Sparks: Smart Materials & Electronics in Landscape Architecture Education

Author Carolina Aragón
University of Massachusetts Amherst

Introduction

As mediators between nature, culture, and technology, designers are strategically positioned to influence the way resources are used to shape our environment, while embedding meaning in the spaces we build. Through the use of materials, designers can signal new relationships to our environment, create direct economic and environmental impact, and shape public perception. Additionally, designers have the unique opportunity to engage in advancing technology by envisioning and developing new applications for materials or new technologies.

In designing for the future, material practices are challenged to create abundance, rather than solely minimize resource consumption (McDonough and Braungart, 2013). To achieve this goal, new approaches to material practices and the development of new technologies are needed. While there is rapid growth in the research and development of new materials in the engineering and science fields, exploration into their potential for design applications remains limited and within the realm of industry and product development (Addington and Schodek, 2005).

The gap of knowledge between innovative materials and their implementation for design applications— which entails both technical and human implications—places design students in an optimal space for experimentation, failure, and dealing with the unprecedented. From a pedagogical perspective, it offers the opportunity for students to be innovators and creators of technology, rather than solely consumers. Doing so provides opportunities to evaluate the role of design education in fostering technological innovation and provides insight into the value of transcending disciplinary boundaries as part of the beginning design student experience.

Experimentation in Landscape Architecture

Current landscape architectural theory and discourse has brought forth the need for experimentation with materials and technologies as necessary in advancing the profession's ability to address issues of sustainability and resilience. Innovation in material use has been presented through a re-examination of traditional materials from a deep understanding of their performance and a renewed look at their theoretical implications (Yglesias, 2014); and from an organizational and conceptual framework that presents technological innovation from multiple diverse disciplines that relate to the dynamic and complex qualities of the landscape (Margolis and Robinson, 2007). Furthermore, there is a growing awareness for the importance of responsive technologies in landscape architecture, including the use of materials and technologies that bring into focus environmental information that escapes our human sensory abilities (Cantrell and Holzman, 2016).

Nevertheless, from a pedagogical perspective, experimentation with materials and technologies as part of the traditional landscape architecture curriculum presents several challenges. Among them is the reliance on representation as the primary medium by which design is learned, understood, and explored. Because landscape architectural education engages students in the design of projects with a continuously expanded notion of scale, both geographic and temporal, graphic representation has inevitably become the main tool for the design and communication of ideas. While a flexible medium through which to explore and communicate ideas, representation is inevitably limited in its ability to provide feedback on how a proposed assembly or design could perform. In essence the drawing of a thing is not the thing itself and could never perform (or not) as a thing in an environment. Additionally, because the landscape architectural practice involves working with living organisms and dynamic environments, issues of temporality can also be a challenge. Experimentation that seeks to better understand the performance of living systems could inevitably take a very long time as they develop, grow, and evolve. The time required to conceive, implement, and record data involving living systems may likely exceed the duration of a course or potentially of an undergraduate or graduate program.

However, there are multiple ways to incorporate experimentation as part of the landscape architectural curriculum. One of them involves direct material experimentation, which may take the form of challenging the use or application of traditional materials (Yglesias, 2014), the transformation of unconventional materials, including waste materials, for landscape architecture uses (Aragon, 2016), or the invention of new applications involving innovative materials or technologies with little precedent in the profession. Material experimentation provides students with the opportunity for hands-on discovery, and the chance to reflect on the relationship between materials and the environment. This relationship may increase knowledge of the use of resources and the processes involved in the manufacturing of materials, awareness of issues of waste, and understanding of how materials perform in response to dynamic environmental conditions. By engaging in abductive processes of inquiry common to design, which focus on what something *may be* by generating multiple explanations to help conceptualize future investigations (Shearer, 2015), material investigations can present meaningful contributions to the development of new applications. In generating multiple interpretations and solutions responsive to material qualities, applications may encompass new relationships to the dynamic environment or better address issues of human scale and phenomenology.

