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Drawing in the Digital Age: Observations and Implications for Education

Seymour Simmons

Department of Fine Art, Winthrop University, Rock Hill, SC 29733, USA; seymoursimmons@gmail.com

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Abstract: This paper looks at recent examples of how drawing is advancing into the digital age: in London: the annual symposium on *Thinking Through Drawing*; in Paris: an exhibition at the Grand Palais, *Artistes et Robots*; a conference at the Institut d'études avancées on *Space-Time Geometries and Movement in the Brain and in the Arts*; and, at the Drawing Lab, *Cinéma d'Été.* These events are contrasted to a recent decline in drawing instruction in pre-professional programs of art, architecture, and design as well as in pre-K12 art education due largely to the digital revolution. In response, I argue for the ongoing importance of learning to draw both in visual art and in general education at all levels in the digital age.

Keywords: drawing; digital media; education; philosophy; cognition; robots; artificial intelligence

1. Introduction

In this paper, contemporary considerations of "Machine as Artist" serve as points of departure for thinking about one of humankind's oldest arts. With the earliest extant example now dating back more than 70,000 years, drawing apparently has been part of the human experience since its beginnings (Henshilwood et al. 2018). Since then, drawing has accompanied the expansion of humanity around the globe and has helped human civilization advance from the Stone Age to the Digital Age. For example, Patrick Maynard (2005) claims that, without technical drawing during the Industrial Revolution and the kinds of thinking it entailed, there simply would have been no modern era.[1] The drawing impulse is equally evident in human development as we watch children come into the world ready, as psychologist Ellen Winner (1986) says, to make their marks with any available implement on every available surface. Taken together, these facts demonstrate that the instinct to draw is innate: to be human is to draw.

At the same time, drawing, like all inborn potentials, demands cultivation for its realization. Thus, across the millennia, drawing has been taught not only to those preparing for careers in the visual arts, but equally as part of general education. In this context, drawing's virtues were praised by philosophers like Aristotle, Locke, and Rousseau; educators like Horace Mann and John Dewey; and statesmen like Benjamin Franklin and Thomas Jefferson (Efland 1990; Simmons 1988). Today, however, drawing instruction is at risk both in K12 education and in post-secondary programs of art, architecture, and design. There are many reasons for this situation including modernist reactions against 'academic' teaching methods in which drawing was the primary concern, the unprecedented pluralism of post-modern art, and the emergence of new forms of artistic expression like performance art and conceptual art. However, the principal threat comes from the power and the proliferation

[1] Explaining the importance of technical drawing to the modern world, Maynard says, that without such drawings, "it is hard to see how there would be a modern world. For there would be neither the kinds of technological thinking nor the kinds of manufacture that make industrial and post industrial societies possible, nor their use and maintenance."

of digital media, which some claim makes traditional drawing instruction obsolete. In architectural education, this threat was articulated as early as 1989 at the dawn of computer-aided drafting and design (CADD) by then Harvard professor of architecture, William J. Mitchell, in an article entitled: "The Death of Drawing" (Mitchell 1989). The phrase continues to resonate (Levin 2002; Yale 2013; Sheer 2014), and not just in architecture.

Here, I argue that Mitchell's dire pronouncement was, as Mark Twain said about rumors of his own death, 'exaggerated' (Twain 2018). Toward that end, I look at four examples of how drawing is being taught, researched, and applied in the 21st century: one recalling drawing's experiential origins, the others taking advantage of new technologies, including machines that draw. Doing so, however, I also take seriously the challenges new technologies pose to traditional drawing study and to the benefits it has long provided in the arts and across the disciplines, including in all four STEM subjects: science, technology, engineering, and mathematics. I will begin with some personal background. I am grateful to Frederic Fol Leymarie and Glenn W. Smith for inviting me to reflect on these topics for this publication.

Background

First, a disclaimer. Unlike many who have contributed to this issue of *Arts*, I am not an expert in robotics or technology of any kind. Far from it! My perspective on "Machine as Artist" and related subjects is as an artist and art teacher accustomed to working with traditional media like charcoal, graphite, and ink. That said, since the 1980's, I have followed with fascination advances in digital imaging and recognize its potential to take drawing, among other art forms, into the future. In fact, one of my initial forays into drawing research (at Harvard Project Zero, a center for research on the arts and cognition) involved exploring ways computers could be used to teach art, music, and social studies (Walters et al. 1988). My task was to develop lessons on linear perspective using the early Macintosh programs, Macpaint and Macdraw, a project I have pursued off and on ever since.[2]

At the same time, drawing instruction was the topic of my doctoral thesis in philosophy of education at the Harvard Graduate School of Education, which has been the basis of my continuing research. The thesis, entitled *Bringing Art to Mind: Theory and Practice in the Teaching of Drawing* (Simmons 1988), traced the history of drawing instruction from ancient times through the late 20th century, highlighting philosophical principles underlying various teaching methods. My premise was that different pedagogical paradigms represented distinct 'philosophies of drawing education.' In part, the term 'philosophy' seemed warranted because each teaching method represented a particular conception of what drawing was and what it was for, e.g., drawing as design, drawing as perception, drawing as experience, drawing as self-expression, and drawing as a graphic idiom. More important, in researching the origins of these methods, I found continuities, explicit or implicit, with prominent philosophical movements at the time. Rationalism during the Renaissance and for centuries thereafter had an explicit impact on academic art instruction where the aim of art was to capture not the actual but the ideal (Pevsner 1973). By contrast, the influence of empiricism during the Age of Enlightenment is evident in the emphasis on observational drawing based, as John Ruskin put it, on recovering the 'innocence of the eye' (Ruskin 1837). The impact of pragmatism in the late 19th and early 20th century is reflected in the emphasis on experimentation in early modernism, while the influence of existentialism is reflected in the Expressionist movement in the early to mid-20th century. Later, I came to link drawing as a graphic idiom, i.e., a visual language, with semiotics and non-representational art (Simmons 2012).

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[2] Working with Winthrop University art and design students and faculty, I developed digital animations to demonstrate perspective principles like foreshortening and convergence of receding parallel lines (orthogonals). Most recently, some of these animations were included in a set of videos to teach drawing to college non-art majors as part of a research project on "Assessing and Fostering Visual Imagination Through Drawing," sponsored by the Imagination Institute. (http://www.imagination-institute.org/2018/06/06/assessing-fostering-visual-imagination-through-drawing/).

