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OPINION ARTICLE

A creative collaboration between the science of ecosystem restoration and art for sustainable stormwater management on an urban college campus

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This article presents an interdisciplinary, on-campus, student project, titled "The Rain Project" that I designed as an urban ecosystem restoration model as well as a collaborative pedagogical approach between ecological science and art at George Mason University (GMU), Virginia, U.S.A. A group of students from several disciplines (e.g. environmental science, art, civil engineering, biology, communication, and film/media) participated in designing and constructing a floating wetland for a campus stormwater pond as part of sustainable stormwater management. The Rain Project has numerous implications for college education, scholarship, and service while presenting a novel way of building a sense of community among undergraduate students for ecological awareness and literacy. The work of Jackie Brookner, a renowned eco-artist who worked extensively on stormwater, and its relevance to the project is discussed. I strongly suggest the need for linking art and the science of ecosystem restoration to best obtain improvements in much-needed communication for the success of community participatory restoration projects. I also believe that this kind of interdisciplinary, campus project can facilitate the changes we need to train higher education students to be able to both think differently and communicate effectively. The Rain Project introduced students to new learning strategies that connected "systems thinking" with art, ecological science, and restoration practices.

Key words: ecosystem restoration, floating wetland, interdisciplinary education, Jackie Brookner, The Rain Project

Implications for Practice

- Green infrastructure such as floating wetlands can be built and used for sustainable stormwater pond management on college campuses, not only for water quality benefits but also for an opportunity to both train the next generation of ecologically literate citizens and form a sense of community among students across disciplinary boundaries.
- There is a great need for linking art and the science of ecosystem restoration to best obtain improvements in much-needed communication to adjust cultural attitudes toward sustainability and interdisciplinary education.

Introduction

We have developed our own, more specialized fields over the past century with little consideration of, and mechanisms for, integrating our findings and learning, and sharing them across disciplinary boundaries. Although interdisciplinary education and scholarship are much needed in contemporary academia to prepare our students to be able to understand and build solutions for the complex problems we currently face, the language and professional cultural differences make it difficult to do so. In addition, the traditional structure or organizational cultures of colleges and universities in the United States still have many barriers that may discourage or even prevent interdisciplinary collaboration across departmental boundaries.

Recently, there have been some progresses in interdisciplinary research and teaching in higher education with an increasing number of students working in the research projects that require interdisciplinary partnership (Hunt & Thornsbury 2014; Jacob 2015). It has become a commonplace to do team teaching and to have students from various departments in a class at the undergraduate level (Jacob 2015). Recent shifts in the use of teaching technologies may provide a new opportunity to collaborate between different disciplines through a variety of co-teaching approaches (Loewer 2012; Jacob 2015). There has also been an increase in interdisciplinary degree offerings among the common interdisciplinary fields including environmental science and studies (Jacobs 2014). It seems, however, still fairly difficult to bring faculty members from various departments to instruct and train students in interdisciplinary fields of study (Jacob 2015).

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There are a number of benefits in art-science collaboration in education. First, art, and/or artistic endeavors can involve students in exercising their creativity, which will contribute to successful training of innovative scientists, for instance. Both artists and scientists share a common drive to depict and analytically explain our experiences, and represent in varying forms the outcome of imagination (van't Hoff & Springer 1967). Innovation in science often is linked to urges to express oneself artistically (Gurnon et al. 2013). Second, many artistic processes are founded in intuition. Involving art in science education can help students to enhance their intuition because creativity and intuition are critical elements in scientific discovery and advance (Gurnon et al. 2013). It is only through interdisciplinary collaboration, particularly in education and scholarship, which we may be able to train a generation of system thinkers who can navigate through the disciplinary boundaries to seek answers to big, pressing questions such as environmental degradation and global poverty (McCoy & Gardner 2012). Restoring impaired ecosystems requires effective communication skills to help build the stewardship capacity of the communities involved. I believe that art can facilitate such communication more effectively.

I started a new initiative called "EcoScience+Art" (ecoscienceplusart.wordpress.com) at George Mason University in 2013, collaborating with a faculty member who is an eco-artist. The main part of the initiative was a lecture series by invited speakers, and has since expanded to include other activities, such as local community group participation, films, and a hands-on student project. To date, we have had five speaker series events, featuring pioneer eco-artists Patricia Johanson, T. Allan Comp, Jackie Brookner, Stacy Levy, Lillian Ball, and Betsy Damon (https://ecoscienceplusart.wordpress.com/speakers/), all of whom and whose work collectively provide outstanding examples of collaboration between art and ecological sciences. Their collective work showed how art can enhance correspondence and understanding for an ecosystem restoration project at a variety of scales, both ecologically and culturally.

