. When computation is assumed, it loses its special privilege. To take poetic license, when it is everywhere, it can also be nowhere. In a fully resourced computational environment, teachers are free to put technology in its place.

In thinking about the pedagogical challenges of the virtual, a Ross School mentor, the physics Nobel laureate Georges Charpak, developed a science curriculum for French primary schools that takes the manipulation of physical objects as its centerpiece. Charpak's program is called *La main à la pâte* (Quéré 2006). In literal terms, the phrase refers to the hand as it kneads dough in the slow, artisanal exercise of making bread. Charpak's curricular mission is to have children "[discover] natural objects and phenomena, to bring them into contact with the latter in their reality (outside of virtual reconstructions), directly through observation and experimentation." My conversations with Charpak about *La main à la pâte* and science education centered on the question of speed.

Today, molecular models once built with balls and sticks give way to animated worlds that can be manipulated at a touch, rotated, and flipped; the architect's cardboard model becomes a photorealistic virtual reality that you can "fly through." These environments provide fertile thinking ground but are kinetic in nature. The metaphor of "flying through" is telling. Digital media rarely seem to want to be used slowly, least of all in the classroom.

Consider a Chicago high school junior's anxious description of the "SMART Board,"[5] an interactive digital tablet that her teacher uses in physics class. The teacher writes on the SMART Board before and/or during class and scrolls through it as class progresses. On SMART Board days, the teacher is simultaneously using an animated presentation tool, surfing the Web, and e-mailing pages of class notes to students. The student describes the frustration of trying to keep up with the pace of the machine: "It begins okay. But then we keep asking her to please, please go back; it keeps going forward and forward, there are a lot of variations, and we want her to scroll back. I wish she used the blackboard so it would all be up. And then she promises to e-mail it [the SMART Board pages] to us. But then she doesn't so it all is lost."[6]

In the hands of a master teacher, a technology such as the SMART Board might certainly be a plus. But like all digital technology, it makes it hard to resist velocity. Velocity tempts because it is so easily achieved. You can use the SMART Board at a measured pace, but to do so takes a control that few teachers seem to manage when the machinery is up and running. It is hard to slow down when you are tuned to a technological A.

The Resistance of the Real

When young scientists across generations write about what inspired them to go into science, they don't write about things that sped them up, they write about things that slowed them down. The computer scientist Gil Weinberg was slowed down when his childhood music box broke (Weinberg 2008). When it worked, each of its six colored buttons played a song. Weinberg enjoyed hitting buttons in rapid succession. In this way he could sample notes from different songs and use them to compose his own. But it was when the box broke that Weinberg's deeper involvement began. He conjured notes in his mind. He slowed down because "after each note I had to think really hard about where to go next. Should I go up or down? Should I take a small step or a wide one? I felt myself to be the melody trying to find its way. This was probably the first time I wrote original music" (Weinberg 2008, 118–

19). His relationship to the box taught Weinberg a new way to think about composition. He "became" each note and thought about where he (the note) "wanted" to go.

I think of the limitations of velocity—of Charpak, the SMART Board, and Weinberg's painstaking steps—as I study paths to science that exploit the pleasure of materials, of texture, of what one might call the resistance of the "real." In the early 1990s, the computer scientist Timothy Bickmore's experiments with lasers—"passing the laser through every substance I could think of (Vaseline on slowly rotating glass was one of the best)" (Bickmore 2008, 144)—recalls the physical exuberance of Selby Cull, whose path into science was through baking. For Cull, geology became real through her childhood work on chocolate meringues: "Basic ingredients heated, separated, and cooled equals planet. To add an atmospheric glaze, add gases from volcanoes and volatile liquids from comets and wait until they react. Then shock them all with bolts of lightning and stand back. Voilà. Organic compounds. How to bake a planet" (Cull 2008, 97–98). Cull's joyful comments describe the moment of scientific exultation, Ingber's "Aha Moment," the famed "Eureka" moment of raw delight.

And I see Charpak's focus on what is "at hand" in computer scientist Andrew Sempere's account of "falling for science" when he became involved with a Holga camera. His is a story of patience brought into the digital age. Sempere (2008) describes his Holga, a primitive plastic device, as having "all the mechanical accuracy and precision of a jar of peanut butter." The camera was literally pasted together: "The back leaked light. The film advance rarely worked. The flash shoe usually malfunctioned. The lens was plastic and distorted the image. On mine, the shutter often stuck. The whole thing obliged one to carry a roll of sturdy black tape, mostly to keep the back from falling off. The Holga was neither more nor less than it seemed—a chunk of plastic that let light onto a piece of paper" (Sempere 2008, 50).