A third reason to associate drawing with philosophy is implied in the title of the thesis, where 'bringing art to mind' alludes to my concern to recall a Renaissance understanding of drawing as the 'cognitive' dimension underlying all the visual arts and connecting them to other disciplines, as mentioned above. Deanna Petherbridge at the beginning of her book, *The Primacy of Drawing* (Petherbridge 2010, p. 2), succinctly states this view in her belief "that drawing is the basis of all art and visual thinking." Further on, Petherbridge describes how that view played out in visual arts study until quite recently, saying: "before the late 20th century, learning to be an artist or architect as an apprentice in a studio or attending an academy or art school was entirely predicated on learning to draw. Drawing was conceived of as a way of learning about past and present art, about recording the everyday world and achieving control of processes of representation, as well as perfecting the conduit between hand and imagination through practice" (p. 210). What this meant for art students at the time was described to me by Professor Alf Ward, former chair of the Department of Art and Design at Winthrop University (Rock Hill, SC, USA), where I taught from 1993–2017. Ward studied at the Gravesend School of Art in the UK during the early 1960's, where, to prepare for a career that would eventually include fine arts, jewelry, metalsmithing, product design, and art education, he took required drawing classes every semester of undergraduate study. Plus, drawing was a component in other studio classes and art history (personal communication).[3]

By contrast, an increasing number of fine art and design programs today require only one or two drawing classes, typically as "foundation courses" (first, or first and second year), and some programs, including former art academies, require no drawing courses at all.[4] This paper offers a response to that situation. In addition to my thesis, I now am able to draw upon a recent body of research on drawing from various perspectives including cognitive science, neurobiology, and several branches of psychology (developmental, perceptual, cognitive, clinical, etc.). In the following sections, I will discuss how this research figured in four events I attended in the summer of 2018. Unfortunately, I am only able to highlight certain aspects of each event specifically relevant to the issues of concern in this paper. However, I will include links for those seeking more information.

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[3] Prior to enrolling full-time at Gravesend, Ward had already taken drawing classes at the school for two years on Friday's and Saturday's. Earlier still, he said he drew regularly in elementary school and took four years of technical drawing in high school. Ward is from Dartford, Kent, a largely working-class city where, he says, technical drawing was taught, not to prepare students to be architects, but to work in the local factories. Ward credits his training in drawing for his future career in fine arts, product design, and his graduate-level concentration, jewelry and metals. A biographical note about Ward for a recent lecture he gave on starting points for creativity at the Bechtler Museum of Modern Art (Charlotte, NC, USA) includes this statement: "As an internationally known designer, Ward served as consultant designer for Spink & Sons in London (by appointment to her Majesty the Queen), where he designed and produced presentation pieces for: the Royal Family, Revlon of Paris, the Royal Air Force and the United Arab Emirates, among others." (http://bechtler.org/Learn/Events/details/alfred-ward-stars-of-start-points).

[4] For some descriptions of drawing instruction in the modernist era, see Goldstein (1996). Concerning 21st century trends in drawing instruction, Associate Professor Christopher Wildrick of Syracuse University surveyed 37 US foundation programs in diverse settings: large and small institutions; public and private; universities, colleges, and designated art and design schools. He found that 35% required one drawing classes, 35% required two drawing classes, and 30% required no drawing classes (personal correspondence). Regarding the UK, I am grateful to one reviewer of this paper for highlighting "the welcome rise of drawing as an autonomous subject in the early 1990's as a backlash to drawing endorsed as a 'preparatory' stage for other fine art disciplines . . . This led to the rise in drawing research and the first dedicated University level programs in the UK and in the Antipodes." By contrast, the reviewer also noted that "recent government decisions have limited the access to study drawing in the UK at secondary level . . . " To investigate these claims, I posted an inquiry on the *Drawing Research Network* website which yielded information about both issues. Equally important, the chain of responses included numerous answers to my query about examples of, and reasons for the decline in drawing instruction. Many responses, primarily in the UK, confirmed the decline with information about their own programs as well as documentation of the reasons for it, including governmental policy. Others stated that drawing instruction had not declined in their institution, but several said that the number of classes varied from program to program and the way drawing was taught varied from teacher to teacher. See: Drawing Research Network: https://www.jiscmail.ac.uk/cgi-bin/webadmin?A0=drawing-research.

2. Four Drawing Events, Summer 2018

2.1. Thinking through Drawing

In June 2018, I participated in a symposium called "Drawing Rocks," sponsored by *Thinking through Drawing* (TtD), a research group on drawing and cognition founded in 2011 by three doctoral students doing research on drawing: Angela Brew, University of the Arts London (UK); Michelle Fava, Loughborough University (UK); and Andrea Kantrowitz, Columbia University (US). Since its establishment, TtD has sponsored annual symposia and workshops at Teachers College, Columbia University; the Metropolitan Museum of Art; the University of the Arts London, etc. These gatherings, based on themes like "Drawing Rocks" and "Drawing in STEAM" (STEM plus Arts) bring together artists, designers, and art educators with researchers studying drawing from the perspectives mentioned above, as well as faculty and practitioners in fields outside the arts, such as engineering, medicine, and mathematics, who use drawing in their work. This year's theme was based on the opening experience, which began as"a Mudlarking session on the nearby Thames beach, led by Emma Fält and Michael Moore." (see Figure 1) Each participant was to find one or more rocks which they then took back to the conference room to be drawn under Moore's direction.

Figure 1. Participants in *Thinking through Drawing* Symposium, Mudlarking on the Thames and selecting rocks to be drawn in workshop. Photo courtesy of Michael Moore.

Recently retired from The Pennsylvania Academy of the Fine Arts, Moore's drawings, though usually non-representational, are evocative of experiences in nature derived from multiple modes of sensory input.[5] Similarly, Moore framed the assignment as follows: "Using any variety of tools, participants will be asked to hold and observe a rock, and to draw that rock from the inside to the outside, gradually configuring random, graphic actions toward the external, visual physicality of the rock itself." Starting from the "inside out," the task was not a scientific investigation of the particular stone as observed by eye alone. Rather, it called for an experiential response to the stone taken from its specific context involving functions of brain, eye, and hand, including tactile and haptic perception, the latter referring to touch in grasping and holding.[6]

By contrast, another part of the workshop addressed drawing from imagination. This was an interview via Skype between TtD co-director Andrea Kantrowitz and cognitive psychologist, Barbara Tversky, with comments and questions by Michael Moore and Michelle Fava. The dialogue exemplified the interdisciplinary collaboration between scientists and artists around drawing that TtD represents.

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[5] See: http://drawingdrawings.com/drawings.html.

[6] Examples of rock drawings, videos of the talks mentioned below, and other aspects of the symposium may be accessed at: https://www.thinkingthroughdrawing.org/symposia--publications.html.

As Kantrowitz's dissertation advisor, Dr. Tversky has been a frequent participant in TtD symposia where she speaks about her research on "visual-spatial reasoning, collaborative cognition, and the mapping and modeling of cognitive processes" (see, for example, Tversky 2011).

