Art-Science for Sustainability

by

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ABSTRACT

The complexity and interconnectedness of sustainability issues has led to the joining of disciplines. This effort has been primarily within the sciences with minimal attention given to the relationship between science and art. The exclusion of art is problematic since sustainability challenges are not only scientific and technical; they are also cultural, so the arts, as shapers of culture, are critical components that warrant representation. In addition to contributing to the production of culture, arts have also been credited as catalysts for scientific breakthroughs; thus it stands to reason that understanding art-science integration will benefit sustainability's focus on use-inspired basic research. I focus on placing art and science on equal footing to enhance understanding of how individual artists-scientists and collaborative artist-scientist teams creatively address sustainability challenges. In other words, I address the question "What does it take to develop high functioning artists-scientists or artist-scientist collaborations?"

To answer this question, I used a multipronged approach to triangulate a richer understanding of *what* art-science synthesis offers sustainability and *how* it functions. First, I performed an historical analysis of a maladapted wilderness aesthetic and turned to the work Aldo Leopold – an exemplar of an artist-scientist – for a new sustainability aesthetic. Then, I engaged in an individual contemporary art practice, culminating in a gallery exhibit, which displayed ecologically-informed work from a three year study of my backyard. Finally, I conducted small group research of artist-scientist teams tasked with developing interpretive signage for the Tres Rios wetland site. For this final element, I collected survey, wearable sensor, and ethnographic data.

Through this composite research, I found that successful art-science practices require significant energy and time investment. Although art-science is most intensive in an individual practice where the person must become “fluent” in two disciplines, it is still challenging in a group setting where members must become “conversational” in each other’s work. However, successful art-science syntheses appear to result in improved communication skills, better problem articulation, more creative problem solving, and the questioning of personal and disciplinary mental models. Thus, the outcomes of such syntheses warrant the effort required at both the individual and collaborative level.

DEDICATION

This is dedicated to you students who struggle. Struggle because the color of your skin, socioeconomic status, cultural upbringing, or all three are out of step with your peers; very few understand the sacrifices you make to finish the race. I feel you.

This is dedicated to you graduate students who struggle. Struggle because your dissertation is more than a requirement for a degree – you treat it as an opportunity to produce something meaningful and creative in the world. Others may not understand what you're doing or why. I feel you.

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CHAPTER 1

INTRODUCTION: SEARCHING FOR CONSILIENCE BETWEEN THE ARTS AND SCIENCE

Introduction and Problem Statement

"The greatest enterprise of the mind has always been, and always will be, the attempted linkage of the sciences and humanities. The ongoing fragmentation of knowledge and resulting chaos in philosophy are not reflections of the real world but artifacts of scholarship." ~ E.O. Wilson

There is an overwhelming consensus in the sustainability literature that interdisciplinarity is a cornerstone of addressing sustainability challenges. However, the emphasis has been on interdisciplinarity in the sciences, rarely including the arts and humanities (Fischer et al., 2007; Kagan, 2011). In fact, two of the seminal sustainability reports, the Brundtland Report (WCED, 1987) and the National Research Council's "*Our Common Journey"* (1999), which focus on transitioning towards more sustainable futures, make no mention of the arts and humanities. Sustainability scientist, William Clark, notes that the field of sustainability science is "defined by the problems it addresses rather than by the disciplines it employs" (2007, p. 1737), suggesting that sustainability science is its own interdisciplinary field. However, the fact that sustainability challenges are scientific, technical, and cultural implies that the arts and humanities, as shapers of culture (Gibbons et al., 1994; Kagan, 2011), are a critical component and deserve representation. It stands to reason that understanding how the arts and sciences can be integrated to help solve human-environment problems will benefit sustainability's focus on use-inspired basic research (Clark, 2007; Kajikawa, 2008).

Therefore understanding how this synthesis can be facilitated both individually and collaboratively will contribute to use-inspired basic research focused on sustainability questions and emergent problems.

This dissertation focuses on the potential benefit of developing an interdisciplinary and integrative dialogue between the arts and sciences as an emerging method for enriching pluralistic perspectives for sustainability challenges. It specifically weaves together scholarship on ecological aesthetics (particularly the seminal work of Aldo Leopold), art practice, and analysis of the social factors that foster or hinder creativity in art-science collaborations. Addressing these seemingly disparate pieces is a way to simultaneously observe patterns in multiple dimensions and disciplines critical for developing a holistic and integrative approach to sustainability (Van der Leeuw et al., 2011). This dissertation addresses humanistic, artistic, and scientific approaches in an effort to integrate their unique patterns of thought.

Addressing the Wickedness in Sustainability Challenges

Scholars have pointed out the varied, often contextually based, definitions of sustainability. As a general concept, the meaning of sustainability is difficult to pin down; there are many different understandings that accent distinct dimensions of the idea (Newton & Freyfogle, 2005; Norton, 2005; Parr, 2009; Thompson, 2007). This challenge is mitigated (at least to some degree), however, when the focus moves from the abstract or conceptual realm to the arena of collaborative problem formulation and to the working through of practical sustainability challenges, including the identification of what are seen as "unsustainable" practices (Jamieson, 1998; Thompson & Whyte, 2012). What has been agreed upon is that sustainability challenges can be framed as *wicked* problems

(Kinzig, 2001; Miller, 2012; Norton, 2005, 2012; Thompson & Whyte, 2012). One of the reasons for this designation is that solutions must account for social, economic, and environmental challenges that cut across multiple scales and domains. As Jerneck et al. (2011, p. 72) point out, these "challenges are multi-scalar, multi-faceted and strongly interrelated in complex" and dynamic ways.

Planning theorists Horst Rittel and Melvin Webber (1973) first identified ten characteristics of *wicked problems* that suggested traditional scientific inquiry insufficiently addressed the complex socio-environmental challenges we faced. In his extensive work in the history, semantics, and epistemology of sustainability, philosopher Bryan Norton has taken those ten characteristics and nested them into four subgroups defined by: (a) the difficulty of problem formulation, (b) noncomputablity of solutions, i.e. no identifiable single best outcomes, (c) nonreapeatablility, i.e. no one-size-fits-all solutions, and (d) temporal open-endedness, i.e. there are repercussions to actions that will be difficult to fully identify (Norton, 2005, 2012).

The difficulties can quickly become compounded. For example, highly complex, large-scale socio-ecological problems like climate change have been further classified as *super wicked* problems (Lazarus, 2009; Levin, Cashore, Bernstein, & Auld, 2007, 2012). Super wicked problems are defined by four additional features: (a) time is running out; (b) those seeking to provide a solution are also causing the problem; (c) there is no central authority; and (d) irrational time discounting pushes responses into the future (Levin et al., 2007, 2012). Furthermore, as sustainability scholar Thad Miller points out, "Sustainability and its problems cut across disciplinary boundaries and defy both problem definition and easy solutions; they challenge not just the analytical tools and approaches

of scientists but the usefulness of scientific knowledge" (Miller, 2012, p. 12). Miller, it is important to note, does not fully discount science but is articulating the limitations of scientific research to advance action in areas that are highly social and contextual (Miller, 2012; Nelson, 2003).

This understanding implies the necessity of linking other types of knowledge to our scientific understanding. In this dissertation I will argue that coupling artistic methods of investigation with scientific methods will develop a more holistic understanding of the sustainability challenges we face.

Collaborators for Addressing Wicked Problems

In an important 2012 paper published in the *Journal of Agricultural and Environmental Ethics,* philosophers Paul B. Thompson and Michael Powers Whyte affirm this *wicked* framing for sustainability, stating that it provides a space for interdisciplinary collaboration that can move us beyond positivist and disciplinary ideals of viable solutions. Understanding sustainability challenges as wicked, they conclude, "opens up a number of tasks that no one has the proper disciplinary training to undertake" (Thompson & Whyte, 2012, p. 489). But we shouldn't despair, they write, because "anyone who can grasp how this kind of team-conducted inquiry into a wicked problem might go can be a convener of teams and develop a unique specialization in this area" (Thompson & Whyte, 2012, p. 491). While Thompson and Whyte are advocating specifically for the role of philosophers in these sustainability dialogues, their argument can be globalized: any person with the relevant critical reasoning abilities and openness to collaborative, experimental inquiry may become a contributor in finding solutions to

longstanding and emerging sustainability challenges. Among other things, it's an insight that evokes one of the core elements of American pragmatism, especially the cooperative and deliberative approach to social inquiry championed by the philosopher John Dewey (see, e.g., Minteer 2012).

Since sustainability research hopes to link knowledge to social action for a better future (Cash et al., 2003; Clark, 2007; Jasanoff, 1996), this knowledge needs to address the social, political, and cultural processes involved in creating a sustainable vision (Norton, 2005; Thompson, 2010) as much as the scientific and technological one (Miller, 2012). In order to tackle these challenges, inter- and transdisciplinary[1] research has become a cornerstone of sustainability (Lang et al., 2012). As previously stated, the emphasis has been on research in the natural and technical sciences; the arts and humanities get minimal representation within these discourses (Fischer et al., 2007; Kagan, 2011).

If more attention were paid to the arts the sustainability community would realize that the arts are not simply reflectors and shapers of culture (Gibbons et al., 1994; Kagan, 2011), they have also been credited as catalysts for key scientific breakthroughs (Edwards, 2008, 2010; Root-Bernstein, 2000; Root-Bernstein & Root-Bernstein, 1999, 2004). David Edwards (2008), an engineer by training and the founder and director of the artscience center Le Laboratoire in Paris, France, points out that Julio Ottino, a chemical engineer, developed his ideas of fluid mixing from his painting practice. This work was

[1] Psychologist and team science researcher, Daniel Stokols (2008), contrasts interdisciplinarity from transdisciplinarity by demarcating the level of integration. While interdisciplinarity is an interactive process of coupling knowledge and ideas he differentiates transdisciplinarity by identifying it as an integrative process, which creates a new, shared, framework and language that transcends disciplines.

published in *Nature* and *Science* and is the basis for one of the most widely cited textbooks on the subject. Diana Dabby, an electrical engineer, was a concert pianist first and drew on these two practices to develop her thesis "Musical Variations from a Chaotic Mapping," a way to create an unlimited number of musical variations from a single original source (Edwards, 2008, p. 28). Furthermore, there are a disproportionate number of Nobel laureates with artistic avocations, some even crediting "artistically creative imaginations" as key components of pioneering science (Root-Bernstein et al., 2008; Root-Bernstein, Bernstein, & Helen, 1995; Root-Bernstein & Root-Bernstein, 2004).

Such examples suggest that understanding the integration of the arts and sciences for sustainability will only benefit the latter's focus on use-inspired basic research (Clark, 2007; Kajikawa, 2008; Spangenberg, 2011) by incorporating multiple epistemologies that may further illuminate new and potentially fruitful paths to tackling complex sustainability issues. This is not to suggest that the arts and humanities do not already contribute to deepening our understanding of the human/environment relationship but in addition to what the arts and sciences already do, the *interaction* of the two domains expands how they can contribute to tackling sustainability problems.

Art and Sustainability: Opportunities and Challenges

For more than a decade there has been an explicit effort to include the arts in the sustainability dialogue to broaden the discussion and to introduce differing perspectives. In 2000, sociologist of art and sustainability, Hans Dieleman, launched "a research program on "art & sustainability" aiming to "explore the various roles artists can play in change processes towards sustainability" and to link the "systems characteristics of sustainable development" with the "beyond rationality" characteristics of art (Dieleman,

2001as cited in; Kagan, 2011, p. 16). Another pioneering event in this domain was the international symposium *Sustainability and Contemporary Art at Central European University Budapest*, organized by Maja and Rueben Fowkes in 2006. The symposium "brought together contemporary artists, environmental scientists and ecological activists to explore common ground around an expanded notion of sustainability" (Bennison & Aloi, 2009, p. 21). The Fowkes have continued to organize symposiums on art and sustainability every year since the 2006 meeting.

In 2007, the European Sociological Association (ESA) Research Network for the Sociology of the Arts organized the conference *New Frontiers in Arts Sociology: Creativity, Support and Sustainability* at Leuphana University in Lüneburg, Germany, an event focused on the role of art in sustainability dialogues and possible transitions (ESA Research Network for the Sociology of the Arts, 2007). Two years later, the Arizona State University Art Museum curated the exhibit "Defining Sustainability." The exhibit catalog carried articles by authors representing both the arts and sustainability science (Lineberry, 2009). The following year, in 2010, a consortium of institutions (including the International Council for Cultural Centers, the International Network Cultura21, and the Latin American Network of Art for Social Transformation) conducted the first international summer school of arts and sciences for sustainability in social transformation. The purpose of the program was to help artists and scientists develop inter- and transdisciplinary methodologies for working together on sustainability challenges (Center for Sustainable Practice in the Arts, 2013; Kagan, 2011).

The creation of these venues is an intriguing and potentially fruitful approach for connecting artists and scientists. These high-energy international events bring together

interdisciplinary scholars and scientists so they can learn from each other and hopefully find common interests to work together on. Sustaining momentum, however, may prove difficult: experience has shown that it is often hard to maintain energy for new collaborations if the opportunities to assemble occur only annually. Ideally, collaborators should have opportunities for daily contact and spontaneous conversations; this is a critical part of developing mutual trust and understanding (Tress, Tress, van der Valk, & Fry, 2003), maintaining motivation, and moving ideas forward (Parker & Hackett, 2012). Edwards (2008) has pointed out that the integration of arts and sciences is a time intensive process; therefore, the ability to expand these dialogues rests on continuous interactions.

Given that it appears to be difficult to achieve, we might at this point ask whether there is a unique benefit to artists-scientists collaborations for sustainability. After all, why exert limited time, resources, and energy to building such demanding collaborations if they add little to efforts to understand and address the wicked problems of sustainability? In this dissertation I argue that it is worth the effort but developing high performing teams doesn't happen simply by recruiting artists and scientists to work together; it takes an understanding of the conditions and dynamics that foster an open engagement of ideas. Therefore – in addition to making a case for an art-science practice – it's necessary to investigate which mechanisms aid in the enhancement of these interdisciplinary collaborations.

Integrating Art and Science for Sustainability

Inter- and transdisciplinary artists-scientists teams require more effort than most science-oriented cross-disciplinary collaborations. One reason for this is because their

institutional structures vary more than those between the sciences. The sciences are often built on the development of *a priori* assumptions that are then built out as hypotheses and empirically tested. Whether you're a researcher in the life or social sciences, for example, you are familiar with the scientific method. The expectation, furthermore, is that research is then published in a peer-reviewed journal.

Although artists may share in *a priori* assumptions about a specific topic, the approach taken is often an exploration of the multiple facets of the particular subject matter. Their method of interrogation, that is to say, is often iterative, without a specific goal in mind. Rather than organize information at the beginning of a project, the artist makes 'sense' of the work by learning, making decisions along the way, and filling in the gaps. Additionally, artists primarily produce work with the intent of displaying it in galleries or as fine art books. Hence, this disparity in approach can be difficult to overcome; not only do they not share a method of investigation, they don't even share a method for dissemination of the work[2].

The above suggests that if we are to attempt collaborations to bridge this divide, at the very least, we should reap unique benefits for sustainability that justify the added effort. I argue that there are three primary benefits of art-science collaborations for sustainability. These are in the primary domains of: (1) idea translation, (2) hot cognition, and (3) problem identification, generation and framing.

[2] I am describing an art method more oriented towards an intuitive mode of practice. However, I do want to note that artists – focused on conceptual work – may develop a project focused more on the execution of a preconceived idea. While conceptual work may leave less room for exploration, artists must still be reflexive and open to regularly shifting directions in an effort to make their idea cohesive and compelling. Hence, even in more conceptual work, artists still must learn and respond in an iterative fashion.

Idea Translation

David Edwards' book *ArtScience: Creativity in the Post-Google Generation* focuses on idea translation. By developing ideas through a combination of the processes we regard as art and science, creators can more easily propel ideas over disciplinary and institutional barriers (Edwards, 2008). Idea translation is the process of moving something from the conceptual stage to its realization, which may bring about any combination of economic, cultural, educational, and social values (Edwards, 2008). The type of realization Edwards is speaking of often crosses disciplinary boundaries, a process in which artscience becomes especially valuable. The National Endowment for the Arts (NEA) has pointed out that, "At their intersection artists and scientists can borrow freely from one another's methods and practices and share insights with each other that they might be unable to find on their own" (O'Brien, 2012). Artist-scientist collaborations open a new spectrum of this cross-disciplinary inquiry, one that aligns with the inter- and transdisciplinary goals sustainability has identified.

Hot Cognition

Social scientist Herbert A. Simon defined "hot cognition" as, "thinking and experiencing in ways that arouse empathy, and thereby the "feelings" associated with experiences" (Simon, 2001, p. 218). The arts and humanities produce work from their ceaseless interrogations of the human experience. Their creation of meaning comes from this reflexive practice (Gibbons et al., 1994). A popular internet meme expresses this idea through a humorous image with text that reads, "Science can tell you how to clone a Tyrannosaurus Rex, humanities can tell you why this might be a bad idea" (Cardenas,

2012). The goal is to connect what we know scientifically with what we understand and feel. Simon wanted to be clear that humanists were skilled in addressing the visceral components of hot cognition but they needed to get the science correct as well. As he pointed out, "If we are to learn our social science from novelists, then the novelists have to get it right. The scientific content must be valid" (Simon, 1983, p. 32). Simon also stressed that scientific validity was insufficient for creating action, commenting on the fact that although Rachel Carson's *Silent Spring* (1962) is widely attributed as bringing the threat of DDT to wildlife and human health to the fore, this knowledge was generally understood by ecologists and biologists in the early 1960s. It was Carson's ability to create an emotional response to the threat that focused the public's attention on the issue.

