Building Technology Educator's Society

Volume 2019 Article 1

6-2019

Transdisciplinarity & Innovation: Smart Materials in Landscape Architecture Education

Carolina Aragon
caragon@larp.umass.edu

Transdisciplinarity & Innovation: Smart Materials in Landscape Architecture Education

Carolina Aragón
University of Massachusetts Amherst

Abstract

Designed landscapes are physical manifestations of natural, cultural, and technological forces. As such, they can physically embody technologies that support sustainable practices, and provide experiences that foster their cultural acceptance. However, the current focus of sustainable design in the landscape architecture profession has centered on ecological performance, largely ignoring the role of aesthetics and new material practices. In particular, the incorporation of energy-generating materials, such as smart materials, has remained largely unexplored. As a result, new methods for expanding engagement with materials and technologies are needed.

The need to address technological innovation while providing meaningful aesthetic experiences points to the importance of transdisciplinarity as part of the design pedagogy focused on sustainability. Transdisciplinarity challenges the conception of knowledge silos, the distinction between the objective and subjective, and embraces different ways of knowing that relate to different levels of reality.[1] In doing so, it presents opportunities for the integration of artful doing as part of technological innovation by simultaneously embracing the analytical, the emotional and the sensorial.[2]

This paper presents student work developed at the University of Massachusetts Amherst that explores the incorporation of smart materials for design applications. Landscape installations and prototypes developed in two courses: *Material Experiments in Landscape Architecture* and *Step and Flash: Creating a Piezoelectric Walkway*, will illustrate how transdisciplinary explorations led to technological innovations that reduce energy consumption while appealing to the senses. Based on this experience, an initial set of guidelines for introducing transdisciplinary practices in design pedagogy is presented. This paper calls attention to the value of transdisciplinarity as a way to engage technology and further engage students with a more holistic approach to sustainable design.

Keywords: Pedagogy, Landscape Technologies, Smart Materials

Landscape Architecture & Sustainability

Current practice and research in sustainability in landscape architecture, has largely focused on technologies based on living systems, such as stormwater gardens, to improve ecological performance. Analytical and science-based methods of understanding and exploration dominate the discourse. While more than a decade has passed since Elizabeth Meyer wrote about the "performance" of beauty in sustainable design as a way to contribute to the cultural acceptance of this type of work,[3] much remains to be explored in the way that aesthetics can support sustainability and resilience. The concept of beauty and aesthetic engagement as part of the design of sustainable landscapes, remains elusive. Furthermore, the problematic of aesthetics, which falls outside the realm of the science-based framework, runs parallel to the timid engagement with creative material explorations as part of the landscape architecture pedagogy. As a result, the profession may largely be missing opportunities for fully exploring its potential contribution to sustainable design.

While current discourse has brought attention to material exploration as a means to expand the profession's ability to address issues of sustainability and resilience, much remains to be explored. [4,5,6] In particular, design explorations that focus on the aesthetic and perceptual qualities of energy-generating materials and technologies are largely missing from the conversation. While exceptions—such as the work of artists like Dan Roosegaarde, and design proposals generated by competitions sponsored by organizations such as the Lands Art Generator Initiative—demonstrate the potential for artistic practices in engaging the public with renewable energy, much remains to be investigated in the profession and the classroom.

Smart Materials in the Landscape

Smart materials provide a unique opportunity for exploring issues of aesthetics and technical performance in the design of sustainable landscapes. Their ability to engage environmental phenomena—through their responsiveness— and to contribute to sustainable practices—through their capacity to generate electricity or reduce its consumption—uniquely positions them as a source for creating productive environments capable of creating meaningful aesthetic experiences. Addington and Schodek describe smart materials as those with the capacity to transform their physical characteristic as a response to surrounding energy fields. Their major distinguishing characteristics: transiency, selectivity, immediacy, self-actuation and directness, allow them to sense and respond to environmental events. 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.[7] 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 are often used as sources of renewable energy, such as photovoltaic panels, but also—as is the case for piezoelectrics—for energy harvesting, normally referred to the conversion of ambient energy into electricity.[8]

Landscapes—with their ever-present dynamic conditions of light, wind, and temperature—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 provide unique experiences through their indexical relationship with dynamic environmental forces and/or human interaction.

Transdisciplinarity in Design Pedagogy

Integrating new materials and technologies in landscape architecture pedagogy can be challenging. This in part due to the unprecedented nature of the work and also the potential lack of expertise in the technical aspects of the materials. This may call into question whether designers, as non-experts, may be able to contribute to technological innovation—and if so, how? Understanding this new role and finding significant ways for students to begin to explore new material practices—often requiring knowledge outside of the field—invites new methods of thinking about design pedagogy. Transdiscipinary pedagogical approaches may provide such a model by promoting and valuing multiple ways of understanding and knowing.