Kantrowitz began the conversation by asking: "What is the kind of thinking/reasoning that drawing allows?" Tversky responded, saying: "It's a kind of test of the idea." An idea put on the page is "never quite what you expected it to be . . . so then you work on it, and it becomes an iterative process" that influences the original idea. Kantoritz then pointed out that, "[e]ven within art and design education and among artists, [there is the view] that drawing is a way of presenting ideas that are already fully formed, but in fact what drawing allows you to do is to see the bits and pieces, and different ways of reconfiguring it . . . You coined a term in some of your studies of architects' drawing: 'constructive perception.'" To illustrate this concept, Tversky described a study she did working with architects making sketches for the design of an art museum. Explaining the process, she said the architects "would sketch out something very tentative, and then reexamine the sketch and find things they hadn't intended; in the sketch, they would see new things. Both novices and experts could make perceptual inferences—they could see patterns, things that were apparent in the sketch, but . . . experienced architects . . . could see conceptual relations, things that weren't in the sketch . . . lighting change over the year [or] traffic patterns." Like chess masters who can see many moves ahead, "it takes expertise or talent to see what isn't in the sketch but what is implied by it or might be implied by it." Moore confirmed this description based on his own drawing practice, saying: "To begin to draw, through the activity of drawing, and then to look for whatever one might have internalized having lived life on earth."

Tversky then went on to give an overview of her research: "What I first studied was how people conceive of the spaces they inhabit, the space of the body, the spaces around the body . . . how we distort them depending on our actions and how they get abstracted . . . into lines that are paths and dots that are places and . . . icons for things . . . in creating drawings, . . . diagrams, [etc.]. So, it's a bit like: 'How does space get into the mind and then how does the mind use space in the world to do more than navigate space.' It's a large agenda." In response to a question by Fava, Tversky spoke about the reasons she got into this sort of research: "When I was a graduate student, the reason I got into this whole thing, language had the hegemony in thinking, [but] it seemed to me that space came first evolutionarily and in the life of every individual. Understanding space has its own logic. We're first acting in space and language is based on that, not vice versa. [In drawing,] it becomes a conversation between the eye and the hand doing the action and what appears on the page. [In this process], language gets in the way. Articulation takes you out of the conversation. [That's] why I got into gestures. Like drawing in the air, [gestures] come before speech; to some extent they [help us] get ideas and communicate ... We think thinking happens between the ears, but the conversation with gesture is spatial motor."

Speaking about students in science learning through small group dialogue, Tversky said that when the students could refer to a visual image like a diagram, they demonstrated better comprehension than when referring only to verbal descriptions. "As a test of completeness, it's easy to see from a diagram that you have all the parts there and, as a test for coherence, you can see if it makes sense. It is a more direct mapping of thought, showing spatial, temporal, and causal relationships" (From video on TtD website).

Tversky's findings on the importance of 'constructive perception' and iterative sketching for ideation were confirmed by architects and designers in recent symposia and articles (Yale 2013; Graves 2012). As opposed to the precision required in perspective renderings and technical drawings (plans, sections, and elevations), which were once drafted by hand but are now largely produced via Computer-Aided Design software like AutoCAD and "Building Information Modeling" (BIM) software like Autodesk Revit (Revit 2018), sketches are rough, typically done by hand with pen or pencil on paper including on the proverbial napkin or envelope. As such, the process remains fluid,

facilitating experimentation, correction, and communication among colleagues or with clients. Equally important, for the trained eye and hand, even mistakes may suggest unforeseen possibilities.

My presentation addressed similar practices in sketching from observation. Commonly called 'gesture drawings' and typically focused on the human figure in the context of fine arts, illustration, or animation, these involve quick poses (one to five minutes) during which time the challenge is to take in the whole figure in fluid lines intended to capture the movement, energy, or feeling of the pose. As in imaginative drawing or compositional design, reviewing the gesture during and after the pose enables artists to see if they captured the sense of unity and expressiveness in the pose while revealing errors, omissions, and aspects that need more work. From a primarily visual standpoint, gesture drawing exemplifies "active vision" (see Findlay and Gilchrist 2003; also, Brew 2015), a relatively recent field of research which challenges common assumptions of seeing as a matter of passively 'taking in' and instead defines it as a process of overt or covert searching and other intentional activities. These actions are in part evidenced by tracing eye movements, called 'saccades', between momentary stationary points, called 'fixations' (Findlay and Gilchrist 2003, p. 24).

Gesture drawing is nowhere better explained than in *The Natural Way to Draw*, a classic figure drawing text by Kimon Nicolaides first published in 1941. Explaining his title, Nicolaides says: "There is only one right way to learn to draw and that is a perfectly natural way. It has nothing to do with artifice or technique. It has nothing to do with aesthetics or conception. It has only to do with the act of correct observation, and by that I mean a physical contact with all sorts of objects through all the senses" (Nicolaides 1941, p. xiii). According to the author, gesture (p. 13) means "the function of action, life, or expression . . . " Gesture drawing thus exemplifies a 'natural,' experiential, way to draw. In this case, seeing involves a combination of visual scanning guided by kinaesthetic/proprioceptive awareness and empathy. As such, gesture is concerned less with the object's shape and more with the "energy" of the subject, including even inanimate objects. Likewise, while contour or outline drawing is done slowly and "painstakingly" in order to accurately capture an edge, Nicolaides says gesture drawing must be done fast and "furiously:"

> The model is asked to take a very active pose for a minute or less . . . As the model takes the pose . . . you are to draw, letting your pencil swing around the paper almost at will, being impelled by the sense of action you feel. Draw rapidly and continuously in a ceaseless line, from top to bottom, around and around, *without taking your pencil off the paper.* Let the pencil roam, reporting the gesture. You should draw, not what the [subject] looks like, not even what it is, but what it is *doing*. Feel how the figure lifts or droops—pushes forward here—pulls back there—pushes out here—drops down easily there. Suppose that the model takes the pose of a fighter with fists clenched and jaw thrust forward angrily. Try to draw the actual *thrust* of the jaw, the *clenching* of the hand. A drawing of prize fighters should show the *push*, from foot to fist, behind their blows that makes them hurt. (ibid., p. 14–15)

As a process of "active vision," gesture drawings distinctly resemble recordings of normal eye movement as it scans a face, figure, or object (see, for example, Noton and Stark 1974). Yet, following Nicolaides, gesture drawing is not motivated exclusively by visual interest. For example, where research on "active vision" indicates that visual attention is often attracted to elements that are similar in shape, color, etc., or to elements in proximity to one another, pursuit of the gesture involves attention to the movement of the body as a whole. Much like drawing a rock from the inside out in order to grasp its weight and density, drawing the figure often begins inside the form, for example, to capture the curve and twist of the spine, the relationship between major skeletal masses such as the skull, ribcage, and pelvis, or to follow a movement from limb to limb guided by impulse, like the boxer's punch 'from foot to fist.' As well as responding to directional lines like an arm pointing upward, attention in gesture drawing may focus on points of stress, tension, or weight, as well as features that express intention or emotion. Gesture drawing is not, however, purely intuitive. It also involves thought, but of a particular kind. As Nicolaides (p. 17) says about the process, "Let yourself learn to

reason with the pencil, with the impulses that are set up between you and the model. In short, listen to yourself think; do not always insist on forcing yourself to think. There are many things in life that you cannot get by a brutal approach. You must invite them."