This point that scientific understanding alone is insufficient was again made clear in a recent study on public attitudes toward climate change. Researchers found that peer group affiliation, rather than scientific literacy, was a better predictor of individuals' perceptions of climate change (Kahan et al., 2012). Accordingly, the authors advanced an argument for developing a science of scientific communication that uses culturally diverse communication strategies.

I would argue, however, that we already understand how to create compelling messages and that another "science" for scientific communication is misdirected. If the issue is one of attitudes and values then more clearly communicating climate change is not going to change how people feel about it. A more appropriate approach to creating compelling messages, and a more essential dialogue, is hot cognition brought about through artist-scientist collaborations.

Problem Identification, Generation, and Framing

The idea of use-inspired or problem-driven research defining sustainability science (Clark, 2007; Kajikawa, 2008; Spangenberg, 2011) can be applied to artist-scientist collaborations as well. This merely entails the inclusion of disciplines that, while not traditionally understood as sciences, are still focused on identifying and solving sustainability problems. However, these problems need reframing and often require a reflexivity that is more common to the arts and humanities (Gibbons et al., 1994; Jerneck et al., 2011; Spangenberg, 2011).

Problem recognition and formulation can be more critical than problem solving (Root-Bernstein, 2003; Thompson & Whyte, 2012). We can find an answer to a question, but if it's the wrong question we run the risk of thinking we have in fact advanced our understanding of the issue, a conclusion that only confounds the desired outcome (Schwartz & Carpenter, 1999). The ability to reach outside the confines of scientific methods and art methods by taking a transdisciplinary[3] approach is the ultimate goal; one that art-science aspires to accomplish (Edwards, 2008; Kagan, 2011; Root-Bernstein, Siler, Brown, & Snelson, 2011; Siler, 1995, 2011). Spangenberg (2011) affirms this ideal by identifying criteria that suit these types of collaborations well. He points out that transdisciplinarity is a demanding form of knowledge integration that is dependent on reflexivity, must be approached from a diversity of angles, scientific and non-scientific; and involves both tacit and experience-based knowledge.

Collaboration between artists and scientists addresses these criteria in a unique way that is difficult to find in other transdisciplinary projects. While we can extract value

[3] I point specifically to transdisciplinarity because I believe the ultimate goal within these artist-scientist collaborations is the transcending of disciplinary boundaries.

from disciplines working independently and imputing their knowledge into the sustainability context, true integration that can better acknowledge the more holistic patterning of (differing but complementary) knowledge sets will bring us closer to resolving complex challenges, including asking questions that better address the complexity.

Artist-scientist practice, undertaken both by individuals and in collaborations, can give us a more nuanced and richer understanding of an issue, creating a scientific and a humanistic knowledge base that allows us to simultaneously ask questions that address our understanding of the interactions experienced in the world – and the relationships we have with those experiences. It can give us quantitative and qualitative[4] information and help us grapple with why this information is meaningful to us. This is the heart of inter- and transdisciplinary approaches: to create connections that, at an interdisciplinary level, bring forward a richer, more nuanced understanding of the issue. At a transdisciplinary level, the goal becomes to bring forward a shift in understanding, a shift that helps us rethink questions and reframe problems, a transformation brought about from new understanding of the problem.

Identifying Elements and Processes in Art-Science Practice

There is a growing literature that speaks to the creative benefit of art-science and identifies individuals who have benefited from this integration (Edwards, 2008, 2010; Halpern, 2011; Root-Bernstein, 2000; Root-Bernstein et al., 2008; Root-Bernstein et al., 1995; Root-Bernstein & Root-Bernstein, 1999, 2004; Root-Bernstein et al., 2011; Siler,

[4] Qualitative information can be addressed both in the arts and sciences. For example, it can refer to the collection of ethnographic information that helps contextualize quantitative data. It might also be art work like the Rephotographic Survey Project (Klett, Manchester, & Verburg, 1984) that aided in visualizing the changes in land-use 100 years after the original USGS surveys of the west.

1995, 2011; Snow, 1960). The interdisciplinary journal *Leonardo* focuses on the intersection of art and science, though it is skewed toward technological projects. The challenge has been in finding literature that accounts for the unique benefits of this type of interdisciplinary[5] work in sustainability.

I believe that we need to better understand the tradition and value of art-science integration and how we might approach sustainability oriented art-science projects as individuals or in collaborative contexts. This dissertation will therefore focus on the potential benefit of developing an interdisciplinary and integrative dialogue between the arts and sciences as an emerging method for enriching pluralistic perspectives for sustainability challenges.

Specifically, it will weave together 1) scholarship on and analysis of the work of conservationist Aldo Leopold (a key historical precursor of the contemporary art-science practitioner); 2) a personal project in art practice; and 3) an empirical analysis of the social factors that foster or hinder collaboration in art-science teams. Specifically, this dissertation research will engage in a rigorous analysis of art-science practice for sustainability that seeks to understand:

1. *The necessity of connecting natural aesthetics to sustainability science*. In particular, we will see how Aldo Leopold personally addressed this integration in his interdisciplinary essays on aesthetics, ethics, and ecology -- and how these

[5] Interdisciplinary scholar, Julie Thompson Klein (2008) has noted that teams often oscillate between multi- inter- and at times transdisciplinary collaborations. While I ultimately champion transdisciplinarity and believe that it is the level that this research aspires to, I also acknowledge that interdisciplinarity is a more maintainable mode of operation. In distinguishing the two I more often focus on interdisciplinarity as the threshold that individuals and collaborators should work to maintain.

insights can aid in tackling similar integrative challenges in contemporary sustainability art-science practice.

2. *How contemporary landscape photography can open another path for connecting aesthetic practice to framing sustainability challenges*. I use contemporary photography and video methods in developing a visual body of work expressing the proposed connection of arts to sciences. The text and project, *one hundred little dramas.,* serve to showcase how an artist-scientist practice can engage in the sustainability and human/environment relationship discourse.
3. *The conditions and processes that support or hinder productive artist-scientist three-person team collaborations*. This empirically-based research investigates how perceived trust in expertise and task conflict effect decision-making and group cohesion. It explores a) how teams collect information, generate responses, and validate their ideas; b) how artists challenge or accept scientists' ideas (and vice versa); and c) how teams go about generating and picking ideas, and how they negotiate disagreements.

My approach in this dissertation bridges concepts that have been addressed in their respective fields but not coupled in a robust manner. By integrating these fields through literature review, empirical social research, and in art practice, I provide a method for reflecting on the cultural components that touch on sustainability, as well as one model for collaborators to cultivate innovative art-science research. This research pioneers a way forward for connecting how art-science integration offers a reflexive, iterative, and

empirically rigorous method that can help us to better understand and tackle the wicked problems of sustainability.

Chapter Layout

Following this introduction, the dissertation proceeds in three chapters. Chapter 2 focuses on the conservationist, ecologist, and "amateur" environmental philosopher Aldo Leopold (1887-1948), a key historical thinker who I argue is an exemplar of an artist-scientist (Edwards, 2008; Root-Bernstein et al., 2011; Siler, 1995, 2011) and whose essays and practice are highly relevant to contemporary sustainability discourse. This chapter is primarily a textual analysis of a selection of Leopold's writing, focusing directly on the connection between his understanding of aesthetics, ethics, and ecology – and his enduring belief that the integration of these domains was a necessity for shaping an ecological conscience, both at the individual and societal level. Specifically, the chapter addresses the role aesthetics have played in framing the human-environment relationship and proposes that Leopold's ecological aesthetic is a valid framework for developing a new sustainability aesthetic.

Chapter 3 builds from chapter 2 by incorporating Leopold's ideas into my own visual art practice. I engage with contemporary photographic and video methods in the creation of the work in tandem with an ecological understanding and ecological design practice in my backyard, which heavily influence the work. I work to connect the aesthetic with the ecological, a process that informs my personal land ethic as well. The result is a project, lasting more than three years, that documents the transformation of my backyard. While this chapter's primary focus is photographic imagery from an exhibition

held in 2013, the text serves to connect how coupling art and science is relevant to new directions in contemporary landscape photography.

Given the prevalence of interdisciplinary collaborations in sustainability, chapter 4 addresses the interaction dynamics of three-person artist-scientist teams at ASU tasked with the development of interpretive signage for the Tres Rios wetland site. The goal is to understand how these interdisciplinary collaborations can be facilitated in order to improve the ability of teams to address these complex sustainability challenges in the future. This chapter reports the results of an empirical qualitative and quantitative study investigating how perceived trust in expertise and task conflict affects decision-making and group cohesion. In particular, the study focuses on how teams collect information, generate responses, and validate their ideas and how artists challenge or accept scientists' ideas and vice versa.

Brendon Larson (2011), interdisciplinary scholar and author of *Metaphors for Environmental Sustainability: Redefining Our Relationship with Nature*, points out that the risk of deeply interdisciplinary and synthetic work leaves the research open for critique from the respective disciplines. Although it therefore may seem more appropriate to pick one area and focus, the work presented in this dissertation is intended to open an emerging dialogue, still in its infancy. As Sasha Kagan (2011, p. 470), sociologist and sustainability scholar, points out, "A meaningful assessment can only be achieved if the qualitative observation is engaging the researcher as a full person, and beyond the limitations of purposive consciousness… This is a collective, combined exploration that has to engage artists as well as (social and natural) scientists."

This suggests that the integration of art and science cannot be fully grasped unless the researcher has engaged in both endeavors. In this dissertation, I've attempted to meet this challenge head on. My purpose throughout this project has been to be engaged as an individual artist-scientist in order to understand what that role demands, a precursor to understanding how that integration might translate to a larger collaborative context, one that extends our ability to tackle current and emerging "wicked" sustainability challenges.

CHAPTER 2

INCORPORATING AESTHETICS INTO THE SUSTAINABILITY DIALOGUE: LESSONS FROM AN EXEMPLAR OF ART-SCIENCE SYNTHESIS

Introduction

"We are using the wrong language…We have a lot of genuinely concerned people calling upon us to "save" a world which their language simultaneously reduces to an assemblage of perfectly featureless and dispirited "ecosystems," "organisms," "environments," "mechanisms," and the like. It is impossible to prefigure the salvation of the world in the same language by which the world has been dismembered and defaced." ~Wendell Berry

Sustainability challenges are inherently interdisciplinary[6], but the community of sustainability scientists and scholars has had difficulty bridging the divide between the sciences and arts and humanities. In this chapter I attempt to address the import of closing this gap by including natural aesthetics in addressing sustainability challenges. I propose that the sustainability science community needs to incorporate natural aesthetics into the sustainability dialogue as a valid component for dealing with sustainability challenges. But the use of natural aesthetics in addressing sustainability challenges is a complicated business, and I provide examples of cases where aesthetic sensibilities were in the past responsible for blocking effective conservation initiatives. I discuss the detrimental role that a particular framing of the *wilderness* aesthetic, derived from the Romantic aesthetic

[6] These challenges are transdisciplinary as well, but as previously stated (Klein, 2008), interdisciplinary is the threshold and transdisciplinarity the ideal. For this reason I will primarily refer to interdisciplinary work from here on out; however, it can be assumed that the work regularly strives for transdisciplinary outcomes.

traditions of the *sublime* and *picturesque*, has played in creating a stubborn human/nature divide. I then address how the noted conservationist, ecologist, and environmental philosopher Aldo Leopold (and his work) provides insight into the development of an integrated natural aesthetic that operates in conjunction with science and ethics. Finally, I discuss how the heuristics for an integrative aesthetic, as I have identified them from Leopold's writings, can be adjusted for developing an informed, engaged, and integrative aesthetic that can operate in combination with sustainability science to further sustainability initiatives.

The Challenges of Collective Change: Scientific Communication, a New "mathematics," a New "language", or a New "aesthetic"?

Transitioning towards a more sustainable future requires a collective shift in how individuals and communities relate to their environments both locally and globally. Even with the growing scientific efforts focused on sustainability challenges, large-scale social change is slow. As mentioned in the previous chapter, Kahan et al. (2012) point out that peer group affiliation is a better predictor of perceptions on climate change than scientific literacy. As a result, they argue for a more culturally diverse science communication strategy. It's a point echoed by sustainability scientist Sander van der Leeuw, who suggests that the focus needs to be less on scientific communication and more on culture change. Van der Leeuw draws attention to the 2011 Nobel meeting in Stockholm on Sustainability (http://globalsymposium2011.org/), confirming that their conclusion was unambiguous, "we need a change in collective mindset to achieve our vision and goal" (2014, p. 115). He addresses multiple reasons for slow progress: cognitive overload that perpetuates heuristics not aligned with sustainability, "unbridled innovation in every

direction" that has promoted a supply-driven consumer and innovation culture, issues with burden sharing creating a diffusion of responsibility, and economic models that are unable to deal with discontinuous change (van der Leeuw, 2014, p. 116). His solution is developing a "mathematics" that can deal with discontinuous change and repositioning science so as to regain the trust lost from its alliances with industry and government.

Environmental philosopher Bryan Norton takes this conversation in a different direction. He believes that a new environmental *language* is necessary, one that can unify environmental science and values for better informed environmental policy (2005). Norton argues that economists have actually done a better job of aligning their language with social values than natural scientists, giving them a strong hold in policy choices. Ecologists, he suggests, still fail to connect changes in ecological systems to broader social values (Norton, 2005; Norton & Toman, 1997).

Norton has been among the most vocal theorists in environmental philosophy and sustainability studies in arguing that we can learn much from the work and thought of Aldo Leopold (1887-1948). Specifically, Norton has woven Leopold's ideas into a broader theory of adaptive management in his book *Sustainability: A Philosophy of Adaptive Ecosystem Management* (Norton, 2005). There, Norton addresses how Leopold's approach to land management can address the uncertainty, complexity, and value pluralism we face in tackling contemporary sustainability challenges.

As valuable as this contribution is, Norton does not directly address an important part of Leopold's work that I believe is critical to sustainability thought and practice. Central to Leopold's process of creating mental shifts that alter world views are his

powerful aesthetic commitments[7], a dimension of his thought that provides an access point to a deeper ecological understanding and conscience (Flader & Callicott, 1991; Leopold, 1966b). Each author addresses the need to shift value structures, but none of these authors (Kahan et al.; Norton; van der Leeuw) explicitly mentions the potential role arts or humanities[8] play in the reframing of value structures. But they are not alone in this oversight. Indeed, any review of the sustainability literature will be hard pressed to find work that pays significant attention to the potential of aesthetics in sustainability.

Artists are not indifferent to scientific work. Artist Julie Anand acknowledges the necessity of technologically and scientifically focused work in sustainability but also understands the necessity of art in the sustainability discourse. She adds that our behaviors are informed by ideas and philosophies, which are foundational to how we engage with the world and what artists and writers do is help us rethink our relationship to the world (Kitch & Adamson, 2010). Hence, artists and writers can aid in creating the mental shift that van der Leeuw draws attention to. However, the arts can also reinforce a culture of unsustainability (Kagan, 2011), one that further embeds us in current undesirable behaviors. For this reason, investigating the role arts and humanities can play in the development of sustainably oriented behaviors is essential.

[7] "Aesthetic" is understood here in its etymological context, which is derived from the Greek words *aisthetikos* (sensitive) and *aisthanesthai* (to perceive, to feel) (Harper, 2012; Kagan, 2011). Most common associations to aesthetics have focused on art criticism or the philosophy of art. This paper broadens the definition of aesthetics along the discourse that has taken place in environmental aesthetics, which focuses on natural environments versus (art)ifacts.

[8] It is worth noting that the humanities are broad in scope, Norton's work can be considered humanistic and social scientific; however, I will be referencing a subgroup in this paper. Specifically, I will be referring to individuals who may identify as artists, poets, and creative writers… those more likely to make art, write poetry, or creative fiction. Additionally, from here on, I will simply refer to the arts or humanities, however, it can be implied that most of my statements about the arts transfer to the humanities and vice versa.

Aesthetics as a Window into Our Collective Priorities and Values

Environmental philosopher J. Baird Callicott (1994) notes that "sound natural aesthetics," such as those expressed by Aldo Leopold, are crucial for a comprehensive conservation policy and land management system. Alternatively, "unsound aesthetics" can create barriers to developing sound conservation policy. Kinsey, Roberts, & Sayre (1999) provide an example of the impact misapplied aesthetic ideals can have on conservation decisions. They reference an Iowa case where an ingrained and ecologically misaligned agricultural aesthetic hindered the 1991 Waterman Creek Prairie restoration project. The project goal was to restore particular sites to prairie conditions prior to Euro-America settlements. The Waterman Creek site had been selected because it contained "a significant number of prairie remnants that could form the core of the ecosystem recovery process" (Smith, 1998, p. 105). Residents of O'Brien County, Iowa were not as opposed to prairie as they were to the idea that the 4,700-acre park represented a loss of agricultural prospects: if the land was restored to prairie then potential farmland was lost. But this wasn't premium farmland, it was steep (making it less moist), and the plots were irregular, which made it impossible for large machinery to farm the land. It was instead a loss of potential prospects that represented a way of life for the community. These deep-rooted ideals of agrarian prospects go back to older ideas of progress on the Iowa prairies and they set the context for how the community saw, read, and appreciated the land.

Ecologist and social scientist Brendon Larson, notes, "The way we speak[9] about the natural world is not a transparent window, because it reflects the culture in which we

[9] While Larson is discussing language, he does so in the context of metaphors; which often create visual understandings for concepts. Hence, I used it in reference to the use of imagery that reflects cultural values and priorities.

live and its priorities and values" (2011, pp. 55-56). Kinsey et al. (1999) provide evidence for this point when discussing the nature of the aerial photographs Vincent Mart, a local photographer, made for patrons in the area. After 30 years of photographing, he donated more than 10,000 images to the State Historical Society in Iowa City. The images focused on cities, houses, and barns; the fields and prairies appeared only as backdrops. The altered landscape represented an ideal, a visual example of the community's ability to make a living on this land. The prairie could be appreciated but not at the cost of true progress, the realization of economic prospects derived from the land. Indeed, Kinsey et al. point out that, "The aesthetic perceptions and economic uses of the prairie cannot be separated, and any attempt to do so deprives an analysis of the conflict of meanings that motivate political participation. The same paradoxical metaphors expressed in art and regional literature are bound into the everyday experiences by which prairie people and communities construct their identities and assert their interests…" (1999, p. 34). The upshot is that if we are to consider redirecting conversations and facilitating mental shifts, we cannot ignore the role environmental aesthetics plays.

