Chapter 8

E-textiles and the New Fundamentals of Fine Arts

Kylie Peppler, Leslie Sharpe, and Diane Glosson

Introduction

Undergraduate Fine Arts student Jillian created an interactive art piece that involved two sock monkey dolls embellished with male and female costumes, a LilyPad Arduino, and various metal snaps. When the monkeys "hug," they connect via the snaps to create two very different reactions (Figure 53): when the male monkey connects to the top two snaps on the female monkey's dress, he's rewarded with an illuminated LED heart; when the male monkey oversteps and affixes his paws to the snaps on the female's derriere, the female doll emits a blaring siren in rebuke. Despite its deceptive simplicity, Jillian's piece is a technically adept exploration of the possibilities of running a circuit through two separate objects. Additionally, her pairing of newfangled technology with the traditional hand-sewn sock monkey dolls—themselves icons of older working-class inventiveness—into her first extended project with e-textiles creates a poignant juxtaposition of nostalgia and looking ahead, of the chasteness of childhood dolls and the nascent relationships of young adults. The symbolism of sock monkeys—the basis of a beginning sewing project for women of an earlier generation, when someone was just beginning to learn the basics of the craft—is an additionally piquant choice for incorporation into her first e-textiles project.

The advent of new digital or media arts programs in Fine Arts departments across the globe reflects a growing recognition of digital media as a medium for expression. Leading theorists, artists, and practitioners describe this burgeoning field of media arts as the intersection of electronic equipment, computation, and new communication technologies (Nalven and Jarvis 2005; Paul 2003; Peppler 2010). Seeking to address the new fundamentals of this emergent domain, new courses on digital arts are being designed to emphasize the exploration of computer programming environments which were once thought to be the sole domain of computer science courses, like Pure Data (PD), Adobe Flash, Java, and Processing, toward aesthetic ends. In this context, Fine Arts students learn to computer program to fully realize their aesthetic goals.

However, the emphases of these programs have thus far been paid almost ubiquitously to creative expression in onscreen digital media production, largely overlooking the intersection between digital and physical materials at the core of much of today's contemporary arts landscape. The expressive possibilities of this intersection are realized with vivid imagination in the world of fashionable technology (Seymour 2008), exemplified in works like Hussein Chalayan's "One Hundred and Eleven" collection of dresses that, while on the wearer, mechanically and electrically transform to tell a visual story of the history of fashion (2007); Angel Chang's explorations of heat-sensitive, conductive, or light-sensitive materials in her ready-to-wear fashions (2007); or XS Labs' "Accouphène" tuxedo, a wearable sound interface that projects a sonic environment controlled by the movement of the wearer (2006).

Fig 53 Image of the Sock Monkey project created by Jillian

Seeking to address this gap between education and current artistic practice, this chapter presents an educational exploration with university digital arts students, which aimed to pull digital arts off the screen and into the physical world by introducing e-textiles via the LilyPad Arduino as an aesthetically compelling medium. The examples of student work presented in this chapter illustrate how Fine Arts students tackle the new fundamentals of new media and physical computing in the process of e-textile creation, which encompasses a range of physical computing skills, including the building of interactive physical systems by the use of software and hardware that can sense and respond to the physical world. Moving e-textiles into the realm of Fine Arts expands our considerations beyond the technical aspects of programming and design to addressing expression and a sense of aesthetics in the work. Student projects are presented along with an exploration of the opportunities and challenges for teaching and learning about the aesthetics of e-textile designs.

Introducing E-Textiles to Fine Arts Students

The undergraduate and graduate students featured in this chapter were members of a mixed-level multimedia class at Indiana University's Fine Arts Department (offered in the fall semester) led by media artist, Leslie Sharpe. The three-hour studio format of the course accommodated both direct teaching methods using an adjoining computer lab, as well as free exploration with materials and peer-to-peer learning opportunities using the materials in the larger open studio space. On the whole, the graduate students rarely utilized the computer lab area, and most direct instruction with this older group was led by one of the students who had prior experience with the Arduino programming environment (although this student was new to the LilyPad Arduino materials). The unit dedicated to e-textiles convened for a total of over 20 hours throughout the semester, though students were invited to refine their projects outside of class. Though all participants (11 in total) were Fine Arts students, many of them came from diverse disciplines within the school, including textiles, retail merchandising, shoe design and multimedia, among others.