Transdisciplinarity embraces multiple views of the world, diverse ways of knowing, blurring distinctions between objective and subjective, and challenging traditional notions of knowledge silos.[9] It can be understood as the final step in which disciplines can relate to each other: *multidisciplinary* collaborations involve fields studying a problem independently from each other, *interdisciplinary* work shares methods to arrive at a mutual understanding of a problem, while *transdisciplinary* collaborations transcend the boundaries of disciplinary fields to bring multiple ways of knowing and relating to the world in ways that include and go beyond disciplinary knowledge.[10] This transcendence of disciplinary knowledge implies being sensitive in non-cognitive ways and linking analytical intelligence, with feelings intelligence and body intelligence.[11] Often times, transdisciplinary knowledge also embraces the contributions and understanding brought forth by non-experts.[12]

Transdisciplinary pedagogical practices are recognized as highly important for 21st century education as they are recognized to be essential in addressing “wicked-problems.” A characteristic of these practices is how they foster students’ abilities to creatively move between disciplines finding opportunities for cross-pollination of ideas between fields, at times in “indisciplined” ways that simultaneously require depth of knowledge in one field, while engaging other fields.[13] Transdisciplinary pedagogy is also linked to innovation as it has the potential to harness intuitive thinking skills—non-verbal, non-mathematical, non-logical tools often employed by creative individuals—into new ideas.[14,15] Innovation has the capacity to break through with old conventions and present new ways of knowing, experiencing, and engaging the world.

Architecture and urbanism—and by extension landscape architecture—have been identified as a fertile ground for transdisciplinary research as they operate both within the academic and non-academic, theory and practice, discipline and profession.[16] Likewise, design pedagogy has great potential to integrate transdisciplinary practices by working across fields, bridging expert and local knowledge, and by incorporating artistic practices and scientific research in design. However, while it could be argued that design pedagogy already supports both the emotive and bodily intelligence, with analytical intelligence –arguably through artistic explorations and incorporation of technological approaches—it may not fully explore the possibilities of promoting innovation by largely keeping these two approaches separate. It is not uncommon for artistic practice to occur during initial explorations to generate design concepts, while technology is often taught outside the design studio in seminar settings, as a fixed set of knowledge that is meant to be understood and implemented rather than challenged.

Step & Flash & Material Experiments

The following examples address pedagogical experiments by the author that explore ways in which landscape architecture education can provide opportunities for technological innovation through material experimentation. Two courses, taught at the University of Massachusetts, *Material Experiments in Landscape Architecture* and *Step and Flash: Creating a Piezoelectric Walkway*, will illustrate how transdisciplinary exploration and artistic inquiry led to technological innovations for prototypes involving energy exchanging smart materials. These explorations demonstrate how transdisciplinary pedagogy can foster increased opportunities for engagement with technology while simultaneously appealing to the senses and emotions.

Step & Flash: Making a Piezoelectric Lighted Walkway

Step & Flash was a one-credit course co-taught by landscape architecture and electrical and computer engineering faculty during the spring semester of 2017. The course, open to all students, sought to integrate art, design and engineering to explore novel applications of piezoelectric technology through interactive art installations. Piezoelectric technology is commonly used in energy harvesting by transforming vibration into electricity. 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.

From its inception, the course adopted methodologies supportive of transdisciplinary practices to gain a new and expanded understanding of piezoelectric technology. In addition to being introduced to principles of electronics and conducting research in related technologies, students engaged on artistic exercises to explore conceptual and creative interpretations of piezoelectricity, and hands-on experiments which provided direct feedback and understanding to further understand the technology. These different ways of exploring allowed students to access their emotive, bodily, and analytical ways of understanding. The “multiple ways of knowing” provided a strong base by which to explore new uses and interpretations of piezoelectric technology, increasing creativity and flexibility in the development of prototypes.

After initial creative visioning exercises and a hands-on introduction to circuits, students tested the performance of a piezoelectric transducer to produce enough electricity to power an LED. This was achieved in two ways: by measuring the electrical output using a digital multimeter (DMM) while tapping the transducer, and by 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, it could light an LED—knowledge that would not have been realized if only the DMM had been used to measure the output.

Fig. 1. “Sandwich” prototype testing.

The discovery of light brought about by friction, led to the creation of early prototypes that looked at creating a tile in which piezoelectric transducers were placed inside a “sandwich” of wooden boards separated by springs, which when pressed could vibrate the transducer against the surface of screws or sand paper (Fig. 1). 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 then took a turn away from springs and looked at three different alternatives by which to create vibration to cause the piezoelectric transducer to light LEDs.