If aesthetic sensibilities produce actionable outcomes, as in the Iowa case, then it follows that individuals most immersed in aesthetic disciplines should be part of the sustainability dialogue. These individuals, normally found in the arts and humanities, create work grounded in a reflexivity rooted in the human experience. As Gibbons et al. note; "…the construction of meaning is considered the essence of what the humanities do…the humanities both stand a bit aside as commentators or performers, while at the same time they are deeply involved in shaping powerful cultural images which in turn influence the entire culture of a society and its stratification systems" (1994, p. 92). The

relevance of this statement is more pronounced now than in 1994, with the preponderance of mediating online venues: social media has extended the reach of the arts with sites like YouTube, Vimeo, Tumblr, Vine, and Instagram, to name only a few. Twitter tells you what's trending and videos that go viral garner attention from television networks, demonstrating these sites' massive influence in the lives of many people today.

An Aesthetic that Connects the Arts and Sciences for Sustainability

Although not commonplace in sustainability, art-science integration is not a new phenomenon. Anthropologist Gregory Bateson and psychologist Rudolf Arnheim became prominent supporters of art-science synthesis in the late 1960's and early 1970's. In his book, "Survival of the Wisest," medical biologist and developer of the polio vaccine, Jonas Salk, stated "reality can be seen not only by the minds of scientists but by the minds of artists, each using his own means for perceiving as well as expressing… The artist and philosopher deal, by and large, with what we have been speaking of as the metabiological[10] universe. We are now seeking the connection, or the relationship, between the biologic and the metabiologic" (1973, p. 46). C.P. Snow's influential Rede Lecture, which was published as the book, *Two Cultures* (1960), brought significant attention to the divide between the humanities and science. Snow operated in both spaces and could attest to the cultural divide between the two, commenting that it was as if they spoke completely different languages (Snow, 1960).

Even though we are able to identify the divide between art and science after half a century of analysis and effort we still struggle to bridge it. Sustainability science has

[10] Salk used the term "metabiological" to describe the human elements within sociobiological systems (Jacobs, 2015). Salk remarked that people who convey by metaphor, such as artists, what scientists try to express explicitly, operated in this metabiological space.

committed to action-oriented research, one that uses any discipline that aids in solving sustainability challenges (Clark, 2007). This implies that, if aesthetics is indeed integral to understanding how "people and communities construct their identities and assert their interests" (Kinsey et al., 1999, p. 34), then they must be integrated into our sustainability practice.

But if the arts are so coupled with the production of culture why does the sustainability agenda (including, but not only, in the sciences) not pay them more attention? I believe the difficulty is finding the starting point for integrative work. This is a significant challenge. Even Leopold, who championed the incorporation of aesthetics into ecology and environmental management (and who serves as an exemplar for this integration here), found connecting the arts to the sciences difficult (Newton, 2006). In his landmark book, *A Sand County Almanac* (Leopold, 1966a), we find Leopold's most succinct integration of aesthetics, ethics, and ecology. History reveals that getting to this synthesis, however, proved very challenging, even for as skillful a writer as Leopold.

Leopold's graduate student and friend, H. Albert Hochbaum[11] noted Leopold's difficulties with integration as he read drafts of Leopold's essays, pieces that would become *A Sand County Almanac*. And Leopold himself admitted that "he indeed struggled with how to bring together artistry, science, and conservation objectives in his writings" (Newton, 2006, p. 222). Even though he had internalized this integration long before writing his classic text, he struggled with providing a framing that expressed the whole rather than the fragments of a coherent conservation philosophy (Newton, 2006).

[11] Albert was not just a former student of Leopold's; he was an artist. Leopold continually encouraged him to continue with his art practice and to use his artistic skills as part of his work as an ecologist.

Similar to the value Leopold saw in integrating the arts and sciences, there is acknowledgment today that the arts are valuable to sustainability (Fischer et al., 2007; Kagan, 2011). Fischer et al. add, "To understand the biophysical world requires science; to conceptualize our role within this world requires the humanities; and to reach sustainability requires their integration" (2007, p. 623). Even though sustainability scholarship and research emphasizes inter- and transdisciplinarity, the integration between the arts and sciences still proves challenging. As mentioned in chapter one, several sustainability events have focused on bringing artists and scientists together to explore how they might collaborate. However, most events are ephemeral and episodic, lasting no more than a couple days. If Leopold struggled to formulate and communicate an integrative land ethic over the course of his lifetime we might wonder how those in sustainability science and practice expect to make progress if they don't dedicate sufficient resources, time, and energy into lasting, long-term collaborations.

More than 75 years have passed since Leopold introduced his idea of a land ethic and more than 25 years have passed since the Brundtland report provided the oft cited definition commonly associated with sustainability: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p. 43). Since then, sustainability science has clearly made significant advances. The body of literature continues to grow in the social and life sciences, engineering has contributed to real, technological advances; institutions such as Arizona State University grant both graduate and undergraduate degrees in sustainability (with a growing number of universities following suit). There are multiple peer-reviewed

journals on environmental sustainability, social sustainability, educational sustainability, economic sustainability, sustainable development, and sustainability science.

Despite all of this institutional and scientific progress, however, we can still ask the question: is this work really achieving the deep cultural change sustainability requires? Even with the large number interdisciplinary research projects focused on sustainability are there pathways that have not been adequately explored? Most of the above mentioned programs, for example, are focused on science or engineering. Can the arts and humanities inject some much needed meaning and cultural force into the concept?

The sustainability community (esp. the scientific community) has often neglected the arts and yet the arts focus on creating a visceral salience that can connect people to the social and environmental problems facing us, a connection that (arguably) currently escapes sustainability science. In some ways, however, the neglect may feel warranted. The influence of the arts creates a tension, potentially crossing into an advocacy space that scientists fear may hinder their credibility. Miller (2012) further demonstrates this tension by asking, "How is science to be engaged in the social, political, and ethical components of sustainability while maintaining its ability to provide credible knowledge where needed?" (2012, p. 13). However, there is no dodging this issue given the post-normal perspective of sustainability (Funtowicz & Ravetz, 1993; Ravetz, 2006). As Norton (2005) notes, sustainability has committed to a normative and pluralistic perspective that understands values are embedded in the sustainability challenges we face.

There is widespread acknowledgement that the arts cover boundaries that the sciences do not, and that they are critical to cultural discourse (Gibbons et al., 1994; Kagan, 2011; Vucetich & Nelson, 2010). But artists have to get the science right as well (Simon, 1983). Otherwise, they risk trading one misinformed mental model for another. Leopold reminds us that a truly integrative ecology, aesthetic, and ethic, however challenging to achieve, is necessary for not only maintaining both the biotic and cultural values of land (Minteer, 2006) but for conjuring an experience that creates the mental shift necessary for reorienting the human/environment relationship.

Developing an Informed and Engaged Aesthetic

"The major problems in the world are the result of the difference between how nature works and the way people think" ~ Gregory Bateson

"Could it be, I wondered, that both good field science and fine art are rooted in the same medium, the ecotone between the cultivated skill of careful observation and the wilds of the human imagination?" ~ Gary Paul Nabhan

Before fully committing to the idea of an aesthetic component as critical to addressing sustainability challenges, it is important to consider three things aesthetics do well; that is, how they shape particular ideas in society. First, aesthetics direct our attention to something specific (Simon, 2001; Sontag, 1973). Second, they can alter and enlarge our notions of what is worth looking at and what we have the right to observe (Sontag, 1973). Third, an aesthetic can serve as an organizing method for articulating ideas and raising questions (Mueller, 1967). This aesthetic development is then translated

and coupled with our understanding oftentimes in forms of metaphor, which help us make leaps in understanding that is difficult through straight serial logic.

As addressed above, the integration of the arts is critical to the mental and cultural shift desired in sustainability. Including them, however, first requires an understanding of the dominant aesthetic sensibility that has influenced environmental appreciation and American views of the environment. Only until this is done may we then clarify what aesthetic frame sustainability wants to adopt and evolve with. In what follows I will therefore discuss how the prevailing environmental aesthetic in the U.S. has mediated the traditional way of seeing and experiencing the environment. This will involve examining first the historical context that produced the 'wilderness aesthetic', followed by a more in-depth discussion of Aldo Leopold's ecological aesthetic. Finally, I'll consider how his aesthetic sensibilities can contribute to inclusion of cultural components that sustainability science has heretofore found challenging.

The Lasting Effect of Beauty, the Sublime, and the Picturesque

On May 21, 2014, President Barak Obama designated Organ Mountains-Desert Peaks in southern New Mexico as a national monument. In his opening remarks, he expressed the awe he felt when he visited the Grand Canyon as a child and the pride he felt when he took his daughters to Yellowstone. He pointed out the impossibility of putting a price on the "towering peaks and pristine forests" of the newly designated monument (Holst, 2014). Visit the multimedia page of the Organ-Mountains Desert Peaks National Monument site (http://www.organmountains.org) and you find images that could be identified as 'scenic' and 'picturesque'; sweeping landscapes that might be found in a Sierra Club calendar.

The imagery and language, in particular the term 'picturesque,' dates back to an aesthetic adopted from eighteenth century Romantic ideals of natural aesthetic appreciation promulgated by philosophers such as Edmund Burke and Immanuel Kant (Carlson, 2001; Carlson & Berleant, 2004). Most identifiable is the articulation of the sublime. The experience of the sublime generates a sense of awe, wonder, amazement, respect, and terror, feelings that stem from exultation and delight. It is, in many ways, a sacred experience (Nash, 1982; Tsang, 1998). These feelings are brought on by the inability of the individual's imagination to comprehend the experience before them. The senses fail and "reason manifests itself to think a transcendent idea in reflective judgment of the object as sublime, that is, as that which evokes our pleasurable awareness of the supersensible in us" (Tsang, 1998, pp. 137-138). In effect, we move beyond our senses to our supersensible faculties of reason, which are supposed to sustain us in the presence of the sacred.

Intriguingly, as philosophers Allen Carlson and Arnold Berleant observe, disinterest actually plays a critical role in the sublime. They write, "The basic idea of disinterestedness is that aesthetic appreciation requires appreciators to abstract themselves and the objects of their appreciation from their own interests, such as the personal, the possessive, and the economic" (Carlson & Berleant, 2004, p. 11). Since the sublime transcends the senses, the observer has no other way to be in the presence of the sublime but from a psychological distance. Carlson and Berleant (2004) further point out that this coupling of disinterestedness with nature appreciation results in a rich tradition of landscape appreciation.

Although the senses fail to grasp the sublime, they, along with cognitive faculties could be "in harmonious interplay in reflective judgment of [an] object as beautiful" (Tsang, 1998, p. 135). While the beautiful was accessible through the senses, the sublime transcended them. This placed the idea of beauty on the opposite side of the spectrum as the sublime. However, Carlson and Berleant note that, "between the two extremes of the beautiful and the sublime, disinterestedness made space for the emergence of an even more powerful mode of landscape appreciation, the picturesque" (2004, p. 12). Through disinterestedness, one could now just as easily enjoy the rural countryside as well as the wildest of natural environments.

The picturesque could now mediate the aesthetic appreciation of these environments by focusing our attention on the "sensuous surface and formal composition" of the object through the distancing it provided. Since particular characteristics made for a picturesque sensibility, this limited the landscapes worthy of appreciation and contemplation. Carlson and Berleant continue, the "appreciation of nature itself, under the lingering spell of the picturesque, ultimately becomes limited largely to the appreciation of those landscapes especially suited for disinterested, formulistic appreciation: scenic views with picture like sensuous and formal properties" (2004, p. 12). Nature provided the materials for the landscape, i.e. rivers, trees, mountains, but it didn't necessarily order them correctly. William Gilpin, the eighteenth century landscape artist, who was also one of the originators of the picturesque, commented that if nature got the composition wrong, he could not help putting it right (Batchen, 1999). Nature could be disorderly but an artist had the skill to properly order it for maximal aesthetic appreciation.

These ideals of beauty, the sublime, and the picturesque, grounded on disinterestedness, not only distanced people from the ecological realities of environment, it also served to create an idea of proper landscapes built on *views*, *effect*, or *prospects* (Batchen, 1999). As historian of photography Geoffrey Batchen writes, "wealthy proponents of the picturesque, like Talbot's[12] mother, employed landscape designers to transform their grounds into a series of "views" thus forcing nature to look more like a picture, to look more ideal" (1999, p. 75). People were so taken with the picturesque that visiting a landscape at times was not enough, the use of devices like a camera obscura or a Claude glass helped further distance the viewer making the scene appear even more painterly (Batchen, 1999). In fact, these ideas took hold in developing American parks as well.

Heavily influenced by the picturesque aesthetic, Fredrick Olmsted (working with his collaborator, Calvert Vaux) designed Central Park so that visitors could feel transported out of the city and into the countryside. He had trees planted around the outer boundaries of the park to drown out the noise and obscure views of the buildings that were to be constructed. The roads that traversed the park were sunken so that they did not obscure the view. Olmsted thought of Central Park as a way to preserve the New York landscape. The value of Central Park would be appreciated even more for its aesthetic qualities, once local resources had been excavated and used for the construction of buildings and roads; the park would become a safe haven. Central park was to be an example of a native New York.

[12] Henry Fox Talbot is considered one of the fathers of the photography and the creator of the calotype process (Batchen, 1999).

The only problem was that it was a native New York that had to be created through a marvel of landscape engineering. “A system of underground pipes would drain the swampy flats; the lowest areas would be excavated and turned into lakes…Barren soil needed to be fertilized and seeded for meadows. The open farmland, long since denuded of vegetation, required extensive planting—three hundred thousand trees and shrubs, by Olmsted’s estimate” (Rybczynski, 1999, p. 174). It turns out the idea of a native New York was constructed from a vision of European gardens, ideas that Olmstead was intent on recreating. Indeed, Central Park was an artifice built from European views of picturesque landscapes where Olmsted had trained.

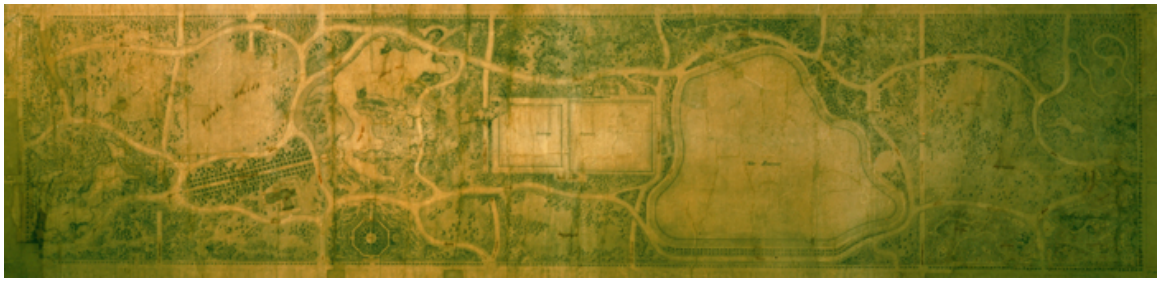


Image 1: Original Greensward Plan for the creation of Central Park from 1858 (New York City Parks, 2015)

It’s generally understood by historians that “Europeans laid the intellectual foundations for a favorable attitude” (Nash, 1982, p. 44) towards particular landscapes. However, as Romanticism was taking hold in the 19th century, writers and artists were beginning to extend that appreciation towards wilderness in America as well (Nash, 1982). The landscape painter Thomas Cole, an early advocate of American wilderness, took on “wild places” in the East as subjects for his paintings. He noted that “the most distinctive, and perhaps the most impressive, characteristic of American scenery is its wildness” (Cole, 1836, p. 3). Cole worked to produce images that evoked the grandness

of these places with “dramatic compositions, filled with precipitous cliffs, dark gorges, and surging storm clouds” (Nash, 1982, p. 78). His intention was to draw associations of the sublime and the sacred by accentuating the wildness of these places. While his paintings can be characterized as picturesque, he begins to tread new ground. In his paintings, Cole accentuates the sublime, perhaps because of the grandness of American wilderness. He may be painting in the picturesque, but it’s an American picturesque deeply rooted in a wildness foreign to Europe. Cole’s work, along with the other landscape painters of the Hudson River School, was instrumental in the development of an American picturesque (Spence, 1999).

Image 2: Thomas Cole’s painting “The Oxbow,” is an example of an American landscape he made to elicited the sublime and picturesque (The Metropolitan Museum of Art, 2006).

In addition to artists like Cole, environmental historian William Cronon (1996) has discussed the role the ‘sublime’ played in the literature of American nature writers

such as Thoreau and Muir, both of whom evoked their experience of the sublime during visits into wilderness. Appreciation for wilderness was further compounded by America's newfound independence; wilderness became a point of nationalistic pride, an American asset (Nash, 1982). Historian Mark Spence notes, "The idea of wilderness functioned as an important tool for patriotic apologists who felt compelled to refute European claims that the North American landscape was fundamentally flawed because it lacked ancient historical associations and refined pastoral landscapes. What American scenery lacked in European qualities, they argued, it more than compensated with an abundance of wilderness" (Spence, 1999, p. 12).