Relating this process to Tversky's explanation of architect's sketches, gesture drawings can be as informative or more informative when they misrepresent their subject. By looking at the drawing in process or after the fact, the artist is forced to recognize what s/he did not see or understand and so must look again, to see more accurately, more sensitively, more deeply, or more comprehensively. I have also related this process to conceptualization outside the arts based on C. S. Peirce's theory of "abductive reasoning:" reasoning by forming hypotheses and testing them out, as in the scientific method (Simmons 2017). Opposed to deduction and induction, Peirce claimed abduction was the only form of reasoning that led to truly original ideas, this in large part because even if the hypothesis being tested proves to be wrong relative to the intended outcome, it may lead to a new discovery. The same is true for the rough sketch which, by its very indeterminacy, can suggest something entirely unexpected. In contrast to the perennial pursuit in schools for the one pre-determined 'right' answer, the processes of abductive reasoning, with its always uncertain outcome and its invitation incessantly to iterate and revise, is now recognized as essential for creativity in the arts and sciences, in business, and even in education itself (Barrett 2013).[7] Like scientific experiments, gesture drawings are constantly being corrected after each new attempt, such that the final image may end up looking like "nothing but a tangle of fishing line" (p. 18) (See Figure 2).

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[7] In this article, Barrett referenced Peirce's ideas on creativity in regard to current concerns in business and education. Speaking of "the value of creativity" in business, Barrett pointed out that: "IBM surveyed 1500 chief executives in 33 industries around the world in 2010 to gauge how much they valued characteristics like creativity, integrity, management discipline, rigor, and vision in an increasingly volatile, complex, and interconnected world. Creativity topped the list." After pointing out that ideas about creativity are widely recognized thanks to psychologists like J. P. Guilford, Barrett adds: "The philosophical antecedents [of these ideas] harken to the late 19th and early 20th centuries, when Charles Sanders Peirce, the American pragmatist, drew on the forms of inductive and deductive logic categorized by Aristotle in his Prior Analytics. Peirce added a third strain of logic, which he often called abductive. Each has its advantages. Deductive reasoning confers a high degree of certainty in its conclusions. Inductive logic works well when data are readily observable. Abductive logic, Peirce posited, relies on inference to make creative leaps in situations in which information is incomplete. It yields a large number of possible answers. The emphasis in the curriculum on Peirce's and Guilford's ideas is particularly notable given the current context. Colleges are weathering criticism that they fail to prepare students to be productive citizens and effective employees. Traditional humanistic disciplines must continually justify their relevance. The rising cost of college is adding urgency to the popular perception that colleges' main task is to train students in practical skills that will enable them to get jobs. Practically focused programs in business have been among the first to embrace creativity and design thinking in their curricula. Such efforts typically serve these programs' efforts to teach entrepreneurship and innovation, which are thought to spark new businesses, create jobs, and stimulate the economy".

Figure 2. *Man playing an Orgue de Barbarie*, ink drawing by Seymour Simmons, 2018. In this gesture drawing, which took about 5 min, the instrument being played is a hand-cranked, mechanical music box. The non-stop lines were inspired by the rapid rhythm of the music and also sought to capture the equally rapid movement of the arms: the left arm turning the crank, the right arm feeding the string of punch-cards containing the score into the music box.

2.2. *Artistes et Robots*

As described in a news release (https://www.aup.edu/news-events/event/2018-04-09/artistes-robots-exhibition-grand-palais), this exhibition at the Grand Palais in Paris "offers a gateway to an immersive and interactive digital world—an augmented body sensory experience that subverts our notions of space and time. In an ever more robotic society, these artists explore new technologies, including Artificial Intelligence, which is potentially revolutionising human lives and even the conditions in which artworks are produced, presented, disseminated, conserved and received." On the face of it, the exposition seemed to have little in common with the 'hands-on' experience and cognitive research perspectives of the *Thinking through Drawing* symposium. However, to me, both were explorations of different facets of drawing, given a standard definition of the term, such as: 'the formation of a line by drawing some tracing instrument from point to point of a surface; representation by lines; delineation as distinguished from painting... the arrangement of lines which determine form' (Victoria and Albert 2018).

Linear images in black and white or color were found throughout the exhibition enlivened by remarkable and diverse means of production. The exhibition began with a mid-20th century piece: *Méta-Matic no. 6* (1959) by Swiss artist, Jean Tinguely, an interactive drawing machine/sculpture that can be set up to produce an apparently endless variety of abstract images. Around the corner, more contemporary installations showed how autonomous drawing machines now can be. *Human Study #2 d La Grande Vanité au corbeau et au renard*, (2014–2017) by Patrick Tresset involved three robot artists attached to school desks surrounding a still life. The robots consisted of mobile camera "eyes" linked via computers to mechanical "arms" holding pens that were then used to draw on sheets of paper. The subject matter consisted of a taxidermied fox and raven next to a human skull, representing a fable by La Fontaine. Each robot was programmed to draw in a style similar to Tresset's. The robotic eyes looked up and focused on the subject, then the robotic arms traced initial lines, built up areas of

tone, and returned to emphasize significant details, all based on what the eye took in. Although each drawing was the same in style, they all came out differently, giving the impression of students in an art class following a specific strategy of "how to draw from observation." For Tresset, these inventions provide the ultimate prosthetic. Although he himself no longer draws, his robotic surrogates can produce drawings endlessly in his style. Further, thanks to Tresset's programming, the images often suggest an almost human selectivity and sensitivity of touch.[8] (See Figure 3)

Figure 3. *Human Study #2*, installation with drawing robots and still life. Image courtesy of Patrick Tresset.

One of the more interactive exhibits was also based on drawing: Edmond Couchot and Michel Bret's, *Les Pissenlits, (The Dandelions)*, (1990–2017). Here, enormous electronically-generated drawings of colorful dandelions floated in front of a sensor into which spectators were invited to blow. As they did, and apparently depending on the force of their exhalation, the flowers exploded, scattering their virtual seeds just like the real thing. An even more expansive example of digital drawing, Peter Kogler's *Untitled* (2018) was a computer-generated image that filled a set of spaces—floors, walls, and ceilings—with an undulating linear pattern seemingly designed to disorient the visitors as they walked through the area. (See Figure 4).

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[8] The first prototypes of these robots were developed by Tresset as part of the AIKON-II project that he co-directed with Prof. Fol Leymarie at Goldsmiths College, University of London.