The Rain Project

Early in 2014, I designed "The Rain Project," a student participatory project with a project-based learning approach aiming to develop innovative interdisciplinary education and scholarship. The goal of the project was to raise awareness of stormwater issues, and to showcase an interdisciplinary, year-long (Fall 2014 through Fall 2015) collaboration activity for the campus community.

I designed this project to be carried out by undergraduate students from a number of different disciplines (e.g. art, biology, environmental science, communication, engineering, and film/media) who worked as a team to design and implement green infrastructure for sustainable stormwater management on the campus. We live in an era of climate change, and climate change is a story of water, especially rainwater. Water is also a big part of sustainability. Many U.S. cities have recently turned to sustainable initiatives, looking out for new techniques, and innovative sustainable infrastructure that mimics the way nature collects and cleans water. A campus-wide student leadership group was formed through one-on-one interviews to engage undergraduate students of different disciplinary backgrounds in the project. The sustainable infrastructure for the project was a "floating wetland" (Chang et al. 2013; Marimon et al. 2013; Borne 2014; Wang et al. 2014) that intended to improve water quality in a stormwater pond by removing nutrients (e.g. nitrogen and phosphorus). Too much of these nutrients often leads to algal blooms and degrades water quality in many waterways in the United States (Mitsch et al. 2001). Removal of nutrients from the stormwater can be provided by the large surface area of hanging roots of wetland plants that trap and filter sediments and by bacterial communities living in the roots (e.g. denitrifying bacteria) that facilitate a biogeochemical process (e.g. denitrification).

An Inspiration for the Rain Project — Urban Rain by Jackie Brookner (1945–2015)

Although I was designing and preparing for the Rain Project, I made a conscious effort to thoughtfully and strategically align the theme of the lecture series of the EcoScience+Art for Fall 2014 with stormwater issues. I discovered the works of Jackie Brookner and have admired her work on the issue of stormwater for some time. Her work was a perfect fit for educating and inspiring the students for the floating wetland project, and something worthy of sharing with a general audience. Brookner's book "Urban Rain: Stormwater as Resource" (Brookner 2009) was especially instrumental in introducing my students to a multidisciplinary approach to stormwater issues. Two amazing pieces of artwork—one was a large steel fingerprint and the other a rectilinear-type slate—were displayed in the book (Brookner 2009). Both structures are located at the new Roosevelt Community Center building near Coyote Creek, in San Jose, California. These installations were designed to collect and filter rainwater from the roof of the community center (Brookner 2009). Brookner's "biosculptures" (Brookner 2009) were also known to reduce the volume, and improve the quality of the rainwater, before it entered the storm sewer system. The book delivered excellent examples of stormwater art projects that provided not only aesthetics but also ecosystem functions.

Prior to officially inviting her to the GMU campus for the lecture series I arranged a trip to New York City in the summer of 2014 to meet Brookner in person to learn more about her thoughts and work. She welcomed me warmly into her home/studio where she had lived for the past 40 years. We spent a few hours together that afternoon talking about her work and sharing our thoughts on ecosystem restoration and experiences with environmental stewardship. Although I have had a number of experiences working with people across many disciplines, her advice on the interdisciplinary work for ecosystem restoration was informative and thought-provoking. Jackie really saw art as a tool for putting cultural, social, historical, and geographic contexts in any kind of ecosystem restoration work to facilitate much needed engagement and participation of local communities. We shared the idea that art could be instrumental for furthering ecological science, restoration practices, and their communication. In addition, art could also assist us to contextualize the backgrounds and outcomes of restoration projects, thus facilitating ways to creatively communicate those with local communities. I believe that art will also help students to cultivate "ecological literacy" (Orr 1992), the ability to understand the basic principles of ecology and to live accordingly (Capra 2007). Ecologically literature citizens should be better able to understand our relationship to the larger context of life. It truly was such an uplifting moment for me to meet a kindred spirit who provided so much encouragement and support for the Rain Project that I felt an immediate connection with her.