Early American tourist sites like Schuylkill River, the White Mountains, the Hudson River, and the Catskill Mountains were more identifiable with the European picturesque aesthetic. But an American picturesque had also taken shape and was further being solidified in the West (Dennis Berthold, 1984; Byerly, 1996). The linking of the picturesque to conservation is perhaps most clearly displayed during the development of landscape photography and specifically with the photographing of the monumental scenery of the American West. As Rebecca Solnit remarks, "If American landscape photography has a birthplace and spiritual home, it is in the Yosemite Valley…" (2003, p. 100). The photographer Solnit specifically references is Carleton Watkins, who, in the late 1800's, made glass plate images throughout Yosemite with his Mammoth 18x22 inch view camera. His Yosemite images became very popular, giving citizens back East a sense of the grandness of the American wilderness. In fact, these images became instrumental in convincing Congress to dedicate Yosemite as the country's first federally created park (Solnit, 2003).

This American picturesque still followed the formal compositional properties of the European picturesque but they were uniquely American in their preference for the sublime. Solnit writes, "The nineteenth-century American era, in which virgin wilderness was invented, is less well understood. Perhaps people do not appear in Watkins's Yosemite photographs because of the long time exposures photographs then required, or perhaps it had to do with the landscape aesthetics of the sublime and the beautiful that Watkins had clearly absorbed. Either way, images of nature without human traces became definitive of the western landscape" (2003, pp. 100-101). These carefully composed photographs that express the grandeur of Yosemite's rivers, mountains, and forests represent a beautiful place not yet spoiled by man, a place where visitors could commune with Nature. The construction of the American wilderness here begins to take a formidable shape: authors like Muir and Thoreau speak of wilderness as sacred places for man to rejuvenate himself in, wilderness is integrated into the national identity, and Watkins gives us a photographic representation of the picturesque in this 'pristine' wilderness called Yosemite. It becomes clear, then, that the idea of wilderness, so close to the hearts of environmentalists, is at the very beginning tightly coupled with and derived from fixed ideals of natural beauty, the sublime, and the picturesque.

The Wilderness Aesthetic and its Disconnect from Ecological Realities

A notion of Wilderness derived from a picturesque aesthetic and from ideas of the sublime creates two significant challenges for proper environmental understanding. First, the 'disinterestedness', integral to the sublime creates a distancing of the individual from the environment allowing for a diffusion of responsibility for the individual. The picturesque becomes a mediator between beauty and the sublime; nature appreciation

becomes a formal construction based on specific scenes, ordered as the artist sees fit. In the national parks, administrators went so far as to remove vegetation that may block scenic views and exterminated predators that could dwindle the popular game animal population, which visitors hoped to see (Byerly, 1996; Spence, 1999). Second, the idea of 'virgin' wilderness built off this aesthetic creates a further divide, abstracting nature into an idea of the pristine and natural, free of human intervention and unwelcome to prolonged occupation. We can visit Eden but we cannot stay.

This reframing of the West actually "led to the creation of an extensive reservation system" (Spence, 1999, p. 4). The idea of virgin wilderness was so embedded that indigenous people living in places, like Yosemite, were uprooted from their homelands (Cronon, 1996; Solnit, 2003). Even many Native American advocates, who sought to dismantle the reservation system and assimilate indigenous communities into American society, opposed their return to wilderness. The only way they should be allowed to return to wilderness would be under the condition that they returned as a "civilized" tourist (Spence, 1999). Spence (1999) further notes that if park literature even mentions Native Americans they refer to them as "first visitors," denying their long-term occupation in these places.

This aesthetic conception, so dependent on the sublime, frames wilderness as sacred and neglects or de-values more common landscapes as well (Cronon, 1996; Nash, 1982). As Cronon observes, "One has only to think of the sites that Americans chose for their first national parks-Yellowstone, Yosemite, Grand Canyon, Rainier, Zion-to realize that virtually all of them fit one or more of these categories. Less sublime landscapes simply did not appear worthy of such protection…" (Cronon, 1996, p. 10). Environments

that are not identified as sublime such as bogs and swamps, dunes, deserts, prairies (and backyards) do not get the deserved attention as ecological spaces (Callicott, 1994). This cultural construct of the sublime museum-ifies wilderness while devaluing the environment outside this distinction (Callicott, 1994; Gobster, 1999). Therefore, the inclination to deeply observe, synthesize, create metaphors, analogize, and empathize is missing from this culturally constructed "sublime" aesthetic. Our culturally constructed idea of wilderness compartmentalizes the idea of what is and what is not nature, focusing our attention on what to protect, how to protect it, and what is not worthy of protecting.

Cronon takes the idea of wilderness head on in his widely discussed and influential essay, *The Trouble with Wilderness*. He begins:

> "Far from being the one place on earth that stands apart from humanity, it is quite profoundly a human creation-indeed, the creation of very particular human cultures at very particular moments in human history. It is not a pristine sanctuary where the last remnant of an untouched, endangered, but still transcendent nature can for at least a little while longer be encountered without the contaminating taint of civilization. Instead, it is a product of that civilization, and could hardly be contaminated by the very stuff of which it is made. Wilderness hides its unnaturalness behind a mask that is all the more beguiling because it seems so natural. As we gaze into the mirror it holds up for us, we too easily imagine that what we behold is Nature when in fact we see the reflection of our own unexamined longings and desires. For this reason, we mistake ourselves when we suppose that wilderness can be the solution to our culture's problematic

relationships with the nonhuman world, for wilderness is itself no small part of the problem" (Cronon, 1996, pp. 7-8).

Given this understanding, environmental maladjustment does not begin with the environmental challenges we face in the twentieth century but begins in the eighteenth century with a framing that works to distance us from our relation to our environments. This creates the opening for taking the actions we do, allowing for unsustainable development, tilling the prairies, and protecting only the most picturesque of wilderness areas[13].

Cronon clarifies that it's not wilderness areas that he wants to do away with but the separation our idea of it creates. "By teaching us to fetishize sublime places and wide open country, these peculiarly American ways of thinking about wilderness encourage us to adopt too high a standard for what counts as 'natural'" (Cronon, 1996, p. 22). Any place that isn't grand enough to lose ourselves in, that doesn't bring us closer to the 'sacred' can be dismissed as unnatural and will not necessitate environmentally responsible use. However, if we can take a similar prospective to *home,* then maybe the re-orientation can be of service.

Tracing the Power of the Wilderness Aesthetic in Landscape Photography

The traditional wilderness aesthetic clearly emerges in the photographic work of Ansel Adams, arguably, the most well-known landscape photographer of the 20th century. It becomes evident that Adams' photographic work is also a tool for wilderness preservation. As early as the 1930's, he used his book *Sierra Nevada: The John Muir*

[13] While Cronon may not be specifically attributing this environmental maladjustment to limited aesthetic categorizations, I would argue that aesthetic objects, paintings, photographs, texts, are manifestations of the primary issue; the construction of a particular idea of nature. In effect we are able to understand how wilderness is constructed through the artifacts that very culture creates about wilderness.

Trail, to campaign for the securing of Kings Canyon National Park (Alinder, 1998). Adams, along with the Sierra Club (which he belonged to and was later a board member of), believed that photography could serve to promote wilderness preservation. The aesthetic of choice would elicit the sublime in its effort to foster environmental reform (Dunaway, 2013).

Aligning with a wilderness aesthetic, the two most consistent characteristics of Adams' artwork are the absence of any visible human presence and the grandness of the views. The majority of his images – from their composition, to their vantage point, to the high contrast prints – elicit an image of wilderness strongly coupled with an American picturesque very much in service of the ideal of these places as sacred. These images provide the viewer a vantage point for experiencing the entire scene, the trees, water, mountains, and dramatic clouds and skies. The dodging and burning of the images serves to further accentuate the dramatic light and exalted nature of the scene punctuating its glorious and pristine characteristics. While Adams is applauded for his conservation efforts the work served to further ingrain which nature was sacred and worth preserving.

Image 3: The cover image for Ansel Adams' book *Sierra Nevada: The John Muir Trail* expresses the wilderness aesthetic he is well know for.

Eliot Porter, also a prominent photographer who worked with the Sierra Club, photographed in a different manner than Adams, often photographing patterns in nature, close-up objects, and primarily in color. His photographs often displayed an intimacy with his surroundings that expressed close observation versus grandiose and sublime views. Between the two (Adams more intentionally than Porter) they helped usher in the "aesthetic parameters for nature photography (as distinct from landscape photography)" (Solnit, 2003, p. 201). This is an important distinction because there is a bifurcation between the direction landscape photography moves into, the man-altered landscape, and

nature photography, which is still often associated with the environmental movement and maintains a wilderness aesthetic.

Image 4: "Redbud and cottonwood, Music Temple" from Porter's book *The Place No One Knew* (Porter, 1988)

Nature photography has largely remained unchanged, so much so that its characteristics are easily identifiable and they fail to engage the viewer in a more complex understanding of the human environment relationship. Solnit addresses this stasis by noting that rules for this type of image can easily be spelled out.

1. No human beings or their trace—that is to say, no history.
2. Nothing dead, sick, rutting, dying, or in a state of decay—that is to say, no natural history…
3. Water's main purpose is to mirror, with glasslike perfection, the landscape looming above it, except when flowing over a waterfall or see close up as dewdrops, preferably refracting a flower field, or dangling from a cobweb.
4. Repetition and pattern are good; fifty maple leaves or dewdrops or lilies are better than one…
5. Colors should be bright, though there is an apparent split between those who simply push the colors as far as they'll go in the darkroom and those who used colored lens [filters] to give us a hotrod-bright purple and orange world. (The latter photographers may be the true decedents of Adams, whose Yosemite pictures often feature the black skies of an atmosphereless planet, thanks to his red filter and darkroom expertise.)
6. All animals are lovable and attractive, and unlike humans, they may appear either in the landscape or up close like flowers… If this is nature vacationland, even the animals are on holiday from biology and the labors of survival.
7. The photograph should be so clean as to never call attention to its own creation, but rather to *Creation*… The merit of such photographs is not

> supposed to be the merit of Art but of Nature, and so they compete—unfairly in many ways—with their subject (Solnit, 2003, pp. 201-202).

Photographers throughout the world have imitated Porter and Adams in their efforts to preserve wilderness in their countries. For example, renowned nature photographers Olegas Truchanas and Peter Dombrovskis used their work to bring awareness to and preserve Tasmanian wilderness; Dombrovskis specifically acknowledged Porter and Adams as major influences of his work (Scott, 2014). Their images, like the images of Adams and Porter, were used to influence the public and politicians into preserving wilderness and expanding the size of already designated national parks (Scott, 2014). Indeed, nature photography has been a powerful tool for wilderness preservation but it has also given us an unrealistic and largely counterproductive view of the human/environment relationship. These images "tell hikers and tourists what to look for in the natural world; as a result, they may experience this aesthetic as nature itself rather than as art" (Solnit, 2001, p. 113).

What is particularly interesting about Solnit's statement is that the aesthetic the viewer assigns to the image may not be the fully intended aesthetic the photographer has attempted to express. Eliot Porter became very aware of the ecological complexities at play in his photographs, possibly as a result of his background as a medical doctor, which attuned his observational skills to sensing the relationships at play in nature. James Gleick's book, *Chaos: Making a New Science*, too, resonated with Porter. He "was struck by the way the new scientific ideas seemed to describe nature as he had been attempting to describe it with his camera…" (Solnit, 2001, p. 123). Porter was aware of the

ecological processes at play in the places he photographed and attempted to express those processes, yet what viewers took away was a more simplistic representation; one that only dealt with the idealized beauty of nature's pristine representation, only now in color.

We find ourselves in a position where there is a give-and-take between the producer of images and the consumer of those images. While we expect photographers to more fully express the complexities of our world in a compelling manner we also require a consumer with a further developed sense of how the natural world operates. We want artists to expand awareness not further reinforce an unrealistic view of the world; however, viewers may not be able to read into what the artist hopes to do if there isn't a threshold of understanding regarding the (in this case) environmental issues at stake. Moving forward requires a cultivation of the artist's and viewer's understanding of ecology, and for us the broader sustainability issues, so that once the discourse is introduced both scientifically[14] and artistically we can be prepared to engage: scientist, artist, and citizen alike. I turn to Aldo Leopold as an exemplar of this artist-scientist method. As I will argue, his process is a developmental approach that seeks to unify and consciously develop our scientific and aesthetic sensibilities.

Aldo Leopold's Path to Incorporating an Aesthetic

One of Leopold's most well known remarks in *A Sand County Almanac* (1949) specifically addresses aesthetic sensibilities. A true land ethic, he writes, requires us to "Examine each question in terms of what is ethically and esthetically right, as well as what is economically expedient. A thing is right when it tends to preserve the integrity,

[14] This is not to suggest that the only necessary development is ecological but that artists have developed the necessary skills to elicit an affective response and the component they are missing is an ecological lens that informs their work. Therefore, what is still necessary is an embodiment of both artistic and scientific practices.

stability, and *beauty* of the biotic community. It is wrong when it tends otherwise" (Leopold, 1966b, pp. 224-225). However, as mentioned above the inclusion of aesthetics is a synthesis that is difficult to articulate, one that even Leopold did not include in his early writings (Flader & Callicott, 1991) – and possibly one that he previously discounted. His professional training as a forester in the early years of the 20th century, which emphasized narrowly scientific management techniques and resource optimization, likely also limited the role aesthetics could play in his early views of resource management.

Leopold began his career in forest management and was trained in alignment with the reigning utilitarian ideals of conservation in the early 20th century (Callicott & Freyfogle, 2001). For Gifford Pinchot, the first head of the U.S. Forest Service, conservation stood for responsible resource development (Callicott & Freyfogle, 2001) – an idea that parallels the anthropocentric construct of sustainable development. However, Leopold's ideas about the purpose of conservation would eventually evolve from these early foundations in utilitarian resource management to encompass a wider philosophical and ecological vision of "land health" in the 1930s and 1940s (Minteer 2006). Indeed, although he grew up with a strong appreciation for the arts and outdoors both as a naturalist and sportsman (Meine, 1988), Leopold's aesthetic and ethical thinking would take some time to reach its full maturity. It did so in *A Sand County Almanac,* which took shape more than 30 years after he began his career and when had established his credibility as a land manager and scientist (Nabhan, 1999).

Leopold had witnessed many changes and challenges in conservation and land management in the first half of the 20th century, and this experience seems to have

created an understanding that neither science, nor economics, nor government regulations alone would single-handedly alleviate the environmental challenges the United States was facing.[15] In spite of great efforts, the Southwest was still plagued by dramatic erosion, in the Midwest topsoil was blowing away, and game management, focused on specific "useful" species, was destroying habitat and those species (e.g., predators like wolves) deemed to lack recreational value. Leopold warned that these methods, when not aligned with a more holistic ecological understanding and appreciation for the land, could only result in environmental degradation and destruction.

As his ecological understanding developed over the course of his career, Leopold continued to provide practical advice for maintaining the integrity of the land. He wrote articles for scientists, farmers, and lay people, and put forward a mix of economic and scientific arguments for maintaining ecological integrity. But his message did not always produce the desired results. He voiced his frustration in his 1947 essay "The Ecological Conscience" by stating, "Everyone should be dissatisfied with the slow spread of conservation to the land" (Leopold, 1991b, p. 338). Leopold's evolving ideas, founded in ecological principles, often conflicted with the dominant and narrower utilitarian ideals of conservation (Meine, 1988; Newton, 2006). The development in his writing implies that he came to a significant realization that people had to care for and appreciate the land, without that, science and economic reasoning alone would only produce mediocre, if not undesired, results.

[15] Curt Meine's biography, *Aldo Leopold: His Life and Work* and Julianne Lutz Newton's book, *Aldo Leopold's Odyssey*, track the evolution of Leopold's ideas and the societal context that led to the development of his land ethic. Susan Flader and J.Baird Callicott chart his maturation via his previously unpublished writings in their collection of Leopold's essays in *The River of the Mother of God and other Essays by Aldo Leopold*.

Leopold recognized that an aesthetic sensibility was just as critical as a scientific one and the treatment of land was a result of a person's ecological, ethical, and aesthetic understanding. The development of this trinity was the necessary social evolution that would create internal change both in the individual and broader community (Leopold, 1966b). "No important change in ethics was ever accomplished," he wrote, "without an internal change in our intellectual emphasis, loyalties, affections, and convictions. The proof that conservation has not yet touched these foundations of conduct lies in the fact that philosophy and religion have not yet heard of it. In our attempt to make conservation easy, we have made it trivial" (Leopold, 1966b, pp. 209-210). In effect, Leopold's continued ecological development was a way of calibrating his ability to see the land more clearly. The ecological perspective produced a change in the mental eye, which created a shift in perception, introducing a nuanced multi-dimensionality. Appreciating the land now took on new meaning as it was seen in its wider evolutionary and ecological context.

Leopold's Aesthetic of Engaged and Educated Appreciation

"If you look at your hand and consider it… as a nest of relations you will find that the object looks much prettier than you thought it looked this means that with a correction of our epistemology you might find the world is a great deal more beautiful than you thought it was. Not only that but you wouldn't be able to collect things, the whole problem of possession begins to look totally different" (Bateson, 51:17).

As mentioned earlier, Leopold grew up with an appreciation for the outdoors (specifically, the woods and fields of late 19th century Iowa) and a personal ethic associated with responsible sportsmanship. The seeds of an integrative perspective, in

other words, were planted in him at an early age (Meine, 1988). But as we've also seen, his land aesthetic did not fully materialize until late in his professional and writing career. Consider, for example, the young Leopold's essay (written when he was still in his teens), *A Tramp in November* (1991e), a piece that expresses a fairly conventional environmental aesthetic in Leopold's discussion of the "picturesque view from the top of Stony Mountain" (Flader & Callicott, 1991, p. 8). Though he demonstrates a propensity toward environmental reflection, it's not hard to conclude that Leopold inherited the culturally accepted schemas of a picturesque aesthetic. It was through his subsequent ecological and evolutionary education and practical experience as a forester, wildlife manager, and most importantly, perhaps, as a landowner, that he developed an aesthetic sensibility more aligned with complex and evolving environmental systems.