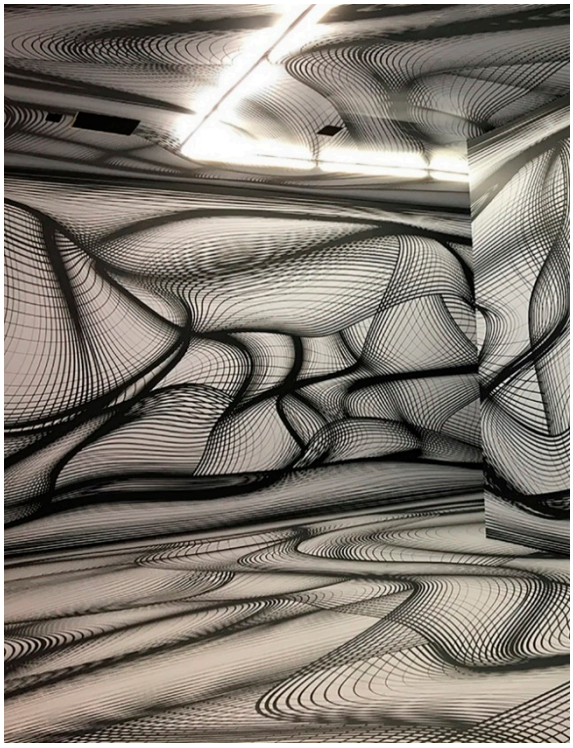


Figure 4. *Untitled* by Peter Kogler, Photo by Seymour Simmons.

Getting back to the press release, the author goes on to say: "These works contain a warning. Although Artificial Intelligence can help us, it also threatens to make itself our master by reducing humans to simple slaves to performance ... Ever more sophisticated software has given rise to increasingly autonomous works, an ability to generate infinite forms, and interactivity with audiences who permanently modify this game. This selection of works explores the questions raised by artists, which are also questions we ask ourselves: What can a robot do that an artist cannot? If it has an artificial intelligence, does a robot have an imagination? [And] What is a work of art?" The last question of course depends on how we define 'art,' a word notoriously difficult to pin down, especially in the post-modern era. Schjeldahl (2018), art critic for *The New Yorker*, recently put it this way: "Today . . . 'art' has come to mean anything that you can't think of another word for . . . " To me, whether or not the creations made by these machines can be called 'works of art,' they are, indeed, drawings as previously defined; that is, simply because they employ the basic elements of drawing: line, shape, form, space, tone, and texture. Moreover, in that these creations extend drawing beyond the limits of what a technically unaided human hand could accomplish, they immensely expand the possibilities of what drawing is and what it can do.

2.3. Space-Time Geometries and Movement in the Brain and in the Arts[9]

The description of this international conference, held at the Institut d'études avancées de Paris, highlights "the importance of understanding how the brain perceives and represents space, time and movement, and how it plans and controls our bodily movement and actions." Thus, the conference took up themes raised by Barbara Tversky, but focused on how the brain applies this kind of information both to visual and performing arts. Even in the latter, drawing figured in several presentations, such as a digital motion capture of performing violinists in the form of animated stick figures. Among

[9] From the IAS website: "International conference convened by Tamar Flash (2017–2018 Paris IAS fellow/Weizmann Institute of Science), Alain Berthoz (Collège de France) and Gretty Mirdal (Director of the Paris IAS)" https://www.paris-iea.fr/en/events/space-time-geometries-and-movement-in-the-brain-and-in-the-arts-2.

those that focused on drawing *per se*, one presentation directly related to the theme: how we process perspectival visual input using non-Euclidian geometry. However, others looked at drawing from unexpected angles.

A presentation on "The Role of Neural Circuitry in Skilled Drawing" by Emilio Bizzi, a neuroscientist from the Massachusetts Institute of Technology, began with Renaissance drawings by Michelangelo and Raphael, then concluded with works by 20th century artist Willem DeKooning, before and after he succumbed to Alzheimer's disease. While first acknowledging that neuroscience can tell us very little about the artistry in great drawings, Bizzi gave a close description of how the brain functions when transferring an image in the mind to the actions needed to produce a skilled drawing. As he explained, the production of a drawing rests upon a number of neural circuits that are organized hierarchically with feedback loops at every level of the central nervous system. He then went on to describe the neurological mechanisms underlying the formation of spatio-temporal patterns of motor activity involved in drawing and briefly touched upon the formation of motor memories that result from the intense practice that is often the daily investment of novices to skilled artists. Specifically, he pointed out that "neural signals representing skilled learning originate in the frontal areas of the brain: dorsal lateral prefrontal cortex, Motor Cortex, SMA (Supplementary Motor Area), and Parietal cortex." From there, signals go into the subcortical area, a specific region in the basal ganglia where they are segmented into 'chunks' or 'syllables' of shorter action commands that descend into the spinal cord shaped in such a way that they can produce movements. Regarding learning, he said that "practice leads to improvement in the quality of drawing by establishing memory traces through a hierarchically organized neural circuitry." Bizzi concluded by saying that fMRI technology now can make visible the more subtle and mysterious factors that lead to art, but that these studies are still waiting to be done. Afterward, a member of the audience, architect Paul Andrue, offered a clue to how a more artistic drawing might occur by pointing out that, for him, ideas often emerged through the act of drawing itself: a bottom up, rather than top down, process.

The following day, Renaud Chabrier, author, draughtsman and film director at the Institut Curie in Paris, gave a talk on the "Epistemological Role of Drawing." In it, he demonstrated animation techniques such as morphing that help us reappreciate the practice of hand drawing in history and today, both as a source of information about the space-time geometries in our brains, and as a powerful tool for cognition. His animations brought to life images of animals from the Chauvet caves, traced the stages of bladder carcinoma, and documented the birth of the brain. (See Figure 5) From an epistemological standpoint, he demonstrated the relative limitations of photography and schematic imagery compared to drawing. In an article on the topic, Chabrier and Janke (2017) explain that "[d]rawing enables the creation of images that are more abstract than photographs but have more depth and are more accurate than schematics. Indeed, drawing can provide spatial visualizations that could never be photographed or easily schematized, thus creating transitions between the different levels of abstraction." Further, working in an interdisciplinary research environment, Chabrier explained how drawings facilitate dialogue between specialists in different areas.