Inspired by toy tops as a mechanism that could spin when pressed downward, two prototypes were created: one which modified a salad-spinner, and a custom-designed mechanical system which transformed vertical pressure into a spinning motion. 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 and focused mostly on the rotating mechanism rather than the whole system. Additional drawbacks included its complex, expensive, and time-consuming nature. Although a valuable development, it proved too complex to be completed or implemented to demonstrate its potential during the course of the class.

Fig. 2. Piezoelectric Strummer.

Alternatively, the third alternative, taken by the students with the least design experience led to the most effective prototype. This “low-tech” approach reconsidered the interaction of the human body with the piezoelectric transducer and realized that the pressure of walking may exceed the capacity of the transducer, causing the creation of complex systems to ameliorate the situation. As such, this approach explored creating vibration through a strumming motion with the hands. In this prototype piezoelectric transducers were inserted at the end of dowels, which were vibrated when strummed by hand. 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. 2).

The transdisciplinary methodologies employed in the *Step & Flash* demonstrated the potential of this pedagogical approach in engaging design and non-design students in the pursuit of technological and design innovation. By setting up the project as an art installation, the project required consideration of aesthetics and human interaction from its inception—in contrast to technological developments which focus on efficiency. Through its “multiple ways of knowing” or “multiple ways of exploring,” the project demonstrated how a technological innovation may be achieved through direct experimentation and “low-tech” approaches that can find new uses or applications of the technology in relationship to human interaction and the body.

Material Experiments

Material Experiments in Landscape Architecture is an elective course in the landscape architecture department that also welcomes students from all majors. The course seeks to expand knowledge about innovative materials in landscape architecture through experiential learning opportunities that bridge knowledge between art, design, and science. As such, it employs transdisciplinary pedagogical methodologies by positioning students in a role of being “indisciplined”—by taking their experience in design (or science) and applying it to create a new innovative application that embodies both technological knowledge and consideration of human experience. The course encourages students to explore different ways of learning and engaging with the materials, from traditional research, through hands-on experimentation, and the final development of art installations or prototypes demonstrating potential new applications. Four major topics are explored: upcycling, smart materials, biomimicry and bio-design. Student work in the past has included new applications for mycelium-based forms such as floating planters, the use of bioluminescent bacteria to assess toxicity in water, the use of upcycled plastic bottles to create a temporary greenhouse, exploration of the capacitance of plants to produce sound when touched using electronics, and prototypes exploring the incorporation of smart materials.

Fig. 3. Orbs photoluminescent art installation.

A notable project involving smart materials was *Orbs* (Fig. 3), a temporary art installation that investigated the use of photoluminescent materials to create an interactive experience illuminating a garden on campus. The project explored the material qualities of photoluminescent pigments and transformed what can be interpreted as a challenge —the rapid decline in illumination after the materials are charged by sunlight or artificial light—to create an opportunity for interactivity. The project consisted of clear acrylic spheres coated with photoluminescent pigments which housed ultraviolet LEDs. The LEDs were programmed using a microcomputer chip and were activated by an infrared sensor which detected human presence. The acrylic photoluminescent spheres were then installed along an existing screen on a campus garden and were activated by people walking by. When activated, the LED’s charged the photoluminescent pigment creating flashes of intense aquamarine light which would slowly fade until activated again.

The project demonstrated how innovation can arise from understanding the limitations of materials, and from a quest to embrace the human experience through aesthetic exploration. 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 fade of illumination).

Through the use of motion sensors, the project increased the material's ability for interaction, play, and capacity for activating an outdoor space at night.

Although *Orbs* required electricity and did not exhibit energy harvesting potential, it presented a novel use of smart materials in ways that engage audiences and invite participation. From a functional perspective, the use of photoluminescent materials could contribute to reduction in the use of electricity for nighttime illumination, while contributing to minimizing light pollution. By creating an engaging environment, the project presented new ways in which these materials could constitute landscapes that have a poetic quality alongside with a technological function.

Discussion

The experience gained by teaching these two courses has led to the formulation of an initial set of guidelines to introduce transdisciplinarity as part of design education.