Although his writing reflected a steady and deliberate process of growth and development, Leopold's 1933 essay, "The Conservation Ethic," demarcates an especially significant evolution in his ecological understanding – and a further development in his idea of a land ethic. To see this evolution, though, we need to go back to his early essay "Some Fundamentals of Conservation in the Southwest" written ten years before. I highlight this piece for two reasons.

First, it's significant because it's a clear indication of Leopold beginning to address moral (and perhaps even metaphysical) considerations regarding land use, i.e., what's right or wrong with respect to the human-nature relationship. Ten years later Leopold's ethical reasoning about the land (by which Leopold meant what we'd refer to today as the ecosystem) had evolved to incorporate a more pronounced and informed method of ecological reasoning (Newton, 2006). Second, he is presenting his

"Conservation Ethic" lecture in the Southwest, so the intended audience for both essays is probably very similar, though the approach has significantly changed.

Leopold spends a good deal of space in "Some Fundamentals of Conservation in the Southwest" making a resource stewardship and economic argument for conserving resources and reducing erosion in the Southwest. In fact, he dedicates more than two-thirds of this essay to economic reasoning before he raises the issue of morality in the essay's final section ("Conservation as a Moral Issue"). Leopold explains his reason for this disproportionate emphasis by stating that "economic determinism is so habitual to Americans in discussing public questions that one must speak in the language of compound interest to get a hearing" (Leopold, 1991d, p. 94). But he then develops his moral argument for conservation by quoting the Bible and catering to the possibility that if the Earth is a 'living organism', as the Russian philosopher Ouspensky argues, then we should reconsider how we care for the land. Leopold's argument for care is more spiritual and metaphysical than ecological at this stage in his intellectual development; we should care about the land because it's morally right to do so. He is still hesitant to state that this framing will change behavior but he is clearly appealing here to moral rather than purely economic reasoning.

A decade later, in "The Conservation Ethic", Leopold has dramatically reorganized his argument. He not only places ethics front and center, he draws attention to two critical normative and ecological elements: the significant issue of identifying land simply as property and our inability to see our symbiotic place in the land community. Interestingly, Leopold is now no longer leaning on scripture; instead he anchors his argument in an evolutionary and ecologically based ethic. Biologically and

philosophically, Leopold notes that ethics are modes of cooperation based on the recognition of interdependence both at the individual and societal level (Leopold, 1991a). He writes that these modes of cooperation are primarily agreed upon among individuals but no ethic has yet been established for our dealings with the rest of the land community, and that they will not develop as long as we view all things not human merely as property. Leopold takes a strong stance in the essay, stating that science cannot dismiss ideas of right or wrong in our dealings with land. He continues, "no ecologist can deny that our land-relation involves penalties and rewards which the individual does not see, and needs modes of guidance which do not yet exist. Call these what you will, science cannot escape its part in forming them" (Leopold, 1991a, p. 182)[16].

He then creates a larger systemic picture of the ecological variables that have economic implications. Specifically, Leopold provides examples of how our historical treatment of the land has triggered particular succession events. The results of these events uncover value-laden motivations for rendering particular lands desirable, such as agricultural lands, or valuing other lands as worthless. He notes that these "Unforeseen ecological reactions not only make or break history in a few exceptional enterprises—they condition, circumscribe, delimit, and warp all enterprises, both economic and cultural, that pertain to land" (Leopold, 1991a, p. 185). Here Leopold is grounding his argument in the fact that economic reasoning is shortsighted and that we are not going back far enough in the causal links that shape our relationship to land. Furthermore, we

[16] Although Leopold's "The Land Ethic," one of his final essays in *A Sand County Almanac,* is built out of several earlier works, "The Conservation Ethic" heavily informs it. Still, it is the land ethic essay, written 15 years later, where he takes his most notable ethical stance on what he believes. He states, *"A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise." (Leopold, 1966b, pp. 224-225).*

are leaving these ecological occurrences to chance by failing to understand the mechanisms that affect change.

Leopold continues to pick apart the potential arguments that legislation or economic self- interest will rectify the issue, providing several failed examples where these approaches were implemented. "The real end", he states, "is a *universal symbiosis with land*, economic and esthetic, public and private" (Leopold, 1991a, p. 188). This statement is significant for what follows. He has defined a purpose for conservation, symbiosis with the land, and then proceeds to identify how several approaches continue to miss the true objective. All the "isms—Socialism, Communism, Fascism, …Capitalism" are in service of "*salvation by machinery"*(Leopold, 1991a, p. 188). Their purpose is to adjust man to machines in service of more commodities; they all fail to adjust man and machines to land. When the purpose is not aligned to the land community no collective label will assist in righting the issue.

Yet Leopold doesn't take it easy on the conservation movement, either. He addresses those he identifies as the "cult of the barbless hook" and the "conservation-booster" again for their misguided objectives. Those belonging to the "cult of the barbless hook" may refrain from particular activities such as the use of modern technologies of the time, but at most, it serves to boost the individual's self-esteem. The "conservation-booster" will champion conservation in order to attract the tourist looking for outdoor recreation. He/she is motivated by the potential increase in tourism versus symbiosis with the land. The methods used by the isms to the conservation archetypes fail to address the real issue, understanding our place within the land community.

This ecological development and internalization takes time, effort, and motivation. Although he is steadily building a scientific argument he does not discount "the love of nature." In fact, he holds it up as one of the critical factors to a re-orienting of our priorities and proceeds with potential methods for appreciating the land and developing a deeper understanding of its processes. This is not merely a "new diversion for the idle rich," the demographic most closely associated with landscape appreciation, but for any willing participant. Furthermore, this wasn't an endeavor merely for "spade and pruning shears" but a way to draw in "invisible forces" that determined land health (Leopold, 1991a, p. 191). This new method of landscape appreciation would be nothing less than a "renaissance," a creative enterprise that could yield both utilitarian and aesthetic outcomes.

While this essay was focused on demarcating a conservation ethic, it also marks a significant shift that reframes his aesthetic sensibilities as well. The notion of the *sublime* central to the *picturesque* is coupled to a sacred and spiritual framing that created a division between man and nature. Leopold's evolutionary and ecological language signifies a break in a traditional aesthetic and the development of an ecological one. He also makes his stance clear regarding disinterestedness, one did not visit the museum to appreciate nature's qualities but found it through direct engagement with the land (Leopold, 1991a). No need for distanced appreciation. Additionally, he was championing a democratized aesthetic development, commenting that even the dirt farmer can be engaged in the creative use of land and perhaps more so than "esthetic priests." He champions open and informed engagement but implies as well that aesthetics have an important role to play in the objective, symbiosis with the land. "Economic laws may be

permanent, but their impact reflects what people want, which in turn reflects what they know and what they are" (Leopold, 1991a, p. 191). Such engagement with land could serve to align individuals and communities with the land; this then could help them see more causal links in the ecological chain, ultimately impacting the economics of land-use. Leopold ends his argument not with a statement of moral duty but by framing an opportunity that will enrich each individual that can expand his/her ecological understanding[17].

[17] Leopold was specifically attuned to the role perception played in our relationship to land. I focus on wilderness aesthetics in this chapter but he applied the idea of direct engagement to all human-environment aspects. His comments that, "There are two spiritual dangers in not owning a farm. One is the danger of supposing that breakfast comes from the grocery, and the other that heat comes from the furnace." (Leopold, 1966b, p. 6) and "Like all real treasures of the mind, perception can be split into infinitely small fractions without losing its quality. The weeds in a city lot convey the same lesson as the redwoods;" (Leopold, 1966b, p. 174) express his focus on the fact that this awareness related to all environmental spaces humans operate in; wild, agrarian, and urban.

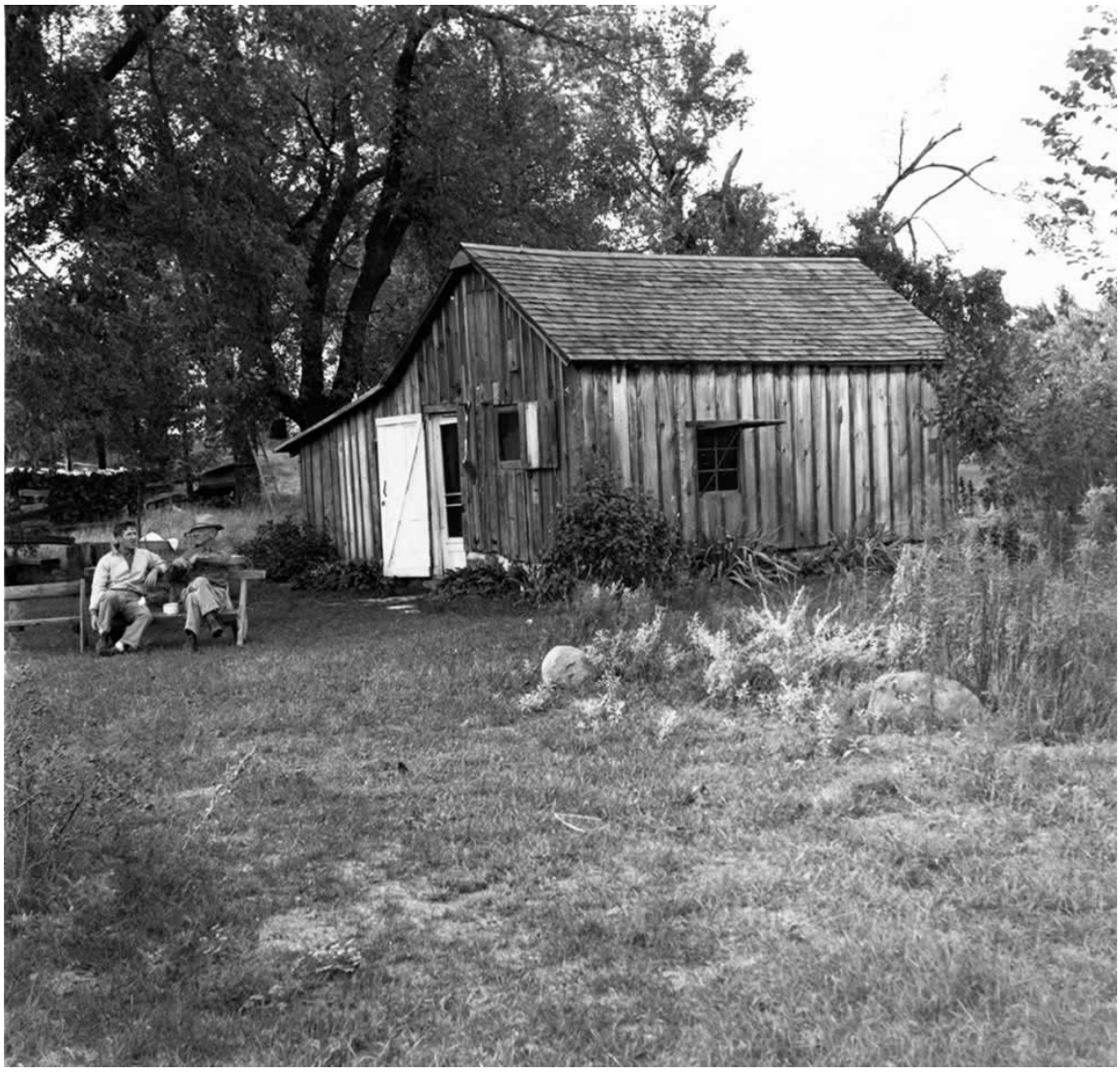


Image 5: Aldo Leopold purchased an abandoned farm near Baraboo, WI and reconditioned an old chicken coop, which became known as "the Shack." The farm became a testing ground for restoring the land health on an ecologically depleted farm. Many of the stories in *A Sand County Almanac* pertain to the time he spent on this farmstead (Aldo Leopold Archives, 1940).

Two years later, in "Land Pathology" Leopold folds together aesthetic, ecological, and ethical values in the creation of his land ethic, which is more potent than the sum of the three (Leopold, 1991c). In effect, his aesthetic appreciation of the environment becomes explicitly coupled to his evolutionary and ecological understanding – and all three become implicated in his moral injunction to promote the health and integrity of the

land. He begins this reasoning by stating that conservation "seeks to preserve both the utility and beauty of the landscape" and it is calling on science in this effort. He acknowledges that science has not previously been called upon to "write a prescription for an esthetic ailment" but "The effort may benefit scientists as well as laymen and the land" (Leopold, 1991c, p. 212). Ultimately, his essay is an effort at unification. He takes issue with the manner in which conservationists break systems up into parts and focus on a single area. Leopold views this subject fragmentation by conservationists as a limitation on "taste, knowledge, and experience," (Leopold, 1991c, p. 213) or the inability to see the whole, which also reflects the art/science divide in addressing land issues. He proceeds with two assumptions. First, all pieces are connected, from the soil to the people; therefore, all conservation issues are of similar origin. The other assumption is that "economic and esthetic land uses can and must be integrated, usually on the same acre. To segregate them wastes land, and is unsound social philosophy" (Leopold, 1991c, p. 213). He has not discarded his pragmatism in addressing land issues but proposes that dismissing the elements associated with land aesthetics is problematic for solving complex socio-ecological challenges. In effect, he is stating that it is impractical to think that people will make good use of land they do not care for it.

There is, then, no separating the aesthetic from conservation issues. The challenge is whether Leopold's understanding of "good taste" and "technical skill" can both exist in one person. He sees no way around it, as individuals and communities we must work to develop both to take appropriate action. We must develop a land ethic and critical to that would be ecological understanding and a "revival of land esthetics" (Leopold, 1991c).

Long before Hepburn's (1966) seminal article, "Contemporary Aesthetics and the Neglect of Natural Beauty," proposes a new environmental aesthetic grounded in scientific understanding and open engagement, Leopold has developed a his own similar approach to nature appreciation. Perhaps Leopold is able to come to this realization because he is not enmeshed in the philosophy of art and, therefore, does not get weighed down by the aesthetic debates. Instead, he begins to embody an aesthetic that does not get articulated in the field of aesthetics for another 20 years.

Leopold is aware that the picturesque aesthetic is maladapted to his time. He states that the "taste for country" like any other taste, displays a "diversity of aesthetic competence." He continues, "There are those that are willing to be herded in droves through 'scenic' places; who find mountains grand if they be proper mountains with waterfalls, cliffs, and lakes. To such the Kansas plains are tedious" (Leopold, 1966a, pp. 179-180). It's as if he's responding directly to the work of Ansel Adams – remarking that while beautiful – it is a naïve and codified aesthetic that reinforces what is appealing, "proper mountains with waterfalls, cliffs, and lakes." and giving no critical reflection to the beauty of the places we live in. All is not lost, however. A more ecological aesthetic can be nurtured, expressing that "Our ability to perceive quality in nature begins, as in art, with the pretty. It expands through successive stages of the beautiful to values as yet uncaptured by language"(Leopold, 1966b, p. 96). An aesthetic, in Leopold's view, can evolve; it is responsive to our ability to deeply observe and perceive the ecological context in which we live. This process, in fact, has been made clear in his own transformation. In *A Sand County Almanac,* he expresses a nature-oriented aesthetic

sophistication that is significantly derived from a synthesis of his evolutionary, ecological, and professional understanding.

As previously stated, Leopold begins his carrier with Pinchotian ideals of resource management, not closely tied to ecologic principles. This focus shifts in the 1930's when his essays begin to express a stronger ecological perspective. This development has in turn a significant effect on his aesthetic perception. His writing during this period expresses the central role evolutionary and ecological understanding has on his aesthetic sensibilities.

In hindsight, several events are thought to have influenced this shift in Leopold's writing. His visit to the overly managed German forests in 1935 brings about an epiphany. He experiences an artificiality that has lost its evolutionary context. The ecological complexity of natural systems is barley recognizable in these overly managed forests. In his essay, "Wilderness," he concludes, "I never realized before that the melodies of nature are music only when played against the undertones of evolutionary history" (Leopold, 1991g, p. 229). Purchasing "the shack" in Sand County, Wisconsin provides him the opportunity to put his ideas to work on the land and witness its development with all its joys and frustrations. The Great Depression and the Dust Bowl create significant frustration regarding the economic solutions suggested. World War II further solidifies the priorities of the country, conservation concerns taking a back seat to war efforts (Meine, 1988). When the focus is set on economic interests, conservation efforts waiver, but an appreciation for the land creates a deeper connection that isn't easily shaken.

Perhaps this realization strengthens his resolve to communicate the evolutionary and ecological diversity in *A Sand County Almanac* with an aesthetic sensibility. In "Marshland Elegy*,"* he refers to the crane as no mere bird and, when his call is heard, "We hear the trumpet in the orchestra of evolution. He is the symbol of our untamable past, of that incredible sweep of millennia which underlies and conditions the daily affairs of birds and men" (Leopold, 1966b, p. 95). Leopold then connects this crane to the marshes they inhabit; "a crane marsh holds a paleontological patent of nobility, won in the march of aeons... The sadness discernible in some marshes arises, perhaps, from their once having harbored cranes. Now they stand humbled, adrift in history" (Leopold, 1966b, p. 97). Although all elements in the ecosystem may not contribute equally, Leopold finds them to be integral to the appreciation of the biotic community. "Everybody knows, for example, that the autumn landscape in the north woods is the land, plus a red maple, plus a ruffed grouse. In terms of conventional physics, the grouse represents only a millionth of either the mass or the energy of an acre. Yet subtract the grouse and the whole thing is dead. An enormous amount of some kind of motive power has been lost" (Leopold, 1966b, p. 137). He expresses an appreciation for the ecological complexity that supports the biologic diversity; his aesthetic appreciation for the land cannot be separated from his cognitive understanding.