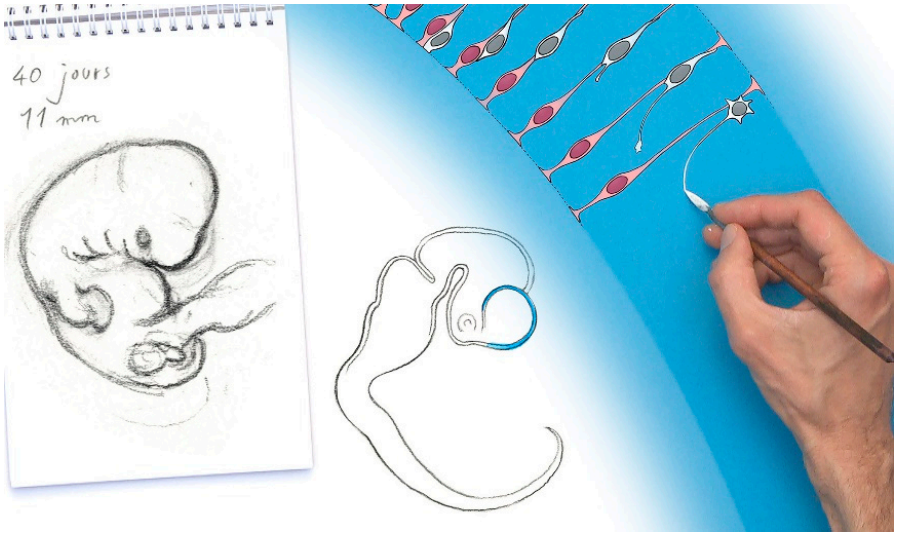


Figure 5. Sketch and color rendering for video, "Birth of the brain," documents the process of working from traditional media, pencil and brush, to digital animation. Image courtesy Renaud Chabrier.

These presentations, both in their content and their methodology, expose the complexity of the drawing process in the brain and throughout the body. Such studies challenge the popular reduction of drawing to a so-called 'right brain' visual-spatial-intuitive phenomenon necessarily opposed to and opposed by the logical-linear-linguistic functions of the left cerebral hemisphere (Edwards 1979).

2.4. Drawing Lab Paris, Cinéma d'été[10]

On my last day in Paris before returning to the US, I visited the Drawing Lab to see the *Cinéma d'été*. The Drawing Lab is located on the lower level of the Drawing Hotel in the "first district of Paris, near the Comédie Française, the Louvre Museum and the Musée des arts decoratifs." Its objective is "to endow contemporary drawing with enduring means for sustainable practices." Concerning specifically *Cinéma d'été*, this is described as "a programme of drawing and animated videos of the young European scene."

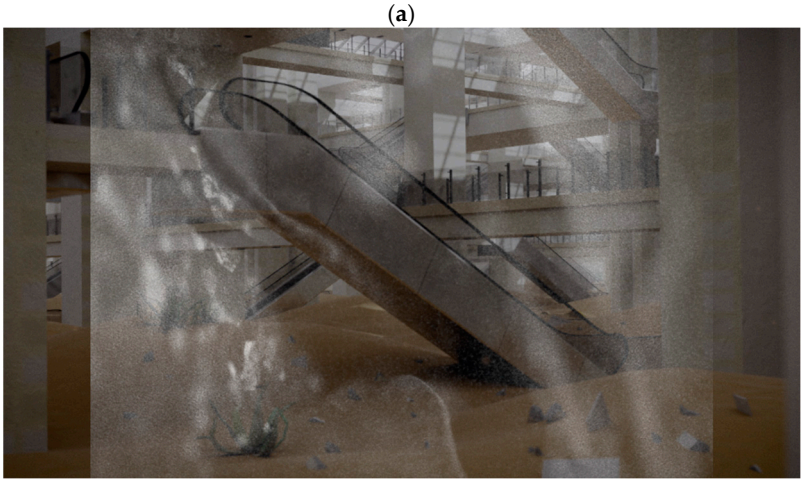
This summer's films featured ten short videos from seven artists. Technically, they included some made with traditional media, including ordinary pencils. Of these, Susi Jirkuff's, *Ginny* (2015), sets a disturbing childhood narrative against a background of high-rise apartment buildings drawn in pencil as if, or perhaps actually, by the child in the story, while Jérôme Allevena's *Émergence* (2007) follows the evolution of a pencil drawing, starting with thin lines drawn on a piece of paper that are then rubbed out by a finger.

By contrast, Thomas Léon's *Ecdysis* (2018), the longest film of the set, could only have been made with digital technology. According to Léon (translated from the French via Google Translate), "[t]he Greek term 'ecdysis' refers to molting in some organisms. This video installation explores uninhabitable places, designed for the management and circulation of human flows (shopping malls, airport halls, etc.) and questions their fate on the scale of geological time. The camera travels through these places of transit (escalators, walkways, elevators), crossed by ghostly silhouettes. Made using 3d software [based on] the engravings of the Series des Carceri invenzione de Piranesi (XVII s°), this impossible architecture constitutes a more than real mental space. (Figure 6a, Scene 1) As the camera progresses in this space, it is subject to climatic disturbances, and is superimposed on other images . . . evocation of human or reptilian bodies" (Figure 6b, Scene 2) For me, this video confirmed the potential of digital technologies (machines) to produce a genuine work of (video) art. Yet the story it

[10] https://www.drawinglabparis.com/expositions-passees/drawing-lab-cinema-dete/?lang=en.

tells is one of 'shedding' the artificial trappings of civilization and yielding a place for humanity in its most essential and enduring form. (Figure 6c, Scene 3) In this, I saw the video as a metaphor for the restoration of drawing in a world of seemingly far more sophisticated media – like grass pushing new life up through cracks in the pavement.

(**a**)



(**b**)

(**c**)

Figure 6. Scene 1 (**a**), Scene 2 (**b**), and Scene 3 (**c**). Images from Ecdysis courtesy of Thomas Léon. (To see the preview: https://vimeo.com/249929364).

3. Conclusions

To conclude, I will sum up the lessons I derive from the discussion above about drawing in the digital age and its implications for education. In the first instance, there is little evidence of drawing's demise. On the contrary, it gives every sign of being alive and thriving, and as it evolves and transforms to meet 21st century needs, it takes advantage of contemporary trends and technologies. In the second instance, however, the ongoing decline in drawing instruction means we still must make the case for drawing's potential contribution to life and learning, today. My work in that regard seeks to demonstrate how drawing's potential can be actualized by defining it as a domain of thinking in the arts and across the disciplines, and also highlighting its role in holistic development. I will end with a few preliminary points on these topics, which in turn will allow some last comments on "machine as artist."

3.1. Drawing in Contemporary Culture and Education

The four events outlined above represent a relatively recent groundswell of interest in drawing from many different quarters, the arts, the sciences, education, etc., resulting in numerous publications, research projects, symposia, and exhibitions (see DRN 2018). In terms of art, Petherbridge says that, "[a]t a time when drawing is relatively neglected in pedagogy and theory, [it is] making a vigorous comeback in contemporary art practice." (2010, p. 2). Later, (p. 412) she highlights two influences on drawing in the early 21st century that are exemplified in the discussions of drawing above: "the impact . . . of digital technology and time-based practices . . . [and] the major shift in the relationship of drawing to other aspects of artistic endeavour, which have expanded to become what [she calls] multi-practice, as artists tackle any number of different media and ways of working with far more freedom than in earlier decades."