As a high school student, Sempere was accustomed to working with digital photography. In that medium he worked quickly, took many photographs, manipulated them fluidly. Digital craft gave him the fantasy that he could capture and manage nature. In contrast, the modest Holga was humbling. It was not the strengths but the limitations of the Holga that "conspire[d]" to "lend even the most mundane subjects an air of analog beauty." In a digital photography studio, Sempere complained about all the materials he didn't have; the Holga taught resourcefulness. It slowed him down. "Working in technology, the lessons of the Holga have served me well. Among these is the notion that to be an artist or scientist implies a willingness to act as an observer, to keep a record that does not seek to eliminate the blurry edges, dark spikes, and imperfections, but rather celebrates them. This means learning to live with the messiness and disappointments of the real world and working through problems by making things that will in some way fail" (Sempere 2008, 51).

Nature encourages us to be messy because it is. When we deal with nature we have to get comfortable with the idea that we may break things that are not easily replaceable. We have to get comfortable with the idea that things may go unresolved for a while. In simulated science, there really doesn't have to be any waiting. Time can be sped up. And when something breaks, the simulation can always be run again; what was broken can be magically restored. Simulations encourage the idea that one can push forward to resolution—of the experiment, of the game, of the quest. One can push forward because possible resolutions are already there, in the program.

In practical terms, the Ross School balances the velocity of high technology with the more stately pace encouraged by art and a rich physical environment. Philosophically, the Ross School balances the temptations of velocity with the image of the spiral and its suggestion of continual return. The spiral is about reflection rather than speed. The spiral suggests that no matter what is being taught, immersion and multiple perspectives are valued, that it is important to take one's time, to live in the moment. Indeed, at Ross, meditation is practiced in the same rooms that are lined with computers.

The great and historically unique virtue of computation is that it is able to present an endless stream of "what-ifs"—thought experiments that try out possible branching structures of an argument or substitutions in an experimental procedure. Object passions, like meditation, bring us to the same enthusiasm for "what-is" that computation inspires for "what-ifs." We now live the tension between these two impulses; we need to cultivate the point at which they court and spark.

When children "fall for science" through art, the experience grounds them. They focus on the pop of colors as they create the Gestalt, on the "solidness" of straws when perfectly strung, on the textures of a grainy photograph. They share the concentration others experience when focusing on Lego bricks or a vacuum tube or on what kind of sand is best for building castles. The Ross School philosophy comprehends the complex ways all of these experiences can come together, how children use art to approach science and nature. Here the stakes for all of us are high because in doing so they may fall for the "what-is" of our planet and wonder at it, not only as a frontier of science, but as where we live.

NOTES

1. This essay draws on (2008a, 2008c), my chapters "Falling for Science" (Turkle 2008a) and "What Inspires" (2008c) in my edited book *Falling for Science: Objects in Mind* (2008b). The "object stories" I quote here, from both students and senior scientists, are from that collection.

2. In a tinkering or bricolage style one gets close to, indeed intimate with, the objects of study. The idea of object intimacy is meant to evoke what the psychoanalyst D. W. Winnicott called the "transitional object," those objects that the child experiences both as part of his or her body and as part of the external world. See Winnicott (1989). As the child learns to separate self from its surroundings, the original transitional objects are abandoned; one gives up the prized blanket, the teddy bear, the bit of silk from the pillow in the nursery. What remains is a sense of a privileged space, a special way of experiencing objects that recalls this early experience of deep connection. Later in life, moments of creativity during which one feels at one with the universe will refer to the power of the transitional object.

3. Keller (1983, 1985) writes about scientists' resistance to acknowledging the intimacy of their connections to objects. She sees its roots in a male-dominated view of mastery that equates objectivity with distance from the object of study.