Interestingly, Leopold adopts and transforms the Kantian aesthetic, as well as discarding of some components. This natural aesthetic he expresses, which is informed by an ecological and evolutionary understanding, echoes Kant's desire to connect the intellect to aesthetics (Callicott, 1994). However, it's transformed in Leopold's hands by scientific understanding. Where contemplation may have been enough for Kant, Leopold

infuses that contemplation with a deeper scientific understanding of the land; appreciation of the picturesque is insufficient.

Where Leopold significantly veers from a Kantian aesthetic is in his divergence from the *disinterestedness* so central to Kant's sublime. He hints at this distancing in his essay "65290*,"* commenting that "Books on nature seldom mention wind; they are written behind stoves" (Leopold, 1966b, p. 91). How can one properly take in the experience of nature without truly experiencing it? In fact, for Leopold the naturalist, the cognitive components serve to enrich the direct experience of being in nature versus providing a buffer. But there was a risk that one part of experience would be taken as the whole. "Education, I fear, is learning to see one thing by going blind to another." (Leopold, 1966b, p. 158). Leopold even warns that a Ph.D. can make one just "as callous as an undertaker to the mysteries at which he officiates" (Leopold, 1966b, p. 174). Not connecting a personal experience to a cognitive one is doomed to pure abstractions.

A Sand County Almanac is full of anecdotes that express Leopold's direct engagement with the land and its sights and sounds, in many ways that was the intent (Daniel Berthold, 2004). However, his focus on understanding and engagement are especially revealed in passages advancing his ideas on education. Here, Leopold makes it very clear that both cognitive and sensual engagement are critically important. In "Wherefore Wildlife Ecology," he identifies the course objectives for his wildlife ecology class, specifically connecting their scientific education to an aesthetic sensibility (Flader & Callicott, 1991, p. 336). He connects the literature to observational skills, stating, "I am asking you to read the best professional literature, but in the field to use only the eyes, ears, and notebook which everybody carries" (Leopold, 1991f, p. 336). He then closes by

warning again about favoring a scientific approach not balanced with aesthetic engagement:

> "I think I know what the fallacy is. It is the assumption, clearly borrowed from modern science, that the human relation to land is only economic. It is, or should be esthetic as well. In this respect our present culture, and especially our science, is false, ignoble, and self-destructive. If the individual has a warm personal understanding of the land, he will perceive of his own accord that it is something more than a breadbasket. He will see land as a community of which he is only a member, albeit now the dominant one. He will see the beauty, as well as the utility, of the whole, and know the two cannot be separated. We love (and make intelligent use of) what we have learned to understand.…Once you learn to read the land, I have no fear of what you will do to it, or with it. And I know many pleasant things it will do to you" (Leopold, 1991f, p. 337).

Leopold states his position clearly; one cannot understand the land solely through scientific understanding or simple aesthetic appreciation. But together they help the student of the land to see more clearly and appreciate more deeply how he/she is connected to the land and why he/she should care.

A Sustainability Aesthetic

The driving argument of this chapter has been that our sustainability science must be coupled to an aesthetic for sustainability. We are not starting at the very beginning in the development of an aesthetic; the idea of a natural aesthetic is not new. Environmental aesthetics has been an established field. Ecological aesthetics took hold in the 1960's giving us a clear connection between ecology, art practice, social action, and

environmental engagement (Kagan, 2011). However, it has morphed in academic circles more steadily than we see in popular culture. Cultural researcher, Hildegard Kurt notes in reference to an appropriate aesthetic that, "The sustainability debate will find its own justification when it shows the way to new strategies and structures, and thus to improve structural conditions for transdisciplinary creative work that includes artists on equal footing" (2004, p. 239). Thus, the work is a process of reorganization and integration into the larger sustainability dialogue. This sustainability aesthetic is not intended to diminish the work in sustainability science, rather, it is meant to further add to the holism and complexity that bridges our scientific understanding, with the values and meaning-making that brings into focus social and ecological relationships.

As the previous section discusses, Leopold's aesthetic, which was inextricably linked to his understanding of ecology and ethics, provides us with a valid starting point for a sustainability aesthetic. I think we can draw three main lessons from Leopold about the constitution of an aesthetic. It needs to be: 1) informed, 2) engaged, and 3) integrative. Leopold provides us with a dynamic aesthetic framework; heuristics that are meant to be adaptive to contextual change so that our aesthetic can evolve with the changes we witness over time.

An Informed Aesthetic

Leopold repeatedly advocated for developing an aesthetic informed by ecology and evolution. He felt that ecology had changed the way we envisioned the world, a *new mental eye*, and that this new understanding affected both our scientific understanding and our aesthetic appreciation. It was not nature that needed reordering but our idea of what 'ordered' meant. This understanding altered our experience of places and helped us

see the "invisible forces" at work. As we develop an ecological understanding of the world our aesthetic perception shifts, our experience becomes grounded in a more sensitive perception of place, both at temporal and spatial scales and in the relationships that unfold. It affects how we appreciate/care about/recognize moral duties toward nonhuman nature.

Sustainability science is inter- and transdisciplinary by its very nature. Scientists in the field have worked to bridge boundaries between the life and social sciences. As this is extended to the arts we can create a "poetic science," one that not only works to organize information but that helps organize our experiences. This is not a simple illustration of scientific ideas, either. It is an internalization by the artist, which informs his/her approaches to creation. The artist includes this understanding into the creative practice now working from a broader epistemological palette. The ultimate result is a product that is both compelling and enhances the viewers ability to engage in the broader sustainability dialogue.

An Engaged Aesthetic

For Leopold an aesthetic was not something to be simply appreciated in books or as secondary experiences; rather, it was to be accessed through direct engagement. He clearly expresses this sentiment in his essay, "On a Monument to the Pigeon" (in *A Sand County Almanac*) in which he writes, "There will always be pigeons in books and in museums, but these are effigies and images, dead to all hardships and to all delights. Book-pigeons cannot dive out of a cloud to make the deer run for cover, or clap their wings in thunderous applause of mast-laden woods. Book-pigeons cannot breakfast on new-mown wheat in Minnesota, and dine on blueberries in Canada. They know no urge

of seasons; they feel no kiss of sun, no lash of wind and weather." (Leopold, 1966b, p. 109).

A Sand County Almanac contains many anecdotes regarding Leopold's direct experience with the outdoors. Such experiences were antidotes to scientific formalism. Indeed, he commented often about the ease with which an individual could develop a callous nature towards what he/she studied. Leopold was after a heightened level of awareness; his essays regularly implied that perception took place during acts of engagement with the environment, whether it was on the farm, in the forests, or in the city (Leopold, 1966b). A quote from photographer and conservationist Eliot Porter drives this point home. Porter writes, "As I became interested in photography in the realm of nature, I began to appreciate the complexity of the relationships that drew my attention" (Solnit, 2001, p. 113). This engagement through the photographic process no doubt created a heightened level of perception for Porter. Individuals can look at Porter's work and appreciate the qualities of the images and connect it to some environmental sentiment they may have, however, this mere contemplation and enjoyment of the images does not necessarily reveal the complexity that Porter experienced; that required personal engagement.

Sustainability science is committed to understanding human/environment *interactions*, therefore operates actively in the world. However, an aesthetic engagement addresses the human/environment *relationship*; it pulls from a more personal understanding. This ability to relate is the empathy that instills an ethic. Ecological understanding was only an element, however crucial, of the internal shift Leopold was after. "To promote perception is the only truly creative part…" he remarked (Leopold,

1966b, p. 172). This perception could not be bought or earned with a degree, but was homegrown; the citizen still had to experience his/her environment, step out into the world.

But with this new understanding one could now see the value of both mountains and weeds in the parking lot (the "relative wild," as historian and Leopold biographer Curt Meine (2015) puts it). Leopold saw ecological principles at play in the wild and urban, they were different on the surface but if one looked deeper, the differences dissolved. His aesthetic opens a door that is still not walked through often today. He bridged the division between the urban/nature divide by focusing on the individual's ability to perceive his/her environment. Nature was in the city and in the wilderness and it followed the principles of ecology. These unifying principles allowed for an informed and engaged appreciation of natural elements in any location. As sustainability science works to synthesize the social and life sciences, Leopold's words remind us that this integration is still missing the critical humanistic perspective. It will not necessarily create the appreciation that he believed was necessary for a mental shift. Without a developed aesthetic the perceptual calibration is incomplete; we are left with a discolored image the world[18]. Hence, creating an engaged method for caring about sustainability issues is a foundational step in further developing a dialogue about what matters.

[18] When I refer to calibration, I envision the process of color calibrating a computer monitor. You place a device on your monitor and it will check the accuracy of your screen color, the operator then goes about shifting the red, green, and blue to arrive at the desired objective. This is an iterative process. Once you correct one color, another color will shift, as you correct the next two colors you may have to return to the first and correct it again. This back and forth continues until you reach the desired result. In a similar fashion, ecology changes how we see but an aesthetic also changes and raises new questions that requires us to return to ecology, on and on it goes. I have pulled these two elements because it's the two we are speaking of. I have not forgotten about ethical aspects, I have merely refrained from commenting directly on them in this analogy.

An Integrated Aesthetic

Most critical to an informed and engaged aesthetic is the necessity of synthesis. The goal is to understand how aesthetics contributes to the framing of issues and decision-making processes in addressing sustainability challenges. Van der Leeuw et.al. (2011) address the fragmentation brought about by a "reductionist" approach and parallel solving sustainability challenges in the same manner one might solve a Rubik's cube. They note, "One cannot get the cube "in order" (so that each side has one homogeneous color) by dealing first with one side, then the next, and so forth. The only way to arrive at "order" is by looking at the patterns (symmetries) on all sides simultaneously and not favoring any particular one at any time. This may be the most difficult of these challenges to meet." (van der Leeuw et al., 2011, p. 2).

Perhaps Leopold's most significant contribution to our framing of socio-environmental problems was articulating the relationships among the parts; what connected the parts and how they operated in conjunction to one another. He illustrates the necessity of this type of thinking in his essay "Natural History." Leopold remarks that students studying the bones of a cat has relevance in that it may teach us about the evolutionary process, but this study fails to tell us about the relationships that cat may have had to its environment. Take these same bright students into the field and see how they fare:

> "We are driving down a country road in northern Missouri. Here is a farmstead. Look at the trees in the yard and the soil in the field and tell us whether the original settler carved his farm out of prairie or woods. Did he eat prairie chicken or wild turkey for his Thanksgiving? What plants grew here originally which do

> not grow here now? Why did they disappear? What did the prairie plant have to do with creating the corn-yielding capacity of this soil? Why does this soil erode now but not then?" (Leopold, 1966a, p. 208)

Leopold then connects how social realities relate to land health as well:

> "Again, suppose we are touring the Ozarks. Here is an abandoned field in which the ragweed is sparse and short. Does this tell us anything about why the mortgage was foreclosed? About how long ago... Does short ragweed have any connection with the human story behind yonder graveyard?" (Leopold, 1966a, pp. 208-209)

He draws on these examples to bring home the importance of understanding relationships, both environmental and social -- and how they are related. I think Leopold is drawing these relationships into a single ecology focused on systems, what Kagan (2011) terms "patterns of complexity" central to understanding sustainability problems. Leopold often extended the idea of ecology to mean the organizing relationships that applied to environmental and social systems. Indeed, Meine notes that Leopold commented on the false social and environmental dichotomy in some of his unpublished work:

> "One of the anomalies of modern ecology is that it is the creation of two groups each of which seems barely aware of the existence of the other. The one studies the human community almost as if it were a separate entity, and calls its findings sociology, economics, and history. The other studies the plant and animal

> community, [and] comfortably relegates the hodge-podge of politics to 'the liberal arts.' The inevitable fusion of these two lines of thought will, perhaps, constitute the outstanding advance of the present century." (Meine, 1988, pp. 359-360)

Likewise, my objective in regards to sustainability is a matter of introducing the environmental and ecological aesthetic practices that have been at play into a meaningful structural integration and dialogue with the sciences. Natural aesthetics are one side of the Rubik's cube that must be addressed in conjunction with the other components. We must recognize that as we act on each element we shift all pieces; we can work to clarify that organization but only by being mindful of all sides.

Finally, the goal Leopold set out is two-fold. He wanted us, as scientists and artists, to develop a more sophisticated understanding and level of communication that created a balanced understanding of our place and responsibility in our professions and as human beings. Second, this was not relegated simply to professional artists and scientists but accessible to every layperson willing to know more about the world he/she lived in and the wonders it could unfold for him/her if they took both ecology and aesthetics seriously.

Conclusion

In this chapter I have identified two specific competencies; scientific and artistic skill sets. The process is one of active engagement and trained observation. The result is a more highly sensitized level of perception. The entire process is iterative, the accumulation of more knowledge in an engaging observational process allows not only for new levels of perception but new questions as well.

What Leopold makes clear is that aesthetics, ethics, and science rest on each other; you cannot hope to develop them in a vacuum (Knight & Riedel, 2002; Leopold, 1966b). If we want something that resembles what he described as an ecological conscience these domains must operate in concert. This is a challenge, one that Leopold struggled with, even though he had internalized this synthesis (Newton, 2006). Understanding his challenges and approaches to communicating an ecological conscience can aid the sustainability community in creating a space for this type of integrative work between the arts and sciences.

We know that systemically, all parts effect each other. Our ecological understanding reframes how and what we observe, which can change our ethic and aesthetic perception and our aesthetic observations also reframe the way we see the world and the questions we ask, potentially affecting our ethical stance and ecological understanding. That understanding helped Leopold create the metaphors that linked these systems together. A shift in perspective meant a shift in relationship to the land and that shift was multifaceted. It was our knowing, caring, understanding, and appreciating the dynamics of the land community that would provide a mental shift. With this realization he knew he could provide a shift with his metaphors and prose, but he also knew that his work was hopefully a catalyst for individual action.

Sustainability science is making progress; it has attempted to encompass the necessary elements; environment, society, and economy but a specific sustainability conscience, like the ecological conscience that informs Leopold's land ethic, has yet to develop. While we work to deal with sustainability challenges, local and global, a firm aesthetic grounding is still in need of being worked out. Leopold realized that this

grounding was a result of a "deeper understanding and appreciation of the land" (Leopold Bradley & Huffaker, 2002, p. X), one that, for him, involved the integration of ecology, aesthetics, and ethics. He was very much a champion of ecology but was also clear that "We can be ethical only in relation to something we can see, feel, understand, love, or otherwise have faith in" (Leopold, 1966b, p. 214).

Science was not going to save the world, in fact, formal education often fragmented our understanding (Kessler & Booth, 2002; Leopold, 1966b) and we needed a holistic comprehension of how we fit into the ecological community. Understanding the elements and the interconnections of a system is important, but developing and understanding the purpose for action is the most critical (Meadows, 2008). I believe that's what Leopold was trying to do for the earlier conservation movement. As he understood, this necessary integration is not an easy process, but the iterative interrogation of meaning making that germinates the seeds of purpose are more easily found in the arts. Leopold realized this and proceeded to create his land ethic from this synthesis, providing readers an access point for their own mental shift (Leopold, 1966b; Meine, 1988; Newton, 2006).

Some sustainability challenges we are witnessing today are similar to Leopold's conservation challenges and some are of a different more global nature. Still, looking at historical exemplars like Leopold is an integral step in creating an understanding about how to move into the future. Most historical analyses focus on creating analogs between the past and present situation (van der Leeuw et al., 2011). Another approach, which I have taken, is what van der Leeuw et.al. (2011) consider an evolutionary approach, which focuses on a systemic understanding of the dynamics at play. This allows us to use the

lessons we learn and apply them to novel situations, as those situations change we can adapt with them. Ultimately, this is Norton's (2005) adaptive management approach, which he attributes to Leopold. What I have attempted to do here is point out that Leopold's aesthetic was an integral part of his 'adaptive management' method, which means his aesthetic was also fluid and adaptive to context. He challenged the idea of a wilderness aesthetic because it was a stagnant perspective that didn't incorporate developments in our ecological understanding.

But let me be clear. I don't believe that sustainability is still tied to a picturesque wilderness aesthetic. What I am suggesting is that sustainability has not chosen *any* aesthetic and that neglect allows for any propagandist to pick one that serves their needs or leaves citizens to choose what aesthetic they identify with sustainability. This is therefore an opportunity for sustainability scientists and scholars, artists included, to create a dialogue and working relationship in service of sustainability. Whether we accomplish this as individuals or as collaborators, the cross-pollination creates an outcome that is humanistic and scientific in addressing and interrogating what we know and what we value. We know that an aesthetic framing affects how a problem is tackled, not only do we not want to leave that to chance, we hope to create an informed, imaginative, and engaging aesthetic that invites everyone to explore their backyards just as much as their national parks. This invitation is a necessary introductory step into developing a sustainability conscience.

CHAPTER 3

MOVING BEYOND THE BEAUTIFUL, SUBLIME, AND MAN-ALTERED LANDSCAPE TO AN EDUCATED, ENGAGED, AND EVOLVING AESTHETIC OF THE LAND

Introduction: A Shifting Aesthetic

Chapter 2 served to demarcate the development of an aesthetic that is integrated with sustainability science. This chapter specifically directs its attention towards the evolution of landscape photography perspectives during its transition from the modernists like Ansel Adams and Eliot Porter to the photographers who participated in the *New Topographics* exhibit, which focused on the man-altered landscape. Furthermore, I will address the need for another transition in contemporary landscape photography that reframes the human/environment relationship from previous perspectives that implied a necessary psychological distancing from the subject to one of active engagement.