Beyond the fine arts, drawing now reaches a much larger audience through the forms it takes in popular culture, including political cartoons and animations, as well as comic books and graphic novels for all ages, which often deal with significant subject matter, hence their inclusion in language arts classes at various levels.[11] Also, in general education, drawing has a potentially important role to play in current movements like "STEAM" wedding the arts to STEM subjects; "Design Thinking," teaching people in non-arts fields to think like designers; and "Graphicacy," thinking in images as a necessary complement to literacy (thinking in words) and numeracy (thinking in numbers) in the common core curriculum.[12]

In visual arts education, proponents of traditional drawing challenge the decline in drawing courses and leading figures in fields like architecture continue to argue for hand-drawing's importance. For example, at an international symposium at the Yale School of Architecture on the question, "Is Drawing Dead?", many participants just said "no!" (Yale 2013). Among them, Graves (2012) published an article in the *New York Times* entitled "Architecture and the Lost Art of Drawing" that addresses many points made in this paper. Responding to "the fashion in many architectural circles to declare the death of drawing," Graves acknowledges that "the computer is transforming every aspect of how architects work, from sketching their first impressions of an idea to creating complex construction documents for contractors." But, then he asks, "where does that leave the architectural creative process?" As an answer to that question, Graves says that "[a]rchitecture cannot divorce itself from drawing, no matter how impressive the technology gets. Drawings are not just end products: they are part of the thought process of architectural design. Drawings express the interaction of our minds, eyes and hands. This last

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[11] See, for example: https://www.edutopia.org/blog/graphic-novels-comics-andrew-miller.

[12] It is interesting to note that STEAM and Design Thinking emerged largely from art/design programs, Rhode Island School of Design (http://stemtosteam.org), and the Stanford D. (for 'design') School (https://www.stanforddaily.com/what-is-design-thinking/), respectively, then penetrated into general education. It was the opposite for graphicacy. The concept and term came from geography education (Balchin 1972) and was taken up by the field of graphic design (Garner 2011). For an overview, see: http://theasideblog.blogspot.com/2015/03/what-is-graphicacy-essential-literacy.html.

statement is absolutely crucial to the difference between those who draw to conceptualize architecture and those who use the computer." In conclusion he adds, "As I work with my computer-savvy students and staff today, I notice that something is lost when they draw only on the computer. It is analogous to hearing the words of a novel read aloud, when reading them on paper allows us to daydream a little, to make associations beyond the literal sentences on the page. Similarly, drawing by hand stimulates the imagination and allows us to speculate about ideas, a good sign that we're truly alive."

3.2. Drawing as Thinking, and Drawing on the Whole

Graves' last sentence invites us to take a wider view of drawing because it applies, not only to architectural drawing, but equally to drawing in fine arts, popular culture, child development, art therapy, etc. All of these are encompassed in the phrase, 'to be human is to draw.' Besides simply highlighting the facts about drawing in human history and human development noted at the outset, the phrase from a pedagogical perspective suggests the potential role learning to draw could serve in helping us become more fully human, that is, in developing our distinctly human capacities. These include our superior ability to acquire and apply knowledge (cognition), to invent and innovate or else to find and solve problems (creativity), and to share ideas and express feelings (communication).

Another way to understand how learning to draw can help us become more fully human, related to the first, is in drawing's potential to engage and integrate the range of human attributes: body, mind, and spirit. Alongside the sensory-physical engagement of eye and hand necessary for making drawings, the role of the body is also indicated in Michael Moore's comment on how we evaluate drawings in progress by basing our judgements on "whatever one might have internalized having lived life on earth." Later, Moore suggested adding to that statement the word, "embodied," which I took to mean: "having lived an *embodied* life on earth." Embodied experience was evidently applicable when assessing work done for Moore's assignment, "Drawing Rocks," in which the object was to represent immediate tactile and haptic qualities. However, a different type of embodied experience must have helped the architects in Tversky's study to envision the effects of changing light conditions over a year as implicit in their museum designs.

Regarding the attribute, 'mind,' Graves' comments about day dreaming and speculating about ideas were echoed by Thomas Léon in a follow-up exchange about his creative process. Among other things, I wondered if, like the architects mentioned earlier, he had started with preparatory sketches in traditional media for *Ecdysis* before going digital. He said he did not, but instead "made a 3D/digital mock-up that was in fact a kind of study of the Piranesi etchings before producing the video." My question also was prompted by a visit to Léon's website where he had posted a portfolio of abstract drawings and collages that suggested imagery from the film. Léon did acknowledge that he had made charcoal drawings while working on the video but insisted that their purpose "was not to prepare something. In fact, [he said] the charcoal drawings are more a form of reverie/daydream for me. I don't use them to actively seek something."Even so, he later admitted that these drawings did have an eventual impact on the film in that they introduced "the problematic of the body in the final video process as well as some concern about an infra-human-life (insects, etc.)" (personal communication).

Such statements, which recall Paul Andreu's reference to ideas emerging out of the act of drawing and Nicolaides' point about "reasoning with the pencil," invite us to think about 'drawing as thinking:' critical, creative, and reflective. Earlier on this topic, I mentioned Maynard's reference to technical drawing as a mode of thinking essential for bringing civilization into the modern age. All these processes might be subsumed within Petherbridge's view of drawing as "visual thinking," or, more inclusively under Tversky's visual-spatial reasoning. Yet, considering the virtually innumerable forms of drawing and the diversity of functions drawing has served over the millennia, even these formulations are too limited. For one thing, they exclude drawing as thinking in fields that are usually not visual, like Richard Feynman's diagrams in quantum physics (Kaiser 2005) or Peirce's existential graphs in semiotics (Simmons 2017). On the opposite end of the spectrum are drawings in which thinking as commonly understood does not seem to figure at all. This relates to the third human

attribute, spirit, both in drawing as self-expression based typically on emotion and in reference to spiritually-inspired artwork like oriental brush drawings (Sze 1959) or perhaps the images of animals on the walls of prehistoric caves (Lewis-Williams 2002). [13]

3.3. Toward a Comprehensive Model of Drawing Instruction for the Digital Age

Such considerations argue for a view of drawing as a holistic endeavor, involving the full range of human faculties: intellectual, emotional, sensory, motor, social, and spiritual. Implied in this formulation, the same basic skills (with line, tone, texture, shape, form, and space) can be applied toward a seemingly infinite array of ends: artistic and scientific, personal and professional. Combined with the unprecedented pluralism of post-modern art and the wide-open definition of the word, 'art,' already mentioned, these factors might suggest an image of drawing instruction today as a potpourri of possibilities, each as good as another. Indeed, some contemporary drawing instructional texts[14] and drawing exhibitions[15] reinforce that impression. On the positive side, these conditions open up vast new avenues for creativity, self-expression, etc., but in doing so they also make it difficult to decide how to teach drawing and assess student work.