The delightful yet inspirational conversation Brookner and I had also addressed "systems thinking" to be able to navigate the complex issues and ideas relating to environmental degradation and problems. Jackie told me that Thich Naht Hahn was one of her spiritual sources and inspirations for her work. I myself have been also familiar with his zen Buddhist teachings. Thich Naht Hahn has written about "interbeing" especially at the beginning of his book, titled "The Heart of Understanding" (Nhat Hanh 2009). Interbeing is a word that you cannot find in the dictionary. However, if we combine the prefix "inter-" with the verb "to be," we have a new verb, *inter-be* (Nhat Hanh 2009). It conceptualizes the importance of realization that everything is connected to one another, the very core idea and teaching of system ecology. It means that there is no independent self—that the perception of self, of "me," of "mine," is an illusion. This indicates the very nature of "dependence" and "connectedness" of everything, which is deeply embedded in systems thinking. Although Brookner and I came from different disciplinary angles, having the conversation on these was invaluable to me. It validated my ideas for the urgent need of educating and sharing systems thinking and approaches to the practices of ecosystem restoration. Brookner's whole systems approach signified how social, cultural, and ecological aspects of ecosystem restoration could be integrated. This resonated with my approach as a system ecologist to look at the linkages/interactions between socioeconomic and ecological/environmental realms.

Jackie's later talk for the EcoScience+Art lecture series was titled "What does the rain have to say"? Unfortunately, Jackie could not make it to the scheduled talk due to her long battle with lung cancer. Just 5 days before the scheduled seminar, I received an urgent phone call to cancel her visit to the campus. It was quite difficult to find someone who could deliver Jackie's message to the students at the last minute; however, we worked together to replace her with Stacy Levy, another great rainwater eco-artist who created "Spiral Wetland" (http://www.stacylevy.com/installations/spiral_wetland.php), a large floating wetland based on the "*Spiral Jetty*" by Robert Smithson, one of the most enduring of the land art pieces, located in an urban lake in Fayetteville, Arkansas. I invited Jackie to be virtually present with the audience during the event. Despite her deteriorating health, she produced a short video with the help of artist Lenore Malene. Her message can be viewed at the EcoScience+Art website (https://ecoscienceplusart.wordpress.com/media/). I was extremely grateful for her participation. Jackie passed away 6 months later in May of 2015. I was deeply saddened to have lost the opportunity to sit down with her again to talk about all the progress of the Rain Project I have been making with students and how much students were learning from it; she would have been excited to hear this. Brookner's art projects, and her contribution and inspiration to ecological restoration that deeply resonated with me, are well summarized in her own words (SER Newsletter 2015):

> Long-term success of ecological restoration, at all scales from the local to the global, necessitates transformation of the dominant ways humans understand, behave, value, and relate to natural processes and ecosystems. Artists and scientists can do more together to affect positive transformation than either can do separately. It is not a matter of the scientists providing the hard-core research and artists the soft outreach; rather, the dynamics engendered in the space between disciplines is full of information necessary to solve complex problems at the systemic level …

Progress of the Rain Project

Progress in this project involved several sessions of design and discussion for the creation of our own model for a floating wetland, mainly through my undergraduate research and scholarship-intensive class, *Ecological Sustainability*. Held in the spring semester of 2015, the design of a floating wetland started with a free-hand drawing (Fig. 1). I incorporated freehand sketching by providing the students with color pens and sketchbooks. Today, many universities, including engineering schools within universities, have abandoned such manual exercises entirely or focus only on computer-generated drawings. Many students were initially not comfortable with sketching or drawing. Comments included, "Oh, I can't draw," "I am not particularly good at it," or "My brain doesn't work that way." Many students described themselves as strictly "right-brained" or "left-brained," with the left-brainers bragging about their math skills and the right-brainers touting their creativity. The left and the right brains might have different circuitry, but according to recent neuroscience research (Nielsen et al. 2013), the two hemispheres need to interact to develop a fully developed and functioning brain. I strongly believe that being able to quickly sketch can be a tremendously useful and powerful tool when used to communicate an idea.