Though none of the participating students had worked with the LilyPad Arduino before, all were versed in a number of skills foundational to e-textiles through their Fine Arts experiences, including prior familiarity with coding in a range of programming languages and experimentation with new media (requisites of the digital arts focal area). The required coursework for all Fine Arts majors (and prerequisites for enrolling in this class) also ensured that all students were adept at designing and creating in three dimensions, including the use of plaster, power tools, wood, soldering, and various other sculpting materials. Despite what might be considered a "leg up" with the programming concepts at play in physical computing, these art students came up against several non-trivial challenges in extending their two-dimensional or screen-based designs to physical media, resulting from the intersection of various skill sets that converge in this landscape. We group these challenges into four building blocks of creating physical interactivity with e-textiles that students must address in the manipulation of these materials toward expressive ends.

Overview of the (New) Domain

In any new domain, it's important to envision the possibilities for working with the materials. In e-textiles especially, Fine Arts students were relatively unaware of the professional work in the field. To address this critical gap, the students were presented with a brief overview of the e-textiles field at the beginning of the course as well as a number of prominent examples of professional work including Lady Gaga's "Living Dress" (inspired by the designs of Hussein Chalayan, and built by Vinilla Burnham) (Burnham, n.d.). However, the relatively short history of existing e-textile works (as opposed to the longer history of painting) of art to extend or react against hindered most of the students' ability to envision the full possibilities of the materials and overcome the "blank page" effect of a new domain.

Creative Coding

As a backbone to any project sitting at the intersection of physical and digital media, learning to use computer code in an expressive and creative way is needed in the context of Fine Arts. While overlapping with goals of computer science, the goals of computer programming in the context of the arts are much less about the efficiency (as few lines of codes as possible) or complexity of the code, it's much more about the functionality of the code. We were certainly surprised, however, to see students struggle with new text-based languages like Arduino, despite their prior experiences with Pure Data (PD), Adobe Flash, C, and Python. At the time of our initial study, the user-friendlier alternative to Arduino, ModKit, had yet to be developed, which would have probably impacted the outcomes of the student work. However, students engaged with these challenges oftentimes with assistance from more knowledgeable others, learning about the new programming language and learning how the on-screen programming they were doing intersected with the physical construction of their projects (Figure 54).

Material Science

When students begin to create new works with e-textiles, they begin to look at mundane materials in new ways, paying particular attention to the attributes of the media to be used in their projects and making educated guesses about whether something is conductive, or insulating. Especially at the start of the workshop, there was a general lack of understanding regarding the energy transfer capabilities of physical objects that was apparent in the majority (but not all) of the students' projects, many of whom had difficulty sorting conductive from insulating materials. This was somewhat surprising to us considering the amount of assumed experience a Fine Art major might have had over the course of a lifetime with physical media in sculpture, ceramics, or crafting experiences. In one instance, a student incorporated oil-based clay into her piece, unaware that oil-based clay would insulate the thread in her design. Another student used single-layer scotch tape in a high-impact area of his project, not realizing that it wouldn't be sufficient to act as an insulator under high impact. Similarly, another student used tape as a link between two non-contiguous conductive threads and was surprised to discover that the tape itself wouldn't conduct energy between the two pieces of thread. In each of these instances, these misunderstandings reveal a need for students to play with the physical properties of the materials and to envision new uses for everyday materials that are well aligned with the project goals.

Fig 54 Manipulating code and physical materials in the computer lab

Electronics

Learning about e-textiles requires an understanding of electronics, including the central microcontroller, various types of LEDs, resistors, and several other devices (like temperature sensors, vibe boards, and buzzers) as well as how the central microprocessor can be programmed in relationship to these devices. For almost all of the students, learning about electronics was a new endeavor, drawing on their existing K-12 understandings at best. Many of the challenges that students faced relating to the reliability of the LEDs lighting up when anticipated could have been avoided with some prior knowledge of the relationships between electrical voltages and currents or a basic familiarity with the electrical resistance of conductive thread. These misunderstandings were made most apparent when the students struggled to power all of the electronic components of their projects with a single battery without a solid understanding of Ohm's Law. Therefore, they failed to take into account that the resistance of the thread and the number of LEDs in series on the circuit would affect the distribution of energy across the conductive path. While this was a central challenge to the course, the students were ecstatic to receive new equations to help them better predict the capabilities of a particular battery and the number of LEDs that could be supported as this just-in-time physics instruction was solving very real problems they were facing in their designs (Figure 55).