Smart Materials in the Landscape

Smart materials present great potential for material investigation as part of the landscape architecture practice and pedagogy. Addington and Schodek (2005) describe smart materials as those with the ability to transform their physical characteristics in response to surrounding energy fields. Some of their distinguishing characteristics include transiency, selectivity, immediacy, self-actuation and directness, allowing them to sense and respond to an environmental event (Addington and Schodek, 2005). Smart materials can be categorized into two major groups: property-changing and energy exchanging. Property-changing materials demonstrate a change in their chemical, thermal, mechanical, magnetic, optical or electrical properties, in response to a change in the environment in which the material is found. These changes can be caused through direct input, such as current or voltage, or through ambient conditions, such as temperature or light (Addington and Schodek, 2005). Examples of property-changing materials include photochromic and thermochromic materials, which change color in response to light or heat input. Energy-exchanging materials have the intrinsic capacity to transform input energy into a different form of output energy. Examples of energy-exchanging materials include photovoltaic, photoluminescent, and piezoelectric, among others. These materials, especially piezoelectric materials, are often used for energy harvesting, normally referred to the conversion of ambient energy into electricity (Kim, Tadesse and Priya, 2009).

Outdoor settings–with their ever-present dynamic conditions of light, wind, and temperature among others– can provide a rich environment in which to deploy smart materials and harness their intrinsic technological capacity for productive and experiential design purposes. Smart materials can be responsive, productive, help read environmental change, and directly respond to human presence. As such, they can be implemented in the design of landscapes to create interactive spaces that can additionally signal abundance through their indexical relationship to the environment.

Material Experimentation in the Classroom

The following projects are highlights of student work involving innovative material investigations for landscape architecture applications developed in two courses taught at the University of Massachusetts Amherst: *Material Experiments in Landscape Architecture* and *Step and Flash: Creating a Piezoelectric Walkway.* Although focusing on smart materials, such as piezoelectric and photoluminescent technologies, the projects also present other innovative material investigations that explore electronics and their relationship to plants and other landscape media. Harnessing designers' abductive strategies of inquiry, with a focus on generating multiple possible explanations (Shearer, 2015), these courses engaged both design and non-design students in the development of innovative material prototypes demonstrating potential applications in outdoor spaces.

Step & Flash

Step & Flash: Making a Piezoelectric Lighted Walkway, was a multi-disciplinary course taught by University of Massachusetts Amherst landscape architecture and electrical and computer engineering faculty, Carolina Aragón and David McLaughlin during the spring semester of 2017. The course, open to all students, integrated art, design and technology by bringing together expertise from multiple fields to create a functioning piezoelectric lighted walkway. Piezoelectric technology is commonly used in energy harvesting by transforming vibration into electricity. While multiple applications have been developed for its use at the MEMS (microelectromechanical) scale and nano scale, its applications at the macro or mesoscales have been limited (Toprak and Tigli, 2014). In response to this, the course explored the potential for piezoelectric technology to create an engaging art installation that harnessed biomechanical energy using footsteps to create light through an affordable and easy to build walkway for campus.

The course was inclusive of students' backgrounds and abilities, understanding that students' range of expertise in electronics and design could vary from novice to expert. As such, the course included both beginning and advanced design and electronics students and was directed by faculty members—both experienced in their field, while relatively inexperienced in the other's field. Thus, initial exercises and introductions were designed to be accessible, demystifying both fields by generously employing a common language and creating a receptive environment.

Initial exercises were designed to allow for student's individual engagement with the principles of electronics through hands on experimentation, while also tapping into the conceptual and creative interpretation of piezoelectricity through sketching. Creative visioning exercises were complemented by hands-on introduction to basic electronics principles, involving the creation of circuits and the measurement of power required to light LEDs. Subsequent activities involved measuring the electrical output of a piezoelectric transducer in order to assess whether it could power an LED (Fig.1).

Students engaged in two ways to evaluate the performance of the piezoelectric transducer: measuring the electrical output using a digital multimeter (DMM) while tapping the transducer, and directly connecting an LED to the transducer. Students using the DMM realized that tapping alone would not provide the necessary power to light the LED unless the electric charge was stored and accumulated in a battery. Students who directly connected the piezo to an LED were more inclined to seek alternatives to tapping to make the LED light work. It was quickly established that by making the piezoelectric vibrate by rubbing it against a rough surface, such as a rock or a screw, it could light an LED.

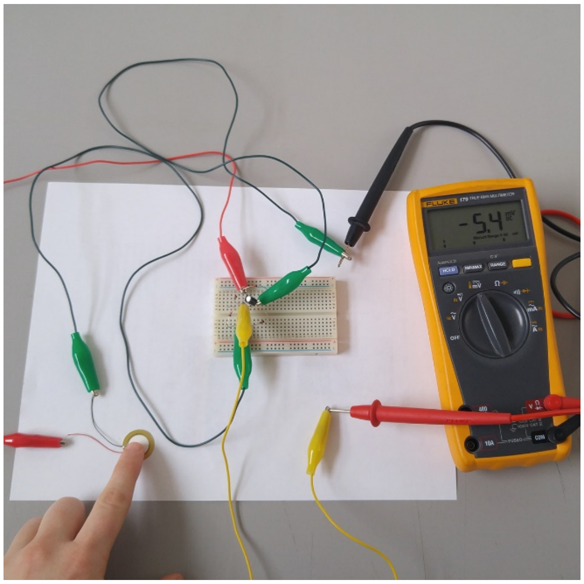

Figure 1 Piezoelectric transducer test using digital multimeter. Photo: Ashley Kaiser