The students went through the several steps that it takes to conduct a scientific research project, building hypotheses, and/or specific questions, to discover what was going to work for each component of the floating wetland. The structure (rigidity and buoyancy) and function (water quality improvement) of the floating wetland required intense literature review

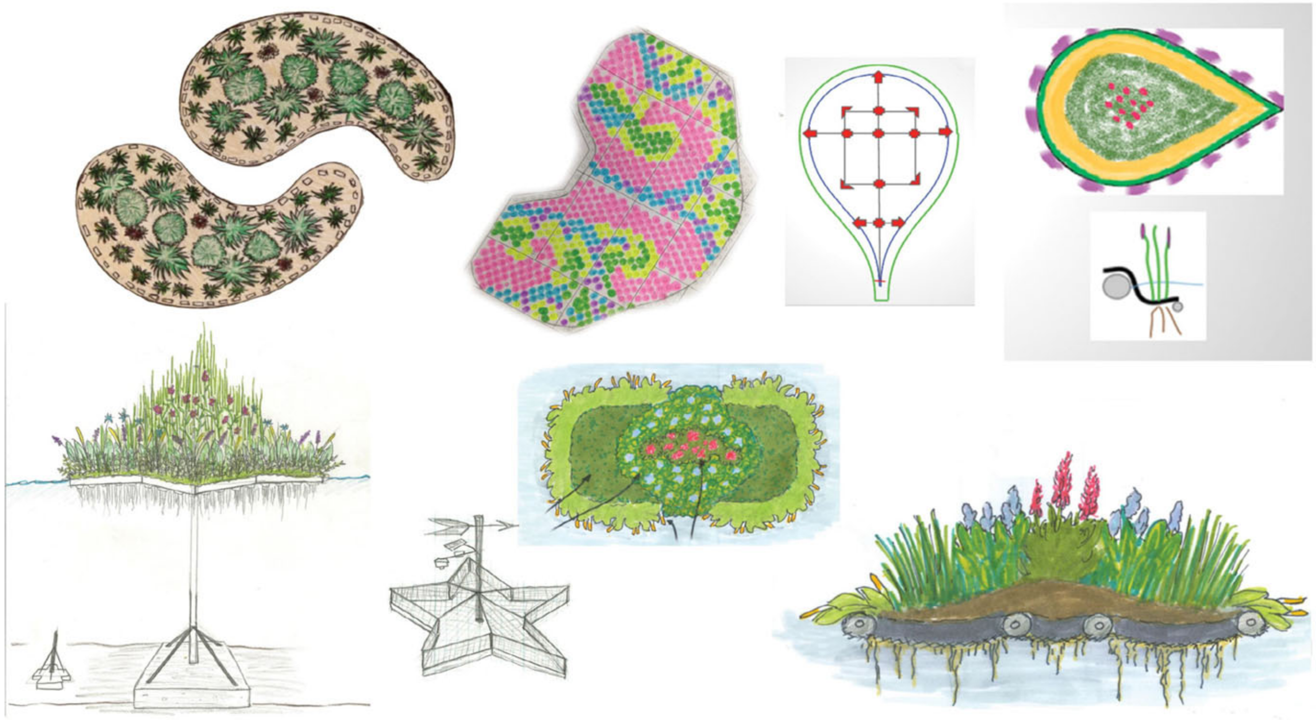

Figure 1. Student drawings for various forms/designs of a floating wetland and its planting scheme (drawing credit to the students in *Ecological Sustainability* class [EVPP378/BIOL379] of Spring 2015 at George Mason University).

and design considerations in hydrology (engineering-water flow, storm patterns, intensity, and duration), botany and/or biology (how tall each species grows and how different plant mixtures can coexist to provide maximum power of water quality function), water chemistry of rain and ponds, living ecology (aquatic biota), and functional aesthetics. Along with these were many discussions of cultural and historical perspectives regarding stormwater management. These types of activities exposed both art and science students to intense research inquiry and hands-on experiential learning (Lakoff & Johnson 1980; Varela et al. 1993). We chose a human kidney as a shape for our floating wetland, as wetlands have often been called "kidneys in the landscape" for their role in filtering contaminants and cleaning water passing through them. This also paid homage to Olentangy River Wetland Research Park, the place where I got most of my training as a wetland ecologist in my early days while working on the famous two kidney-shaped wetlands (see Ahn & Mitsch 2002). The students worked with me also to come up with details for planting of native wetland plants known for their abilities to take up nutrients. We did a small-scale simulation in early April with a small floating base (approximately $6\,m^2$) as a proof of concept before we took on a full-scale installation (approximately $54\,m^2$) for two kidneys. Through this experience, we better gauged the logistics and preparation needed for the full-scale construction and installation. We also surveyed and monitored the target campus stormwater pond for its depth, water flow pattern, and physicochemistry regularly while developing a post-installation monitoring plan.