Learning about any of the concepts listed above—resistance, conductivity, electronics, and programming—under the umbrella of the arts shares some distinct similarities to and differences from the context of engineering, physics, or computer science courses. For artists, "making it work" isn't enough. The balance of technical competencies with aesthetic decisions and the advancement of a unique artistic vision is what makes this intersection an art form. In contrast to other approaches, the ultimate objective of a work of media art is not merely that the sensors and microcontrollers successfully translate analog inputs to a software system, but that it advances an artistic voice, one that adheres to and reflects a longstanding aesthetic vision of its creator. Though the successful programming of simple circuits was not that difficult for the students, fully conceptualizing and troubleshooting the operations of projects that lacked any precedent proved the most difficult to overcome.

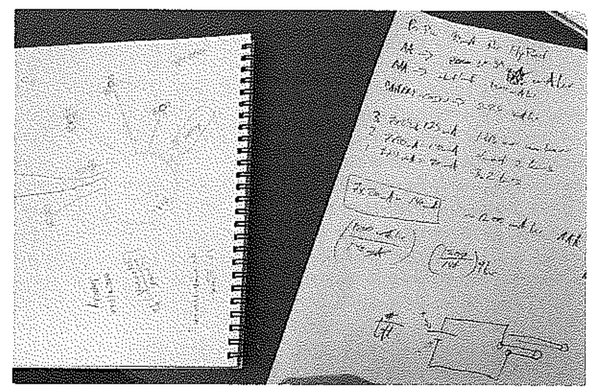

Fig 55 (L to R) Student drawn diagram of aesthetically placed LEDs, expert's calculations of amps required and battery life expectancy

In the following pages, we present a range of three projects produced in the Fine Arts course and the evolving understanding of the materials' affordances and constraints (i.e., the competencies needed) before the materials can be envisioned aesthetically.

Temperature-Sensing Dance Gloves

"One other issue I ran across was, I was purely thinking of aesthetics, oh wouldn't it be cool if [the LEDs] all kinda spiraled down my hand? (Animated and in a lower voice:) 'Oh, they are going to start crossing if I do that!'"
—Rachel, Undergraduate Fine Arts Student

Rachel was a Fine Arts undergraduate student who traditionally worked on the screen and appeared excited when the opportunity arose to work on a project she called "installation-esque." Rachel shared at the critique at the end of the semester "... it's really interesting to get outside of that (screen) and do something concerning the body itself other than press these buttons."

To capitalize on the kinetic control possibilities of an e-textiles project, Rachel wanted to design a wearable object that would respond to elements in the environment. After brainstorming a number of potential designs, including wearable art that could be sensitive to auditory stimuli (the materials available to the class lacked any microphone or vibration sensors capable of accepting aural input), Rachel chose to explore the potential of a light behavior to be modulated by data from a temperature sensor. She designed a pair of gloves that featured LEDs that would increase in brightness when the temperature of the wearer's hand increased. Rachel ultimately modified her design by limiting the interactive elements to one glove, while the second glove was embroidered similarly to the first, only using non-conductive thread (Figure 56). It was also decided that the temperature sensor would not only sense body heat for a patterned LED behavior, but if a cold object were held against the sensor (e.g., from a refrigerated glass, can, or bottle) another LED pattern would display.

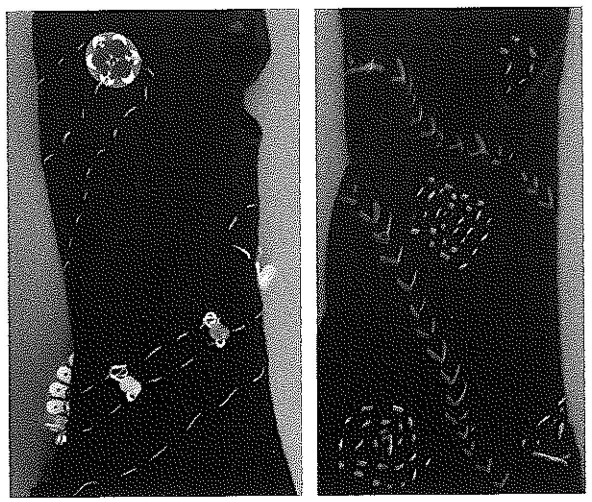
Fig 56 Image of the Temperature Sensing Dance Gloves created by Rachel

Rachel's manufacturing of the electronic glove presented unforeseen challenges, many of them pertaining to her first experiences working with needle and thread (e.g., being careful not to mistakenly sew the layers of the glove together). Additionally, the behavior of the conductive thread proved problematic, as Rachel didn't think to secure each knot with clear fingernail polish, resulting in threads that would frequently fray and unravel. Additionally, she needed assistance understanding how to secure proper circuit connections between the LilyPad, battery, sensor and LEDs.