Ansel Adams and Eliot Porter took Americans on a photographic journey that was intended to make society reflect on its relationship to the environment. Specifically, they drew from the written works and transcendentalist ideal of environmental writers John Muir and Henry David Thoreau to present viewers with a wilderness worth saving. Indeed, their work had real and lasting impacts on the landscape, particularly the protection of the wilderness. Porter's 1963 book *The Place No One Knew* was instrumental in the passage of the Wilderness Act. While the book did not prevent the construction of Glen Canyon Dam it "led to the federal review of all reclamation projects on rivers in the American West and to the passage of the Wilderness Act of 1964, which had been languishing in Congress since 1956" (Martineau, 2012, p. 19). As mentioned in

the previous chapter, Adams's photography in his 1938 book *Sierra Nevada: The John Muir Trail* was influential in the designation of Kings Canyon National Park in 1940. William Sherman elaborates on the scope of Adam's impact by pointing out that, "at the height of his career, [he] produced a body of work that shifted commonly held models of the world, realigning the cultural perception of an endangered natural wilderness" (2013, p. 58).

However, as we saw in chapter 2, the work of Adams and Porter was suffused with ideologies that romanticized wilderness and often excluded the rest of the everyday, mundane world. They worked to protect the 'pristine,' but inadvertently alienated the 'ordinary.' Photographer Mark Klett notes that Adams, "reinforced the beauty and durability of the natural world and the land's ability to counter the negative effects of modern society. The photographs seemed to fulfill the legendary promise of the West: that it was vast, sublime, immutable, and redemptive" (2014, p. 65). Modernism had permeated American ideals of the landscape and these photographers, aligned with Muir's Sierra Club, were content to continue presenting the same framing of the world. This was evident from Sierra Club's Exhibit Format series of photography books, which pitted pristine natural landscapes against imagery of the (seemingly always tarnished) built environment.

In response, a small group of photographers in the late 1960s and early 1970s began creating work as a broad critique of the venerable Sierra Club wilderness aesthetic. While Adams and Porter had used the emotive power of images to convey a specific message around nature preservation, this new group of photographers sought to make images that served as documents of a world that acknowledged the "man-altered

landscape." They were not inherently interested in the environmental concerns[19] that were so central to the work of Adams and Porter. Interestingly, these photographers were working independently and it was not until William Jenkins, a curator at the historic George Eastman House photography museum in Rochester, NY, observed their emerging, shared aesthetic and decided to curate an exhibit in response to this observation that this "counter-movement" in American landscape photography took on a distinct shape. In 1975, Jenkins compiled works from photographers Robert Adams, Lewis Baltz, Stephen Shore, Nicholas Nixon, Joe Deal, Henry Wessel, Frank Gohlke, Bernd and Hilla Becher, and John Schott, an exhibit that functioned to solidify these artists as an identifiable group within the photography community. The exhibit (and subsequent book) was titled *New Topographics: Photographs of a Man-Altered Landscape*.

These photographers acknowledged the artifice in Ansel Adams wilderness aesthetic and sought to identify new directions to explore in reconciling the nature/culture divide. One of the photographers, Joe Deal, distilled one of the common sentiments of the New Topographics, "When I actually went to Yosemite, it was like seeing everything in quotation marks" (Salvesen, 2009, p. 17). His reaction highlights the growing awareness of the pretense of a pristine West in photographic circles in the 1970s. Not only was the ideal of untouched, "untrammeled" wilderness being questioned in such responses, but the veracity of the photograph itself had been called into question. In this, the New

[19] It's clear that Robert Adams, one of the photographers in this cohort, held environmentalist sentiments and had great appreciation for Ansel Adams and his work. He did, however, feel that the latter's work did not relay the true state of the West. Robert Adams expressed a concern, not with conservation, but with the neglect of man-altered environments people primarily occupied (Kemmerer, Stilgoe, & Weinberg, 2001; Salvesen, 2009). Hence, the issue was the veracity of images that "objectively" expressed the world they lived in.

Topographic artists aligned more with Walker Evans, a Farm Security Act photographer and a contemporary of Ansel Adams, who championed a documentary style of photography.

While Adams worked in the national parks, Evans was making images in response to the Great Depression. One of his seminal pieces, created in collaboration with the writer James Agee, was the book *Let Us Now Praise Famous Men,* a documentation of the life of three sharecropper families in the South. Writer William Stott hailed the book as a "classic of documentary" (1973, p. X). However, Evans was not simply documenting as a form of evidence, in fact many of his portraits in the book were posed. John Hill (2013), a designer, photographer, and colleague of Evans at Yale remarked that Evans' aim was to get at a deeper understanding of these sharecroppers' situation, which required direction at times., While Evans was "documenting," his images were not to be taken as mere pieces of evidence. There is a difference between "a document" and using a "documentary style." Evans remarked that "documents," like a forensic photograph had a utility, whereas art (a category that included his "documentary style") had no specific utility and was "open to frame the same information while multiplying or ignoring its potential purposes" (Salvesen, 2009, p. 16). This documentary style was a way of revealing truths about a situation that extended beyond information in the photograph.

It was a style that appealed to many of the New Topographics photographers. Gohlke, Nixon, Schott, and Shore, for example, commented on their affinity for Evans' work, especially how he neither glorified nor condemned the subject of the images (Salvesen, 2009). This 'documentary style' more closely aligned to a sense of neutrality over objectivity, a way to remove any hint of judgment by the photographer.

Furthermore, the New Topographic photographers turned from Adams' sentimental presentation of the picturesque and sublime West to a focus on the far more prosaic man-altered landscape.

Image 6: Bud Fields and His Family at Home (Evans, 1935) is an example of this "documentary style."

The Nature of New Topographic Photography

In addition to the shift in focus away from idealizing a romantic aesthetic of the wilderness toward a more neutral gaze focused on the built environment and the modified landscape, the New Topographic artists also shifted their photographic techniques. They did so by: (1) using a documentary approach, (2) taking and presenting more than one

image on a subject, and (3) refraining from providing normative instructions to the viewer.

First, the New Topographic artists' imagery focused on the built landscape, most of it vernacular in nature. While most of the photographers refrained from providing any directed meaning behind their work, they definitely relayed a particular style. The images were skillfully made but the subject matter was quotidian; tract housing, parking lots, industrial parks, etc. The work relayed the everyday in a very straightforward fashion. In many ways not only were they evoking Evans' documentary style, they were evoking the original photographers who accompanied the USGS to survey and document the West in the second half of the 19th century. Photographers such as Timothy O'Sullivan, William Henry Jackson, Jack Hillers, and William Bell were relevant again and clearly had an influence on the New Topographics photographers (Klett, 2014). The West had changed but the manner of neutral documentation did not have to change. In fact, this method was necessary for understanding the shifts the American West had undergone.

Image 7: Frank Gohlke, "Landscape, Los Angeles" 1974 (Salvesen, 2009, p. 163)

Similarly, the function of photographs was also changing, shifting away from Ansel Adams' modernist style of making an image that "was a self-sufficient, free-standing masterpiece" (Westerbeck, 2014, p. 40). In contrast, the photographs of the New Topographics photographers created meaning through the variation articulated in a *sequence* of images (Salvesen, 2009). Frank Gohlke clarified that "the series is what gives the individual photograph its interest, although parking lots for example are interesting in themselves because there is variation. Tiny details within them become very interesting" (Salvesen, 2009, p. 28). Gohlke was referencing the work of artist Ed Ruscha who heavily influenced the New Topographics photographers and consistently

used seriality as a method; some of Ruscha's work showing this method being *Twentysix Gasoline Stations* (1962)*, Some Los Angeles Apartments* (1965), *Every Building on Sunset Strip* (1966)*, Thirtyfour Parking Lots* (1967)*,* and *Real Estate Opportunities* (1970). Bill Jenkins, one of the curators of the New Topographics exhibit later commented that Ruscha's work aligned with the premise of the exhibit and that he should have included his work as well. The images were evidence used as an attempt to express a truth about the world these photographers were exploring; seriality accomplished this more effectively than a single image.

The New Topographic images were meant to be free of any expressed judgment by the photographer. Salvesen addresses the power of this 'neutral' photographic style:

> "According to the logic of preference, indifference is an equivalence relation, extremely stable in its symmetry, reflexivity, and transitivity. The visual analogue would be these photographs, which reconcile beauty and ugliness, love and hatred, progress and degradation, and a host of other contradictions. They epitomize the paradox of indifference in being both boring and interesting" (2009, p. 37).

The New Topographics photographers, in short, had ushered in a new presentation of the landscape. Klett notes their work is, "less a condemnation of the man-altered landscape than an introduction, and ultimately an invitation, to view landscapes in a different way" (2014, p. 76). The *New Topographics* exhibit was a turning point for landscape photography. Photographers were leaving the modernist ideals behind and turning to photographing the man-altered landscape. Even Robert Adams, who expressed great respect and admiration for Ansel Adams, and was the most conservation-focused of

the New Topographics photographers, understood that the sentimentality elicited in Ansel's work would not serve to express the reality he saw (Salvesen, 2009).

The Present Day Splitting of the Photographic Movements

Environmentally conscious photography (a subsection of landscape photography) bifurcated as it evolved in the 1970's. Those who followed the tradition of Ansel Adams and Eliot Porter became known as "nature photographers" and still photograph today in a style that evokes the idea of a pristine natural world. Landscape photographers who followed after the *New Topographics* continued to develop the human-modified landscape aesthetic. Styles varied, from the deadpan to reconstructed notions of the beautiful and sublime, but a constant remained: the vision of the man-altered landscape.

As some photographers continued to photograph the banal, those who were more environmentally focused took to photographing more dramatically altered landscapes, even places that would register as "ruined" under the traditional wilderness schema. Rather than photographing tract housing and industrial parks, they photographed large-scale degradation like toxic waste dumps, nuclear testing sites, and strip mines (Klett, 2014). Although the work of the *New Topographics* photographers does not seem to imply that humans *inevitably* ruin their environment, much of the landscape work that followed seems to been driven by this insight. At the very least, the work seems to convey the view that the human-nature relationship is fraught with great tension, one that only increases as we extract ever more resources and transform the land in the service of material progress.

Interestingly, the movement towards the human-altered environment by many contemporary landscape photographers has not necessarily shied from notions of the

beautiful or sublime. Photographers like John Pfahl, Richard Misrach, and Edward Burtynsky have been critiqued for eliciting the beautiful and sublime in their images of environmental degradation (Bargmann, 2013; Bright, 1985). However, the argument follows that if we are able to maintain a psychological distancing while provoking beauty and the sublime in images then a particular veracity is maintained via the guise of neutral observation. The issue is that this distancing is a double-edged sword; it provides a sense of credibility to the image while simultaneously allowing the viewer to maintain a psychological distance via the art object. The viewer can be appalled, disgusted, angered, even pleased by the beauty in the image but he/she does not need to be invested in the subject matter.

This may not be an issue in the world of art, since the art object is considered the end product, but within the sustainability community there arises a sense of social and environmental accountability that suggests there is a kind of utility to art. That does not mean that the art merely serves a particular agenda but that the manner in which art operates as a creator of presentation and meaning impacts our view of the world. Photographer and visual culture historian, Deborah Bright articulates the power of landscape images and its affect on the collective conscious:

> "Thus, whatever its aesthetic merits, every representation of landscape is also a record of human values and actions imposed on the land over time. What stake do landscape photographers have in constructing such representations? A large one, I believe. Whatever the photographer's claims, landscapes as subject matter in photography can be analyzed as documents extending beyond the formally aesthetic or personally expressive. Even formal and personal choices do not

> emerge sui generis, but instead reflect collective interests and influences, whether philosophical, political, economic, or otherwise. While most art historical/curatorial scholarship has concentrated on the artistic genius of a select few (and the stake in so doing is obvious), it is time to look afresh at the cultural meanings of landscapes in order to confront issues lying beyond individual intuition and/or technical virtuosity. The sorts of questions we might ask concern what ideologies landscape photographs perpetuate; in whose interests they were conceived; why we still desire to make and consume them…" (1985, p. 2).

In other words, there is no simple, neutral presentation of the landscape and there never was. Both wilderness and the man-altered environment have been presented in particular, and inevitably biased ways. Seeing them together gives a more nuanced understanding, however.

Since the *New Topographics* exhibit in 1975, there has been a broader acknowledgment that humans have dramatically changed the landscape and more importantly ecosystems and biogeochemical processes. The field of sustainability science has been working diligently to address those influences – but how can artists address this altered state of the world and re-present the human/culture/nature relationship? It's not fleshed[20] out, but more importantly, artists must be engaged in recontextualizing their relationship to the world in novel ways. The condition of the world is different from the one that Ansel Adams, Eliot Porter, and the New Topographics photographers showed us,

[20] This chapter focuses on further articulating not only what I have done to address this recontexualization of the human/culture/nature relationship but what other artists might consider in their process of making new work, primarily what breadth of knowledge is necessary for grappling with the challenges of presenting the landscape we live and act in. Since art is a creative and emergent practice I cannot say what novel approaches and works artists will make, only that if the work is to be novel and compelling, artists must expand the intellectual toolbox that they pull their ideas from.

so contemporary photographers need to become more informed about the world they live in, explore their subjects, and make work according to this new socio-ecological context. Artists can look for inspiration or ask questions similar to the ones that the *New Topographics* photographers investigated, but in new ways. Can they revisit the methods of the survey photographers who worked side-by-side with scientists in mapping out the West? Is there something that both the modernists and post-modernists were missing in this interrogation of the human/environment relationship that can still be explored?

These questions are not a condemnation of the photographers who have captured the man-altered landscape. They have exposed and expressed the world we live in. Taken together, the survey photographers, who documented the West, the modernists, who asked that we pay attention to wilder spaces, the New Topographics photographers who asked us to look at the banal and interrogate the veracity of images, and the photographers who have expressed the violent and benign occupation on the land all make us more aware of the human/environment relationship. As with all art, however, once an idea has taken hold and become codified, we must ask the question: what's next?

Specifically, what human/environment relationships questions do we now ask? What reflexive practice must we be engaged in? Being didactic can create momentum but also polarizes the issues. Artists have created work that argues for observed neutrality in order to skirt sentimentality or the instrumentality of art. Artist, Chris Wainwright, articulates this dilemma in his own art practice.

> "I for example would not define myself as a climate change artist even though my work is significantly informed by the urgent need to address the extreme changes to our climate as a result of human activity. There needs, however, to be a

> continual critical distance from the issues in order for the photographic works to function pluralistically and with reference also to informed and relevant visual traditions and theories of representation. In other words, to seek to problematize the relationship of the photographic representation of beauty in the light of imagined and impending catastrophe" (2014, p. 119).

The challenge is creating work that opens a discourse on problems like climate change and its effects on people. The thin line the artist walks is that of making work on a time sensitive issue that is compelling and yet not interpreted as being sentimental and activist centered; two components that create barriers to open discussions. Today's issues are complex and while previous imagery taught us to see things more clearly, we need new imagery today to teach us to better understand, explore, and think about our current relationship to the environment.

Scientists have begun to understand, for example, the profound influence humans exert on the planet's ecological processes, an impact captured in current talk of the "Anthropocene" (Crutzen, 2002). As Ben Minteer and Stephen Pyne note, this designation (i.e., of our current geological period as the "Age of Humans") has "exposed deep fault lines and areas of strategic disagreement over the motives, practices, and goals of nature protection in the twenty-first century" (Minteer & Pyne, 2015, pp. 4-5). Is recognition of the Anthropocene an opportunity to practice "smart planetary management?" Or is it instead a sign of the destructive power of man's uncontrolled exploitation of the planet? One thing is certain, humans have dramatically altered their relationship to the planet. So how do we move forward knowing that we act not only in but also *on* the planet in deep and lasting ways? How can artists make work that invites

exploration and engagement in this time of increasing human influence on and control of the landscape, something more than distanced reflection or nostalgia for a different time and place?

Indeed, we have transitioned from the man-altered landscape to the man-altered planet and yet our ability to act on the environment as individuals is primarily limited to our immediate landscapes. So we turn back to the landscapes we know but with this new realization that our individual relationships to land have lasting and compounding effects, which have created the world we inhabit. As artists, that realization must be interpreted (not illustrated) into an aesthetic that acknowledges both our impact on the planet and the little things – like caring for backyards – that express a cultural calibration in understanding our relationship to land. Klett affirms this line of reasoning asking, "Isn't it time for a new revolution in how we photograph the land—and more importantly how we view our relationship to it?" (2014, p. 85).

Seeking New Directions in Landscape Photography

I agree with Klett's sentiments and, as a partial answer to his question, I propose that artists make work that puts humans back into the environment, not just as subjects but also as active participants in transitioning towards more a sustainable planet. As Klett (2014) notes, whether the environment is treated as sublime or ruined, both imply that humans don't belong – there is no human agency and hence no intimate engagement with place. By making work that directly engages with one's environment (urban, suburban, or rural), the artist infers agency to the viewer, relaying the idea that engagement with the environment is a vital and necessary path forward. This is a natural progression that acknowledges the work of previous artists that turned their cameras to man-altered

landscapes and asks what role is to be played in how we want to alter/engage with the landscape. This is not activism but an acknowledgement, as Aldo Leopold (1966b) often pointed out, that humans are part of the ecological community not separate from it.

Additionally, this re-presentation of the environment and our relationship to it requires a more holistic ecological and cultural understanding, one that requires an informed artistic and scientific approach. In order to develop the necessary knowledge sets artists need to become more invested in a scientific understanding of the land, both ecologically[21] and culturally. It requires not just a better individual understanding of human/environment relationships but also collaborations that bridge the arts and sciences so that neither artists nor scientists are compromised in their work and so they may create a stronger bond between how their work is linked, which potentially produces a transdisciplinary outcome. This is a move towards Herbert Simon's (1983, 2001) "hot cognition," (discussed in chapter 1) a viscerally informed understanding of our relationship to our environments; one that resists codification by continually evolving through both an artistic and scientific interrogation of the human/environment relationship.

I have attempted this mode of art-science integration in my own work. My multimedia project "one hundred little dramas." used my own backyard in Tempe, Arizona, as a point of reference to explore this human/environment relationship. My intent was to create a body of work exploring the principles of sustainability as it related to these personal spaces. This means that I was documenting the space while also actively

[21] A better ecological understanding should not be interpreted as a negation of the methods artists already use to organize information, communicate ideas, and address the human experience. Scientific understanding serves to enhance the questions and messages they interrogate.

transforming it. This project, lasting from 2009 to 2013, served as an intimate exploration and transformation of the backyard, its ecology, its aesthetic, and an ethic that develops from such close and multifaceted engagement.