This kind of project involved students in strong collaborative training to work as a team to deliver the outcome, which I believe is an important element for any ecosystem restoration practice. The opinions and voices of science students were not necessarily in agreement with those of art majors who focused more on the aesthetics and resulted in heated debates about the functionality of the floating wetland during several design sessions. Biology/ecology majors designed it for a biodiverse habitat to be whereas engineering majors demanded to plant one species known to be the best in removing nutrients from water, for example. They told me that they learned how to communicate with one another to work together, and how to reach an agreement to move forward with the project to produce an outcome regardless of their differences in backgrounds, perspectives, and opinions. We installed the full-scale floating wetland on 12 May 2015 (http://newsdesk.gmu.edu/2015/05/students-launch-floating-wetlands-on-mason-pond/). The story of the Rain Project was delivered to the Washington D.C. metropolitan area on 22 May 2015 via local news coverage (http://www.nbcwashington.com/video/#!/news/local/Students-Say-Pond-Class-at-GMU-Really-Floats-Their-Boats/304771321). Figure 2 shows several scenes of student activities on that day.

Correspondence as a Key to the Success of Ecological Restoration Project

All students who participated in the project presented their research outcomes to a lay audience, local high school students,

Figure 2. Installation and launching of the floating wetland for the Rain Project on 12 May 2015 on the Mason Pond at George Mason University (photo can be credited: Evan Cantwell, Creative Service of George Mason University).

immediately after we launched the floating wetland on the pond. I coordinated this with the science teacher of the school several months before the installation. For the past few years, I have been applying “near-peer presentation” as a useful tool for student training in science communication (Ahn 2015; Bestelmeyer et al. 2015). It is usually easy for students to explain things to their peers with whom they studied together all throughout the semester, but presenting their project results to near-peer group students (especially those who came with no prior knowledge about the subject matter) required students to translate their results into more common or lay terms (Ahn 2015). To successfully accomplish this, the college students needed to revisit and relearn some of the basic underlying concepts and outcomes of their research projects before explaining them to the near-peer group. This activity seemed to help the students to consolidate and reinforce their learning experiences, being an effective means of scholarship training for college students.

In all fields of natural sciences, there is a current call for training graduate students as “Renaissance scientists”—individuals with strong disciplinary expertise, in addition to the ability to communicate effectively about science to diverse audiences (McBride et al. 2011; Bestelmeyer et al. 2015). Planning and achieving desirable outcomes of any ecosystem restoration project necessitate our ability to get communities to agree with us to move forward, a process that demands great negotiation skills. Effective correspondence is a necessary ingredient to facilitate collaboration across the disciplines to restore complex ecological and cultural systems we often face in the practice of ecosystem restoration.

Final Thoughts

Artists offer communities a cultural and visual context for engaging scientific data and principles that can assist with modifying behaviors, ultimately transforming our environmental stewardship (Abbott & Rutherford 2005; Watts 2010). I see art as a catalyst for the changes we need to make to close the gap that only science-based ecological restoration work has been unable to fill. It is truly about furthering restoration ecology and developing innovative education strategies. To be truly successful, ecological restoration should be elevated beyond the technical to include the social, cultural, and/or experiential considerations (Watts 2010). Adding art to ecological science as a whole will facilitate communication among stakeholders for both planning restoration projects and evaluating the outcomes of those projects. We have seen numerous ecological restoration projects that were not well connected to sound ecological principles due to the lack of correspondence often end up as failures (Perring et al. 2015). Creating the rationale and effective discourse in decision-making required for successful ecological restoration also requires "art" as a critical element of that process. We must encourage, and strategically position, scientists to work directly and more actively with artists on ecosystem restoration projects. And that can start from a college campus.

The current crisis of the environment is a crisis of education. There is still a great lack of correspondence and collaboration between different disciplines on college campuses where fundamental training and schooling should occur for those who will work on a variety of future ecosystem restoration projects. We have programs and departments to teach specialized courses but I cannot say that we know exactly how to educate a "rigorous generalist" (Kineman & Poli 2014). People often think that generalists are failed specialists, but a rigorous generalist can be a scientist, an engineer, an artist, or a humanist (Kineman & Poli 2014) capable of working with others to integrate seemingly disintegrated parts into a collective whole that can be greater than the sum of those parts. I believe that art should be incorporated in undergraduate curricula and pedagogy of various college disciplines. The Rain Project appeared to cultivate "ecological literacy" among the participating students. Students will be able to better understand our relationship to "the larger context of life" with stronger communication skills through the collaboration experiences they had in this project. I hope that the approaches taken in the project can be adopted in many other college campuses in the United States with adaptation and modification.

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