Rachel's final product included a LilyPad Arduino, AAA battery power supply, 3 LEDs, and a temperature sensor. The LilyPad was programmed to run two different light patterns; if the wearer's hand was cold, the LilyPad executed an initial pattern and if the wearer's hand was hot, the LilyPad executed a second pattern.

Rachel's aesthetic conception of the glove and the technical aspects of it were difficult to reconcile. Decorative, colored thread was used in places to augment the stitches of conductive thread that traced between electrical components, though the visual identities of both (conductive and non-conductive threads) were unique unto themselves—the decorative and the functional aspects of the piece were fundamentally kept separate—which emerged partly from necessity, as the decorative lines threatened to interfere with the circuit in early drafts. In her final critique, Rachel observed, "I should have realized, it may look cool but it may not get it working just right." To which Sharpe replied, "I don't think it's a problem at all for you to be thinking aesthetically, you're an artist. So you want to bring things in that you think are going to make it more interesting, or more beautiful or whatever your intentions are."

Ruby Slippers Reinvented

"I love drawing, I love design, I love the idea of 'art you get to wear.' And it is art—why buy a painting when you can buy a pair of shoes?"
—Matthew, Graduate Apparel Merchandising Student

Matthew, an Apparel Merchandising major specializing in Footwear Design & Retail, sought out a project that reflected his personal interest in shoes when he was introduced to the LilyPad Arduino materials. For Matthew, shoes walk a fine line between the "balance of performance and aesthetics" so it stands to reason his dream job would include working for the company that makes "Michael Jordan's line of shoes" (Anon. 2008). Therefore, it seemed quite natural that his project would focus on another pair of iconic footwear: the magical ruby slippers from the *Wizard of Oz*.

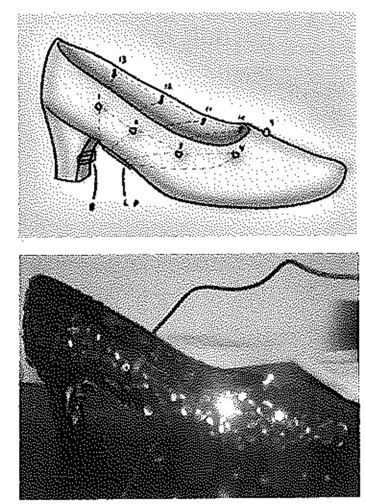
Fig 57 Images of the Ruby Slippers created by Matthew

The goal of this project was to modernize the shoes worn in the 1939 classic film, augmenting the sparkles that accompanied Dorothy's famous clicking of her heels through strategically placed LEDs. He began the project by customizing some preexisting high-heeled shoes by poking 4 holes for the LEDs along the top edge of each shoe. He then envisioned that each LED would uniquely link to a petal on the LilyPad to enable individual control of each light. However, Matthew quickly realized during the production phase that the materials themselves presented some unique constraints.

One of the challenges faced was being able to hide the LilyPad Arduino (a large circular disc) in a discrete place on a shoe while also ensuring that it won't be damaged or fall off. The battery holder posed a similar design challenge, compounded by the fact that, at the time this project was created, the only known battery option for the LilyPad was an AAA battery and battery holder. To accommodate these constraints, Matthew had to increase the size of his shoe to at least a size 10 to obscure and secure both electronic components (Figure 57).

Stitching in a large number of LEDs inside of a leather shoe proved to be challenging for Matthew as well. Originally he planned to sew fifteen LEDs per shoe, knowing that the sequins would cover any stitching. However, he only included nine due to the size limitations inside the shoe reporting that "even with nine lights, I still ran into issues with threads touching" and shorting out the signals. Despite the modifications to his design, Matthew was able to retain his vision of connecting each LED to separate petals on the LilyPad to create flourishing configurations of light when the signal is triggered. Although they were not installed by the time of the final critique for the class, Matthew envisioned adding switches to the heels of each shoe to trigger the light effects by replicating Dorothy's iconic heel click gesture. Matthew commented that he would have liked to have had the opportunity to prototype and construct the shoe from scratch instead of modifying an existing shoe form, which would have allowed him to incorporate a special compartment for the invisible electronic elements of the LilyPad Arduino and battery holder.