To counter this 'anything goes' attitude while still keeping options open, I identified five paradigms of drawing instruction that address distinct but interrelated facets of drawing with applications across the arts and across the disciplines. In their most recent formulation (Simmons 2012), they include: drawing as design, drawing as seeing, drawing as experience and experiment, drawing as expression, and drawing as a visual language. These formulations are now being developed in a book entitled, *Drawing Instruction for Cognition, Creativity, and Communication across the Curriculum: The Case for Learning to Draw in the Digital Age.* (Simmons forthcoming) The concerns for cognition, creativity, and communication in the title have been discussed already. Added to these is the concern indicated in the subtitle: to determine the respective roles of traditional and digital media in regard to the applications of drawing in various spheres. Reference to 'the digital age' also implies a related issue: the need to address the challenges of teaching drawing in a social and academic climate dominated by

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[13] In both examples, the term 'painting' is commonly substituted for 'drawing,' a distinction based on the use of materials, such as pigment rather than chalk. On the contrary, many images in each instance fit well within the definition of drawing as delineation noted earlier. Needless to say, drawing in the service of spirituality and religion is restricted neither to pre-history nor to non-western cultures.

[14] Among the most inclusive instructional texts for drawing at the university level is: *Drawing: A Contemporary Approach.* (Sale and Betti 2008) For example, where more traditional drawing books, especially those used at the foundation level, allow considerable space, often several chapters, to teaching linear perspective, here this topic is addressed in one chapter, called "Antiperspective: The Triumph of the Picture Plane." Before addressing linear perspective, the first section of the chapter covers "Contemporary Challenges to Traditional Perspective." Following several sections on linear perspective are sections on alternative projection systems, including: Axonometric Perspective, Multiple Perspectives, and Stacked Perspective.

[15] An exhibition addressing differences between academic drawing instruction, drawing instruction under modernism, and post-modern art instruction with or without drawing was the subject of a 2015 exhibition at the École Nationale Supérieure de Beaux-Arts in Paris. The exhibit, *TRANSMISSION recréation et répétition*, juxtaposed images and artifacts from academic art training in the 17th–19th centuries and modernist art studies in the early 20th century against the work of current students and contemporary artists. Artifacts from the academic period included figure drawings, anatomical renderings, and perspective studies, as well as a cast made from a sculpture by Houdon, *Écorché au bras levé* (1776), one of thousands like it used by art students across the western world to study anatomy. The modernist tradition was represented by abstract geometric drawing exercises taught by Bauhaus-trained artist and teacher, Josef Albers, in the United States at Black Mountain College and Yale University (Goldstein 1996). Although the work of Albers and his students was itself a stark contrast to what was done in previous centuries, both parts of the historic display clearly demonstrated the rigor, relative uniformity, and explicit standards that were hallmarks of earlier art instruction. By contrast, the contemporary work reflected a vast diversity in aesthetics and media, including drawings, but also photos, videos, installations, performance art, etc. Two drawings reflect the extremes that might be found in post-modern exhibitions anywhere. One, Mladen Stilinovic's: *Bol (kriz)/Pain (cross)*, 1989, ('pain' in French means 'bread') is on a 20.6 by 29.2 cm sheet of rough beige-ish drawing paper (possibly newsprint), without a frame. In the middle of the page, single hand-drawn (in pencil) vertical and horizontal lines cross each other with the hand-written word 'BOL' inscribed at the end of each line. The other, *Air d'Olympia, dit de l'automate*, 2013, by Christelle Tea, is a complex and ambiguous mural-sized digital image, 3.20 m high × 8 m long, in which the subject, a female robot clothed in a plastic-looking white suit with black trim, is repetitively depicted whole and in parts in multiple poses and combinations against a black background overlaid in intricate patterns of white lines evocative either of circuitry schematics or city planning maps. The author of the catalogue (Basta 2015) says the work brings together drawing, photography, and (referring to the title) lyric singing, notably Offenbach's "Tales of Hoffmann."

digital media (see for example, Gardner and Davis 2013). In the final section, I will discuss how these issues play out in considering the question of "machine as artist."

3.4. "Machine as Artist" with Implications for Drawing Instruction in the Digital Age

Here, the question is whether machines (robotics, artificial intelligence, and digital technologies in general) can create what has long been recognized as among the highest forms of human achievement. That topic was broached in a sense at the *Artistes et Robots* exhibition on a wall text under the heading: "The Robot Emancipates Itself." Its opening lines addressed such mechanical potential by saying, "In 1951, mathematician Alan Turing wondered whether a digital calculator could think. Taking this thought a step further, the controversial pioneer of transhumanism, Ray Kurzweil, has predicted the emergence of an absolute form of Artificial Intelligence applicable to all social and personal fields in the near future." For me, the epitome of such an eventuality would be a machine capable of making art on the level of a Rembrandt or a Käthe Kollwitz. In the exhibition, Patrick Tresset's inventions came closest by creating accurately observed drawings, each original in its interpretation of the same subject in a style similar to, if not exactly the same as, what the artist might have done. Necessarily missing, however, is Tresset's quality of touch and emphasis resulting from what Moore would call his embodied experience based on a lifetime of living in the world. Lacking bodies with their sensitivities and frailties, lacking minds and spirits rich in memory and aspiration, machines are unlikely ever to be capable of the nuances and search for salience that humans, including young children, can infuse into their artworks, let alone well-trained, mature artists whose work, whether consciously or not, is imbued with human life deeply lived.

As an alternative to, or at least a complement to, the excitement of finding out how close we can get to creating "machines as artists," our efforts, especially as educators, might be better turned to using whatever means are available to help learners develop their *non-mechanical* human nature to its fullest. This has been the 'work of art' and the work of drawing in particular since humans made their first meaningful marks, and it continues as each child finds her or his own way to continue the tradition. In an era immersed in machinery that substitutes for seeing and for interpersonal interaction, drawing as the least mediated art medium retains the potential to reconnect us to our experiences and to one another.

Considering such conditions, the burgeoning interest in visual thinking, visual-spatial reasoning, and drawing should come as no surprise. Rather, as Barbara Tversky wrote to me on the topic, that interest may reflect a broader zeitgeist, or 'spirit of the times.' In my research, I identified similar zeitgeists when drawing, widely taught, became a skill accessible to all levels of society, from the artisans to the aristocracy and even to royalty. It is no coincidence that these eras, the Golden Age of Greece, the Renaissance, the Age of Enlightenment, and the Industrial Revolution, where among the most informed, innovative, and interconnected in history. In my view, universal drawing instruction could make a similar contribution to the present visual age. As such, it may be "an idea whose time has come," again.

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