Figure 2 Experimentation with tops and salad spinner. Photo: Ashley Kaiser

The discovery of light brought about by friction, led to the creation of early prototypes that investigated ways to make the piezoelectric transducer vibrate in response to foot pressure. This led to several prototypes containing piezoelectric transducers inside a "sandwich" of wooden boards separated by springs which would cause the piezo to be vibrated as it touched the surface of screws or sandpaper. These early prototypes made apparent many of the challenges of this configuration: the piezo transducer could be easily damaged as its surface was eroded through friction, and the springs provided an unstable system. The investigation took a turn away from springs and looked at toy tops for inspiration on mechanisms that could spin when pressed downward. This research led to the creation of two prototypes: one which modified a salad-spinner, and a custom-designed mechanical system transform vertical pressure into a spinning motion (Fig. 2). The salad spinner was reconfigured to house fins that would rotate and make the piezoelectric transducer vibrate. The system was incased in a box and LEDs were installed on the surface: when the button of the salad spinner was pressed, the spinning action vibrated the piezo transducers, which in turn powered the LEDs. Although this prototype demonstrated the viability of the concept, it did not provide a promising configuration for a tile, as it could not support the weight of a person, was not accessible, and was too expensive. In a similar fashion, the custom designed mechanism for creating spinning motion from pressure, had many challenges. Designed by the most experienced design and electronics students, the system was almost exclusively made of custom 3D printed parts. As such it was highly complex, expensive, and time-consuming to build. Although a valuable development that could contribute to future product development, for the purposes of the exercise, it proved too complex to be completed or implemented to demonstrate its potential.

Alternatively, the approach taken by the students with the least design experience led to the most effective prototype. This approach looked at alternative "low-tech" ways of vibrating the disc, turning away from the original concept of pressure created through walking. In this prototype piezoelectric transducers were inserted at the end of dowels, which were vibrated or strummed by hand (Fig. 3). Using a simple wood frame and dowels, the Piezoelectric Strummer was developed to respond to human touch, effectively lighting up two LEDs per dowel (Fig. 4).

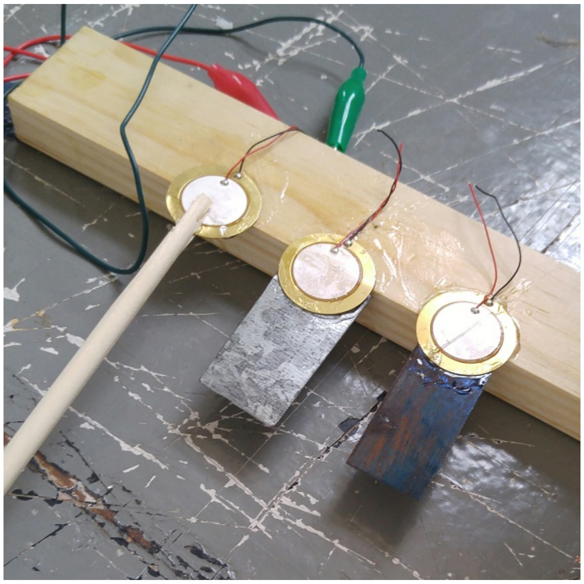

Figure3 Piezoelectric transducer strumming prototype. Photo: Nick Hewitt

Figure 4 "Piezoelectric Strummer." Photo: Nick Hewitt.

The *Step & Flash* course demonstrated the value of direct material experimentation in the pursuit of technological and design innovation. Calculations of the performance of piezoelectric technology on paper were surpassed through direct engagement, such as when the transducers were vibrated against a rock. By continuously developing and testing prototypes, major advances were achieved. Additionally, limitations of time, materials, available technology, and even expertise in both design and electronics fields, also led to innovation. These limitations helped reframe the problem and redirected the course of exploration into the search for simple attainable solutions. This proved to be a highly valuable approach, as it demonstrated a better suited scale and approach for interaction with the piezoelectric transducer. By lightly touching, rather than stepping on the technology—which generated additional challenges requiring energy, materials and technology to overcome—a better design application was developed.