Sewing any electronics into a high-impact object, like a shoe, can be challenging not only in functionality, but also in the aesthetics of the wearable object, especially if the designer is someone who compares shoes to a painting.

New Costumes for Performance Art

"You learn from failing at least some of the time."

—Jay, Graduate Textiles Major, posted on her personal blog

Graduate students Jay and Amy collaborated closely in the class. Both textile majors, they had a keen appreciation for the uniqueness of materials and the importance of finding the most appropriate fabric for a given application. This perspective naturally positioned them well to deal with the affordances and constraints of some textiles over others in this domain.

Exploring the possible materials in the design was high on Jay and Amy's agenda and was evident at the first "sew session" of class, when most of the students sewed their own textile circuit. Both had sewn a circuit previously, so instead of sewing,

they focused on the sample e-textile projects brought to class and on the diverse sets of conductive materials and other electronics available. They discovered new materials and processes they could use while thinking of a design for their final LilyPad Arduino project, exploring conductive fabrics and specific techniques like how to stitch on stretchable materials.

One of Jay's first challenges was her attempt to repair conductive thread stitching on a glove she had designed with LEDs at the end of each fingertip. While working off-site, she discovered she had a short somewhere in the stitching, so she sewed over the parts that she thought could be the problem areas with a second layer of conductive thread. While this approach may work with decorative thread, it did not fix electrical shorts and resulted in a glove that failed to illuminate.

This team also struggled with translating the specialized language inherent to physics concepts to their artistic vision, a challenge that Jay referred to as the "two dialects." Jay often searched for information on the Internet, so while the physical or electrical phenomena at work in their project contained parallels in other fields of study, the students found it difficult to pull these more advanced STEM concepts into the language that art students are more accustomed to speak and use for conceptualizing creative ideas.

The team decided to create a costume shirt that was to be part of a performing arts piece. Their partnership included a distinct division of labor: Jay designed and constructed the LilyPad shirt, while Amy designed and constructed three stretchable pods for the performing artist to climb into and maneuver during the performance. The initial design included a shirt with LEDs on it and a temperature sensor on the sleeve with the LilyPad controlling the pattern of light displays. The LEDs would be connected by conductive patches of material on the inside of the elbow, so when the performer's arm is folded up close to the body the patches would meet and complete

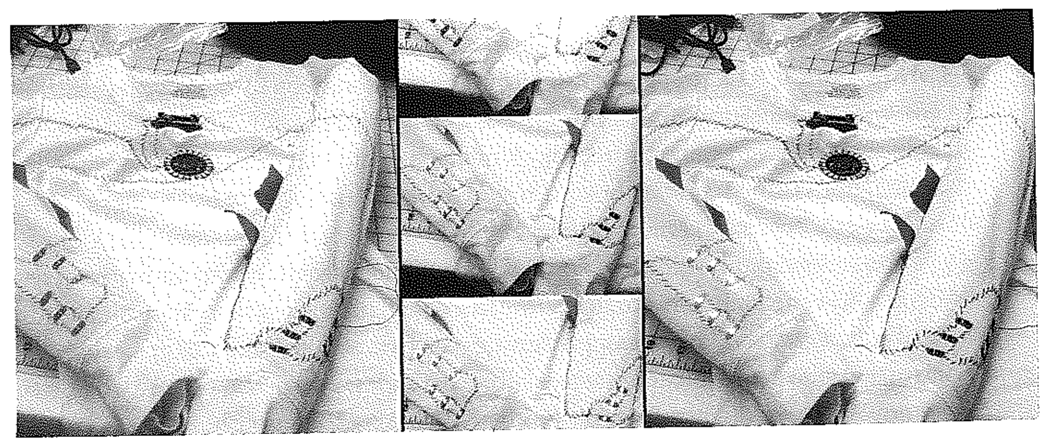

Fig 58 Images of the Shirt created by Jay and Amy

the circuit displaying light inside the pod. However, designing a performance shirt led to other challenges, such as what material to use for comfort, performance, and to hold electronics. Additionally, further contingencies had to be accommodated for, such as what would happen to the electronics if they touch the performer's sweating skin, what is the best stitch for stretchable material, and how could they cover the sharp edges of the electronics so material pods would be protected.