1. *Ask for the unprecedented:* challenge students to create original projects that simultaneously investigate the technical properties of a material or technology while evoking a significant aesthetic experience on the observer.
2. *Encourage disciplinary diversity*: when possible, co-teach with faculty in other fields or support teaching assistants from other departments to aid students in overcoming technological challenges. Foster a culture welcoming of non-design students in the course.
3. *Be "indisciplined"*: encourage multiple processes by which to gain knowledge, moving across fields, and considering contributions from outside academia.
4. *Simultaneously pursue the functional and the experiential*: by encouraging students to explore the technical and aesthetic qualities of a project, they are positioned to engage with multiple forms of exploration requiring the analytical, bodily, and intuitive thinking.
5. *Abandon representation:* creating original projects involving technological and experiential innovation can only happen when directly manipulating materials. This direct experimentation leads to rapid feedback and the possibility for haptic engagement, increasing possibilities for innovation.

Conclusions

This paper argues for the value of transdisciplinary practices as part of design pedagogy supportive of the development of landscapes for resilience and sustainability. By encompassing the rational and the emotional, transdisciplinary practices can support the continued quest for technical innovation while allowing for the richness of the human experience to inform the shaping of our environment. As such, these practices are positioned to be particularly relevant in expanding the reach of design practice as it relates to technological innovation and promoting the design of sustainable landscapes in ways that address both technical performance and engagement by the public. In this role, designers have unique opportunities for humanizing and making technology accessible.

In particular, the findings of these paper point to the potential for further exploration of the use of smart and energy-generating materials in landscape architecture and design curricula through transdisciplinary pedagogical practices. These materials are not only relevant for their ability to generate electricity or reduce its consumption, but also because of their intrinsic ability to react to environmental stimuli. As such, they provide a rich medium by which to provide students with "different ways of exploring" and "different ways of knowing" through scientific research, experimentation, hands-on exploration, and creative visioning.

In addressing challenges set forth by climate change, landscapes that can embody technological solutions become resilient, not only through their physical performance but through their ability to foster ongoing creativity and reflexivity in their users. Transdisciplinary practices in design education can foster the necessary skills and experience for future designers to become more active participants in creating innovative applications for technologies and materials in the landscape. These new practices and landscapes may contribute to the necessary cultural shifts required to address current and future environmental challenges.

References :

[1] Nicolescu, Basarab. *Manifesto of transdisciplinarity*. Suny Press, 2002.

[2] Dieleman, Hans. "Transdisciplinary artful doing in spaces of experimentation and imagination." *Transdisciplinary Journal of Engineering & Science* (December, 2012): 44-57.

[3] Meyer, Elizabeth K. "Sustaining beauty. The performance of appearance: A manifesto in three parts." *Journal of Landscape Architecture* 3, 1(2008): 6-23

[4] Yglesias, Caren. *The Innovative Use of Materials in Architecture and Landscape Architecture: History, Theory and Performance*. McFarland, 2014.

[5] Margolis, Liat, and Alexander Robinson. *Living systems: innovative materials and technologies for landscape architecture*. Walter de Gruyter, 2007.

[6] Cantrell, Bradley E., and Justine Holzman. *Responsive landscapes: strategies for responsive technologies in landscape architecture*. Routledge, 2015.

[7] Addington, Michelle, and Daniel Schodek. *Smart Materials and Technologies in Architecture: For the Architecture and Design Professions*. Routledge, 2012.

[8] Kim, Hyunuk, Yonas Tadesse, and Shashank Priya. "Piezoelectric energy harvesting." In *Energy Harvesting Technologies*, pp. 3-39. Springer, Boston, MA, 2009.

[9] Nicolescu, Basarab. *Manifesto of transdisciplinarity*. Suny Press, 2002.

[10] Ibid.

[11] Nicolescu, Basarab. "Transdisciplinarity: past, present and future." *Moving Worldviews: Reshaping sciences, policies and practices for endogenous sustainable development, ETC/COMPAS, Leusden* (2006): 142-166.

[12] Nowotny, Helga, Peter B. Scott, and Michael T. Gibbons. *Re-thinking science: Knowledge and the public in an age of uncertainty*. John Wiley & Sons, 2013.

[13] Mishra, Punya. "Rethinking technology & creativity in the 21st century: Crayons are the future." *TechTrends* 56, no. 5 (2012): 13-16.

[14] Mishra, Punya, Matthew J. Koehler, and Danah Henriksen. "The seven trans-disciplinary habits of mind: Extending the TPACK framework towards 21st century learning." *Educational Technology* (2011): 22-28.

[15] Root-Bernstein, Robert, and Michele Root-Bernstein. "Intuitive tools for innovative thinking." *The international handbook on innovation* (2003): 377-387.

[16] Doucet, Isabelle, and Nel Janssens, eds. *Transdisciplinary knowledge production in architecture and urbanism: Towards hybrid modes of inquiry*. Vol. 11. Springer Science & Business Media, 2011.