Material Experiments in Landscape Architecture

The next set of examples demonstrating the use of smart materials and electronics in landscape architecture pedagogy come from the *Material Experiments in Landscape Architecture* course at the University of Massachusetts Amherst. Although the course is intended for graduate and upper level undergraduate landscape architecture students, it is also open to students with no extensive design experience in the Sustainable Community Development program and other fields. The course introduces students to innovative material approaches for landscape architecture through an overview of contemporary approaches, and provides students with an opportunity to engage in direct experimentation with materials. The course gives an overview of upcycling, ideas of reusing biological and technical nutrients (McDonough and Braungart, 2013); biomimetic materials, materials and innovation inspired by natural organisms (Benyus, 2002; Pawlyn, 2011); smart materials, materials with intrinsic technological functions (Addington and Schodek, 2005); and biodesign, which looks at the use of living organisms, plants, bacteria, and fungi for design applications (Myers, 2012). As such, the class yields a wide range of projects, including some that do not comfortably fit within the categories established. Examples include work with photoluminescent pigments, use of bioluminescent algae for indoor lighting applications, custom mycelium bricks, and a soil battery. Two recent projects that demonstrate original interpretations or applications of smart materials and electronics for landscape architecture uses include *Plant as Instrument* and *Orbs*.

Plant as Instrument

Plant as Instrument, developed by Melody Tapia and Jeremy Paradie, reveals how plants act as capacitors storing electric charge. Plants capacitance can be amplified when touched, by increasing their electric charge storing ability. The plant can be understood as a bucket that fills with water. The time it takes to fill is interpreted by the microcontroller as a frequency. When the plant is touched, it makes the bucket bigger thus increasing the need for a larger flow which is interpreted as a higher frequency. Designed with the help of an undergraduate electrical engineering teaching assistant, the project measured the capacitance of the plant and interpreted this measurement through sound frequency. The result is an interactive sound display of varying pitches emanating from a plant as it is being touched: this varies in the amount of skin contact with its leaves (Fig. 5).

Although creating sounds with plants has been previously accomplished by artists, as a pedagogical endeavor the exercise helps to brings a new awareness of plants as materials for their ability to be capacitors. Additionally, it points out to new relationships between electronics and plants, potentially paving the way for new applications in the landscape. Not only does this entail technological understanding but also demonstrates possibilities rich human interaction through sensory experience. It is not difficult to imagine the potential for interactive sound gardens created with this technology.

Figure 5 Plant as Instrument by Melody Tapia.

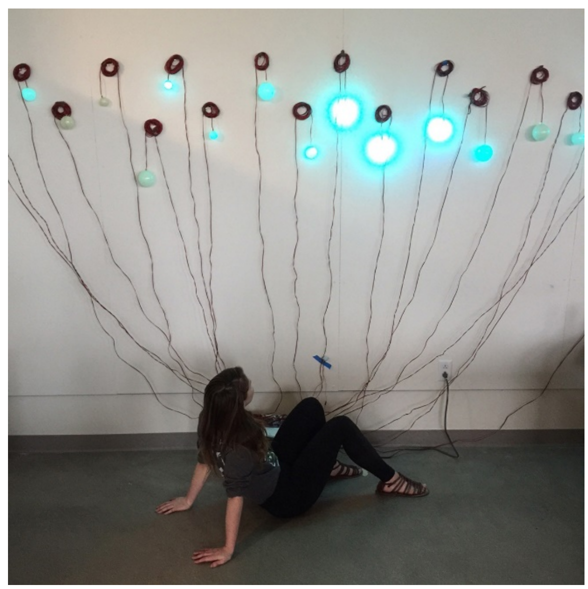

Figure 6 Orbs by Keira Lee. Photo: Prof. David McLaughlin.

Orbs

Orbs, developed by Keira Lee, was a temporary art installation that investigated the use of phosphorescent pigments to create an interactive experience illuminating a garden on campus (Fig. 6). The project took the challenge of the rapid decline in illumination exhibited by phosphorescent pigments after they are charged by sunlight and created a system to recharge the pigment as part of the design. Phosphorescent pigments were added to clear acrylic spheres containing ultraviolet LEDs. The LEDs were programmed using a microcomputer chip and were activated by an infrared sensor which detected human presence. The acrylic phosphorescent spheres were then installed along an existing screen providing flashes of aquamarine light which would slowly fade until activated again by human presence.