The temperature sensor was eventually eliminated from the final design, the stitching issue was solved with an aesthetically pleasing diagonal stitch and the sweat issue was eliminated by incorporating a second layer of fabric between the electronics and the performer as well as a second layer of patches over the knot areas to keep a smooth area when in contact with the skin. Lastly, the front side of the electronics was covered with a clear plastic as not to disrupt the aesthetic unity of the shirt and to protect the pod material. This project was the most complicated of the textile projects, but the end result was an artifact of beauty (Figure 58) that was used in a departmental art installation at the end of the semester.

Lessons Learned for Introducing E-textiles in Fine Arts

Preparing students with a skillset to execute innovative work in contemporary art necessitates the instruction of the fundamentals of e-textiles—a familiarity and flexibility with computation that exists both within and beyond the screen. These new fundamentals empower students with the means to create radical innovations, such as those exemplified in the work of leading e-textile designers (such as Hussein Chalayan) as well as artists who explore alternative forms of media (like Cory Arcangel). Across this span there exist common rudiments that must be taught as part of the Fine Arts curriculum, those that enable artists to take greater control of various media as a form of artistic expression rather than having their artistic choices predetermined by the limitations of the technology.

New technology is certainly a large part of the 21st century, yet training and digital media alone do not prepare artists to integrate technology into physical media or to creatively explore this intersection. Additionally, this mission also prepares artists to help shape what the next technology landscape could look like, as high-quality design and alternative visions for how to engage with technology are linchpins of many of today's most successful media applications.

The case studies presented above highlight some of the tensions in introducing e-textiles into the Fine Arts curriculum. One of the primary strains stems from the lack of exposure and everyday opportunities for free play with these types of materials, making e-textiles creation a radically new endeavor for the majority of these students. Though it might be expected that Fine Arts students should have ample experience expressing ideas on and off the screen and with a breadth of tools (students in this chapter were versed, for example, in both sculpture and digital art),

there is something unique about this intersection of digital and physical media that poses a substantive hurdle. Perhaps this is because the primary interests of this community extend beyond immediately functional concerns, just as they extend beyond making a product that "looks nice." Though any concise response to "what is art" is generally viewed by artists with suspicion, one could attest that the process of creating art involves the projection of ideas that explicitly respond, question, or subvert established cultural and historical aesthetic perspectives with singular imagination and creativity. In the cases presented here, we find the Fine Arts students tapping into ideas and phenomena that encompass more than the artifact, itself, ranging from a commentary on representations of physical/magical technologies (by transporting Dorothy's telekinetic ruby slippers into the 21st century), to two approaches to extending the visual language of dance by creating relationships between light and movement (Jay and Amy's dance costume) or exertion (Rachel's heat-sensing dance gloves). Though the works shown above may not *look* ostensibly different from the works created by "non-artists" in other chapters, what differs substantively is the intent of their designers. Whereas an engineer working with e-textiles might push the boundaries of the materials in service of creating something that other technologies cannot do, the artist seeks to explore the transactions between performer and audience, the aesthetic relationships between the wearer and viewer. Indeed, there is a performative aspect in each of the case studies presented in this chapter.

It should be noted that making a novel contribution to technology, engineering, or design—something we often assume falls in the purview of engineers more so than artists—is a common feature in the work of today's most successful media artists. This involves flexibility of thinking and creative approaches to STEM principles that might be familiar to artists experienced in making digital art but not to Fine Arts students, writ large. As this skillset pertains to the work of fashionable technology designers, the required "fundamentals" and domain familiarities of these artists further extend to include crafting, circuitry, and physical computing—cousins many times removed, as it would seem from our observations of the Fine Art students, from their core disciplines in wood, clay, plaster and other physical media taught in most arts classrooms though diminishing in presence in the world's contemporary art museums and galleries.

Expressive flexibility in a new domain demands a mastery of tools and materials insomuch as it allows the artist to think beyond the behaviors of the medium, itself. A fundamental source of the challenges the Fine Arts students faced in this chapter potentially stems from the translation of principles commonplace to STEM disciplines to those that can also suit a studio-like approach to Fine Arts classes. While the approach described in this chapter represents one way of breaking down this new subject area for Fine Arts settings, it would be ideal for students to engage in open-ended exploration beyond the fundamentals of each of the disciplines involved at this cross-section of fields.

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To Seymour Papert, the grandfather of this work

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