4. Keller (1983, 117) takes the exploration of the "close to the object" style as part of a feminist project in science but makes it clear that many male scientists work in this way. The scientific culture has made it hard for them to talk about it or even, perhaps, to recognize it for what it is. But once young male scientists are asked about their objects, they offer rich evidence of such intimacies. One of my students spoke to me about translating the tactile experience of playing with marbles to feeling the laws of "physics in his fingertips"; another spoke about diving deep within a prism for inspiration, shrinking himself, as did McClintock, to its scale in order to make his body feel at one with its structure: "Visualizing waves of light bouncing off nuclei, slithering through electron clouds, and singing across the vacuum between the stars became an obsession. I never tired of leaving the ordinary, everyday world, shrinking myself down to the size of an electron and diving headfirst into my prism where a front row seat for the spectacle of nature awaited" (Hermitt 2008, 46).

5. The SMART Board is marketed as a teaching tool that "energizes presentations and motivates learners." See www2.smarttech.com/st/en-US/Products/SMART+Boards/default.htm.

6. This citation is from an ongoing study of teens and digital technologies. All participants in this study have been granted anonymity.

REFERENCES

Beaudin, Jennifer. 2008. What we see: Walls. In *Falling for science: Objects in mind*, ed. Sherry Turkle. Cambridge, MA: MIT Press.

Bickmore, Timothy. 2008. What we build: Lasers. In *Falling for science: Objects in mind*, ed. Sherry Turkle. Cambridge, MA: MIT Press.

Cull, Selby. 2008. What we model: Chocolate meringue. In *Falling for science: Objects in mind*, ed. Sherry Turkle. Cambridge, MA: MIT Press.

De Bonte, Austina. 2008. What we build: Straws. In *Falling for science: Objects in mind*, ed. Sherry Turkle. Cambridge, MA: MIT Press.

Erikson, Erik. 1964. *Childhood and society*. New York: Norton.

Friedman, Thomas. 2005. *The world is flat: A brief history of the twenty-first century*. New York: Farrar, Straus, and Giroux.

Gardner, Howard. 1983/1993. *Frames of mind: The theory of multiple intelligences*. New York: Basic Books.

Gates, Bill. 2005. Speech presented at the National Education Summit on High Schools, Washington, DC, February 26, www.gatesfoundation.org/MediaCenter/Speeches/Co-chairSpeeches/BillgSpeeches/BGSpeechNGA-050226.htm.

Hermitt, Thomas P. 2008. What we see: Prisms. In *Falling for science: Objects in mind*, ed. Sherry Turkle. Cambridge, MA: MIT Press.

Ingber, Donald. 2008. What we sort: Venus Paradise Coloring Set. In *Falling for science: Objects in mind*, ed. Sherry Turkle. Cambridge, MA: MIT Press.

Keller, Evelyn Fox. 1983. *A feeling for the organism: The life and work of Barbara McClintock*. New York: W. H. Freeman.

———. 1985. *Gender and science*. New Haven: Yale University Press.

Papert, Seymour. 1980. *Mindstorm: Children, computers, and powerful ideas*. New York: Basic Books.

Quéré, Yves. 2006. Science education for children in France: The "La main à la pâte" program. In *First South-East European Summer School for Hands On Primary Science Education: Proceedings* [June 11–16, 2005, Zlatibor, Serbia].

http://rukautestu.vin.bg.ac.yu/handson1/pdf/quere.pdf.

Sempere, Andrew. 2008. What we see: Holga camera. In *Falling for science: Objects in mind*, ed. Sherry Turkle. Cambridge, MA: MIT Press.

Turkle, Sherry. 1984/2005. *The second self: Computers and the human spirit*. Cambridge, MA: MIT Press.

———. 2008a. Falling for science. In *Falling for science: Objects in mind*, ed. Sherry Turkle. Cambridge, MA: MIT Press.

———, ed. 2008b. *Falling for science: Objects in mind*. Cambridge, MA: MIT Press.

———. 2008c. What inspires. In *Falling for science: Objects in mind*, ed. Sherry Turkle. Cambridge, MA: MIT Press.

———. 2009. *Simulation and its discontents*. Cambridge, MA: MIT Press.

Turkle, Sherry, and Seymour Papert. 1990. Epistemological pluralism: Styles and voices within computer culture. *Signs: Journal of Women in Culture and Society* 1 (16): 128–57.

Weinberg, Gil. 2008. What we play: Music box. In *Falling for science: Objects in mind*, ed. Sherry Turkle. Cambridge, MA: MIT Press.

Winnicott, D. W. 1989. Playing and reality. London: Routledge.