Although *Orbs* required electricity, thus was not self-powered, it presented a novel use of photoluminescent materials to engage audiences and invite participation. The project demonstrated how innovation can arise from understanding the limitations of materials. By embracing the decay in illumination of the pigment, *Orbs* developed a new application with a built-in recharge system that allowed it to create a new choreography of light (ranging from the initial burst of light to a slow fading of illumination). By incorporating motion sensors and programming the sequence by which the LEDs were activated, the project increased the material's ability for interaction, play, and capacity for activating an outdoor space at night. The experience of luminescence in the landscape as a response to human presence is not unprecedented. *Orbs* could be understood as a technological interpretation of a person wading through a bioluminescent bay, where the light-emitting mechanism of dinoflagellates creates sparks of light in response to motion.

Conclusions

Introducing design students to technological innovation through interdisciplinary hands-on exploration of materials has several benefits. One of the primary qualities of this type of work is that it provides students with opportunities for experiential learning through direct experimentation. As students engage with materials in their construction, they are able to receive direct feedback on whether their construction is working. This type of experience is especially valuable for landscape architecture students, who traditionally tend to rely on design methodologies developed through graphic and digital representation, rather than material experimentation.

Smart materials and electronics play a particularly important role in this type of pedagogical endeavor, as they are often able to provide direct feedback to indicate whether a system is working. A flash of an LED when strumming a dowel attached to a piezoelectric transducer, or a change in the sound pitch indicating a change in a plant's capacitance when a person touches its leaves, are some examples. This rapid feedback allows for experimentation to occur within the limited time of a semester, as opposed to the longer time-span associated with living materials and processes associated with the landscape architecture practice. Through the use of smart materials and electronics students can develop meaningful experiences through experimentation which can lead them to question established practices and become more avid innovators in their field.

In addition to receiving rapid feedback, it could be argued that the use of smart materials and electronics supports the pedagogical value of innovation by pursuing the unprecedented. In part because this field of materials is relatively new, and because its use in landscape architecture is limited, students are both challenged and motivated by the existing gaps of knowledge between technological research on the materials and its design applications. In pursuing the "ungoogable" the playing field between student and faculty is often-times levelled, allowing for creativity and insight to rise naturally throughout the process. Through this dynamic exchange, innovation is supported by fostering diversity of thought and approaches, while allowing students to take chances and fail in the process. Failure is then demystified and presented as feedback to inform the next iteration. Success is not necessarily the project outcome, but a framework for continued inquiry and confidence in the value of creative work as part of technological innovation.

In conclusion, this paper argues for the value of introducing design students to technological innovation through interdisciplinary exploration by presenting examples of work involving smart materials and electronics in two landscape architecture courses at the University of Massachusetts Amherst. These examples illustrate the pedagogical value of experimentation in advancing the role of designers in shaping future technologies and present a case for supporting a culture of originality within design education. By preparing students to travel through the uncertain path of innovation, they will be better equipped to creatively solve future design challenges.

REFERENCES

1. Addington, M. and Schodek, D. (2005). Smart materials and new technologies for the architecture and design professions. Boston: Architectural Press.

2. Aragon, C. (2016). ‘Upcycled furniture prototypes in public space design studio’ in National Conference on the Beginning Design Studio 32, California Polytechnic State University, San Luis Obispo, CA. pp. 25-32.

3. Benyus, J. (2002). Biomimicry: Innovation Inspired By Nature. New York: Perennial.

4. Cantrell, B. and Holzman, J. (2016). Responsive landscapes: strategies for responsive technologies in landscape architecture. New York, NY: Routledge.

5. Kim, H., Tadesse, Y., and Priya, S. (2009). ‘Piezoelectric Energy Harvesting’ in Priya, S., and Inman, D. (eds.) Energy Harvesting Technologies. Boston, MA: Springer, pp. 3-36.

6. McDonough, W. and Braungart, M. (2013). The Upcycle. New York: North Point Press.

7. Myers, W. (2012). Bio design: Nature, science, creativity. New York : Museum of Modern Art.

8. Pawlyn, M. (2011). Biomimicry In Architecture. London: Riba Publishing.

9. Shearer, Allan W. ‘Abduction to argument: a framework of design thinking’, Landscape Journal, vol. 34, no.2, pp. 127-138.

10. Toprak, A., & Tigli, O. (2014) 'Piezoelectric energy harvesting: State-of-the-art and challenges', Applied Physics Reviews, 1 (3). Available from: https://doi.org/10.1063/1.4896166.

11. Yglesias, C. (2014), The innovative use of materials in architecture and landscape architecture: history, theory and performance. Ipswich, MA: McFarland & Company, Inc., Publishers.