Image 8: Squash growing out of our compost (March, 2011)

I approached this project, first and foremost, through a contemporary photography and video art practice. The tools, techniques, creation of objects and time-based media were created in a language accessible to those trained in art. My method of exploration was often intuitive, responding to my environment and ecological training. Additionally, pieces like my yearlong time-lapse of the backyard were more conceptual in approach, for investigating both my transformation of the backyard and seasonal effects on the

space at a higher temporal resolution that is normally afforded through more common photographic methods. I would make images or videos of observed ecological processes. Then, I would reflect on the images and new information I acquired either through reading, discussions with ecologists, or close observation of the backyard. This open-ended process was a constant negotiation of what I was learning both as a scientist and artist and then making work in response to that new knowledge. By the end of the project I had a large body of work, over 3,000 images and 100 video clips, but it lacked coherence.

The work could only take on a semblance of clear cohesiveness through a rigorous edit. Mark Klett often remarks that the true purpose of editing is not to organize the images into a predefined story but to pull the narrative from what the images reveal. In effect, editing is a form of data analysis, through this process information is revealed that might go unnoticed if the artist is intent on merely expressing what he/she already expected to say. By parsing down this editing process again was informed and iterated over several sessions, informed yet not confined, by my training both as a scientist and artist. The result was an exhibit of a sequenced collection of approximately 60 images and a video installation.

One of the most difficult aspects of creating interdisciplinary work like this is situating it in a specific discourse. As I would discuss the work and its relevance to sustainability, artists and curators would regularly ask, “Do you consider this work art?” I would have to affirm that I did indeed consider the work to be art; i.e.. it was not merely for illustrative purposes (e.g., to serve as an emblem for a particular sustainability agenda). When I shared my work with scientists, they compartmentalized it by default to

the realm of art. Yet, the work does not easily sit fully in either domain (art or sustainability) but at the intersection of the two. Still, I must admit, having focused on contemporary art practice, that it is more easily situated within the arts. However, since I am primarily focused on its relevance to sustainability, it is work that uniquely informs sustainability. Therefore, the work extends beyond art and its success must be defined and measured beyond its relevance to the contemporary photography field.

There are, in my opinion, a number of key questions that should be considered in terms of sustainability art-science: Is the work salient and compelling as it relates to human/environment relationships? Does it organize scientific and artistic ways of knowing in a coherent manner? And does it allow us to better understand the quality of human agency in – and responsibility to – place? If the answer is "yes" to each of these questions, then the work is succeeding in extending the human/environment discourse, which I would argue is the primary motive of both the arts and sciences interested in this intersection, even if they differ in approach.

Here I return again to the writing of Aldo Leopold, in particular a passage I discussed in the previous chapter. In "Wilderness," an unpublished manuscript Leopold wrote in 1935, he noted that the uniting the of sciences and the arts would "constitute the outstanding advance of the present century." He states:

> "One of the anomalies of modern ecology is that it is the creation of two groups each of which seems barely aware of the existence of the other. The one studies the human community almost as if it were a separate entity, and calls its findings sociology, economics, and history. The other studies the plant and animal community, [and] comfortably relegates the hodge-podge of politics to 'the liberal

arts.' The inevitable fusion of these two lines of thought will, perhaps, constitute the outstanding advance of the present century" (Meine, 1988, pp. 359-360).

one hundred little dramas.

I have made a case for an educated, engaged, and integrative art practice. In what follows, I present my artist statement and an edited selection of images from the full body of work "one hundred little dramas." The full selection can be viewed at http://www.edgarcardenas.com/littledramas/.

Artist Statement

"THERE are some who can live without wild things, and some who cannot. These essays are the delights and dilemmas of one who cannot."

(from the Foreword of *A Sand County Almanac*)

We all have a natural space we interact with daily. Typically, we thoughtlessly engage with this space, using it in the same manner as it was first presented to us. The backyard, our private landscape, often gets no more than mowing and weeding, nonetheless, it is the space we touch. My relationship to my backyard changed in August of 2009 when I moved into a rental home that had an inhospitable backyard of thorns and dust. With the exception of using it for letting our dogs out and bringing the garbage to the dumpster, it was as though it didn't exist.

Then, the winter rains came.

I watched the backyard transform from dusty brown to brilliant green, from barren to fecund. Watching the tall grasses sway and the lizards do their pushups on the fence, I realized that a wild space had been lying dormant and was now awake in my

backyard. Perhaps all backyards could be thought of as wild spaces if we just learned to see them. I wondered if personal sustainability could be studied in a space like this. ***"The objective is to teach the student to see the land, to understand what he sees, and enjoy what he understands."*** (Aldo Leopold, "The Role of Wildlife in a Liberal Education")

As a doctoral student in the School of Sustainability, I am continuously examining what sustainability means—how it's practiced and who practices it. In discovering the wilderness in my backyard, I initially considered questions like: Beginning with a current state of one's own backyard, how does one go about changing it for the better? What would be considered better? What does personal sustainability look like?

I was getting ahead of myself, though. Before I could consider these questions I had to first learn to "see the land" and my relationship to it. I had to set aside my utility-oriented mindset and what I understood in theory. I needed to lead instead with curiosity and be open to the role exploration would play in this space.

"Here, then, is a man who has found adventure, exploration, science, and sport, all in the back yard of current history, where millions of lesser men find only boredom." (Aldo Leopold, "Natural History: The Forgotten Science")

This exploration led me on two journeys, attempting to articulate these experiences in ways that capture the dynamic relationships I was witnessing, and an inquiry into how we approach and think about our human-environment relationships. In this work, I have sought to intentionally blend the historic with the contemporary; to

access the use of natural history and its re-emergence in observational ecology approaches and to express these sentiments in my work.

"In June as many as a dozen species may burst their buds on a single day. No man can heed all of these anniversaries; no man can ignore all of them." (Aldo Leopold, "Prairie Birthday")

Stepping back from the targeted questions of my discipline, my methods were informed by two questions: If Aldo Leopold were alive and in my backyard, how might he explore the space? How might he express the backyard's drama?

The backyard proved to be larger than I expected, not in its physical length or width but in the depth of complex relationships that were to be found in such a small space. Climbing atop ladders, crawling on my hands and knees, flipping over rocks and wood, I explored, engaged in, and observed the yard intently for three years and still only scratched the surface of the activities taking place; from the microbial life in my compost, to the seasonal habits of the lizards and birds, to the feral cat predators leaving bird remains in our yard - and this is merely the fauna. I was continuously intrigued and excited about the plant life growing in our yard. I would dig up creosote and brittlebush sprouts to replant, I would inspect the plants and food in the garden, looking to see what was growing and what the bugs were eating. I would check to see when our flowers were blooming, study the moths and bees pollinating, and then wait to collect seeds for the next season to initiate the exciting process again.

"Our ability to perceive quality in nature begins, as in art, with the pretty. It expands through successive stages of the beautiful to values as yet uncaptured by language." (Aldo Leopold, "Marshland Elegy")

While ecology has taught us about the relationships and processes of natural systems it has not conveyed the "hundred little dramas" that play out, the stories that make the principles salient in a visceral way. These qualities do not reveal themselves to us all at once either, we develop an, often tacit, understanding that is difficult to put into words but can be hinted at with images.

Susan Sontag points out that, "photographs alter and enlarge our notions of what is worth looking at and what we have the right to observe." I have decided to take another look at the backyard, one that aligns with Leopold's aspiration to integrate the ecological, ethical, and aesthetic and reintroduce this dialogue to our sustainability discussions. These observations are the delights and dilemmas of one who cannot live without wild things, and has found them in the backyard.

"It is fortunate, perhaps, that no matter how intently one studies the hundred little dramas of the woods and meadows, one can never learn all of the salient facts about any one of them." (Aldo Leopold, "Sky Dance")

Image 9: One of the first images of the backyard (October 2009)

Image 10: Two months after heavy rains (May 2010)

Image 11: Sparrows in flight after eating seed (September 2010)

Image 12: Young chickens that were given to us. (November 2010)

Image 13: Steaming compost. Waste collected from the School of Sustainability and community members. (December 2011)

Image 14: Chipped trees collected then transported via wheel barrel into the backyard (March 2012)

Image 15: Freshly killed juvenile pigeon by feral cat (July 2012)

Image 16: Egg shell from recently hatched lizard (August 2012)

Image 17: Cloud and eclipse obscura (January 2011 & May 2012)

Image 18: Eclipse obscura through a Chinese Elm we planted (May 2012)

Image 19: Sparrow (albumen print)

October 19, 2011

Pepino, one of our Chihuahuas, was sniffing intently in our vines and pointed me to a baby sparrow that had fallen out of his nest. At first, the tiny, featherless body was cold and limp in my hands. As he absorbed my body heat, he grew ornery – lifting his little head high and squawking before collapsing back down.

As he grew more animated, so did we as we tried to figure out what to do for him (though we did pause to name him Henry). We couldn't reach the nest to put him back, but we did take him to Wild Wings Rehabilitation.

I have been wanting to return and see how Henry the Sparrow is doing. I'm sure he is quite big by now.

Image 20: Haboob approaching the backyard (July 2012)

Image 21: Lost flower

April 23, 2012

The other day, I found a little flower in the yard. I didn't know its name, but it was the only one of its kind. Just this morning, as I was watering the plants, I saw it laying on its side. Seeing it, broken off at the stem, made my heart pound - such a little thing, losing a flower. I could have lost any other flower in the yard and I probably wouldn't even have noticed, but this was the only one.

To lose that flower was to lose the possibility of any other like it in my yard. I suppose I could figure out what kind of flower it was and get more, but in that moment all I could feel was a sense of loss.

"We grieve because no living man will see again the onrushing phalanx of victorious birds, sweeping a path for spring across the March skies, chasing the defeated winter from all the woods and prairies of Wisconsin." ~Aldo Leopold

Image 22: Hornworms collected from my tomato plants. (August 2012)

Image 23: First worm found in the backyard after 2 years of remediation. (February 2013)

Image 24: Final image of the backyard before we moved out. (May 2013)

Image 25: Two years after having moved out (May 2015)

CHAPTER 4

CONNECTING AN ART-SCIENCE PRACTICE TO COLLABORATIONS

Introduction

In the previous chapters I argued for the need to integrate the arts and sciences and developed an aesthetic and historical foundation for this activity. Specifically, in chapter 2, I addressed why it's critical for the sustainability science community to seriously consider the role aesthetics plays in how sustainability challenges are conceptualized. In chapter 3, I focused on the unique role photography has and still can play in opening a dialogue about the role of the artist in the sustainability discourse.

I have advanced these arguments working in the capacity of researcher and artist. The dual-role nature of the artist-scientist practitioner presents a demanding challenge. Most significantly, perhaps, it requires the investment of substantial time, intellectual commitment, and energy; one must maintain a practice in both spaces and you are held to a standard set by each disciplinary community. This disciplinary subculture is not a new dilemma; indeed, one of the most commonly cited examples regarding the differing epistemologies and ontologies between the sciences and arts/humanities comes from the physical chemist and novelist C. P. Snow. As mentioned earlier, his highly influential, *Two Cultures,* an extended essay about the reintegration of the sciences with arts and humanities, is one of the most widely discussed examples regarding this cultural divide (Snow, 1960). Sitting in both worlds, he discussed the fact that scientists and humanists lived and worked in different academic cultural contexts. But bridging this gap, he argued, would enrich both communities.

An alternative approach to the individual artist-scientist is artists-scientists collaborations. There are numerous examples of artists and scientists working to bridge this divide; however, they often focus on the outcomes of the projects, which does very little to help us understand how to create the necessary conditions to navigate the art-science borderland consistently -- and in collaborative settings. If they are multi-person collaborations, they tend to be short-term (e.g., a conference setting). Consistent interaction, however, often occurs between two people that have developed a working relationship. Given the necessity of collaboration for wicked sustainability problems, it follows that understanding the conditions and mechanisms that foster these kinds of interactions should be a priority. Shedding light on these interactions within team collaborations may help us foster effective artists-scientists collaborations in the future.

This chapter lays out the components I find critical to fostering these team collaborations. First I present my reasoning for focusing on artist-scientist teams versus artist-scientist pairs. I then present specific characteristics, conditions, and dynamics involved in the production of creative outcomes by teams. Finally, I present my study, which focuses on three-person artist-scientist teams who are tasked with the development of informative signage for the Tres Rios wetland site in Phoenix, AZ. I use a mixed-methods approach consisting of surveys, ethnography, and wearable sensors. I use these three methods to triangulate how team members believe they and their team performs, how I believe they perform, and how wearable technologies can provided high-resolution datasets that allow for deeper quantitative analyses of speech dynamics.

Individual, Paired, or Team Approaches

Individual Approaches

The most common approach to bringing art and science together has been the training of individuals in both art and science practices. Research on polymaths who have *artist-scientist* capabilities has given credibility to the benefit of pulling from both domains (Edwards, 2008; Root-Bernstein & Root-Bernstein, 2004). Though far from impossible, attaining individual expertise in both domains is unrealistic for most individuals due to the amount of effort and time that would be required to develop and maintain both the respective skill sets of the artist and the scientist.

Paired Approaches

Paired projects, where a single artist and scientist collaborate, are often studied after the fact, creating anecdotal understandings about what has worked in the partnership. The participants might explain what the working relationship is like, but very few studies have attempted to empirically study artist-scientist interactions.

One exception is the work of science communication scholar, Megan Halpern (2011). Halpern served as a participant observer for 4 artist-scientist pairs she recruited for the event "Across the Great Divide" at the Light in Winter Festival in Ithaca, New York, a project that resulted in the creation of a ten-minute performance after hours of collaborative artist-scientist meetings. Her aim was "to understand the creative process that might occur between an artist and a scientist asked to collaborate on a scientifically informed performance." (Halpern, 2011, p. 4). In the first meeting, Halpern provided the pairs with eight prompts she conceptualized as "cultural probes" to initiate conversations

on what they identified as art or as science. These prompts served to identify how the study participants demarcated the differences between the art and science. Additionally, during the meetings, team members used their existing work, built objects, and appropriated objects as *boundary objects* (Star & Griesemer, 1989) to better understand and connect each other's work. Star and Griesemer define boundary objects as, "those scientific objects which both inhabit several intersecting social worlds ... and satisfy the informational requirements of each of them" (1989, p. 393). Halpern notes that these objects served as "visual metaphors" that served to bridge the two fields and that they "can indicate a set of ideals, rules, or principles shared across disciplinary boundaries." (Halpern, 2011, p. 14). Her findings provide insight into how artists and scientist view similar topics differently and how boundary objects and cultural probes can open a dialogue between them for productive collaborations. Ultimately, the cultural probes and boundary objects aided in navigating how the pairs created meaning from a shared project.

Collaborative Approaches

As mentioned above, larger artists-scientists collaborations often happen in a conference-oriented setting. They favor short-term interactions and rarely go beyond a single interaction event. The most intensive art-science collaborations I have participated in (and have helped lead) have been the "Emerge" events (http://emerge.asu.edu) that have been held at Arizona State University. They extend beyond arts and science to design, engineering, and the humanities; the goal being intensive interdisciplinary collaborations on projects envisioning the future. These collaborators work closely for

two days to conceive and execute an idea about what the future might look like. The execution of that idea – in the past it has taken the form of artifacts, imagery, and performances – is then presented to the other groups as well as the public on the third and final day. Understanding the interactions of the teams, however, has not been the focus of the event.

These are all valid approaches to art-science integration but current group dynamics research has not focused on understanding the artist-scientist team dynamics necessary to fully realize the potential of this synthesis. Each method has its advantages and disadvantages. The key benefit of practicing as an individual artist-scientist is the level of synthesis possible due to the internal nature of the process; each new art or science experience is integrated into ever evolving mental models that continually build new connections between art and science. The disadvantage is the many years of training required to become well versed in multiple disciplines and the near impossibility of developing expert-level knowledge of both the arts and the sciences. Artist-Scientist pairs begin to move us in the right direction, these pairs are able to divide the needed expertise e.g. one artist and one scientist. It may become more difficult to internalize both fields but the one-on-one interactions allow for in-depth exchanges. Collaborative approaches, which I focus on, allow not only for the further extension of expertise but they also provide more opportunity for a diversity of experiences[22]. However, as team size grows it inversely affects the level of energy necessary for idea integration. In effect, art-science individuals grapple most with the necessary expertise and least with the synthesis, while

[22] Teams provide more opportunity for dissent, which is critical to developing creative products. I will discuss this in more detail in the upcoming section on minority dissent, appropriate conflict, and team diversity.

teams grapple least with expertise and most with synthesis. Complex sustainability challenges require both high levels of expertise and synthesis and since individuals cannot be expected to develop ever-increasing levels of expertise it follows that focusing on fostering team based collaborations is the path forward. These collaboratives can overcome significant barriers encountered at the individual level by shortcutting the time and energy necessary for building expertise in multiple fields; however, since the synthesis becomes more challenging, finding approaches to aid in synthesis are a priority.

Interdisciplinary collaborations in the sciences can be challenging. Stokols et.al. (2008) note that shared conceptual frameworks are critical for effective interdisciplinary collaboration. Yet in the case of the arts and sciences, the methods, mental models, and perceptions of successful outcomes can diverge considerably. For this reason understanding the interaction patterns between artists and scientists in collaborative work is critical to effectively integrate the ideas that all participants contribute to the group. The focus is not on the demarcations of art-science but on the conditions under which artists and scientists are likely to produce something that is new and valuable or interesting (Hackman, 2012; Simon, 2001). Specifically, I seek to understand how these novel outcomes come about through social creativity measures.

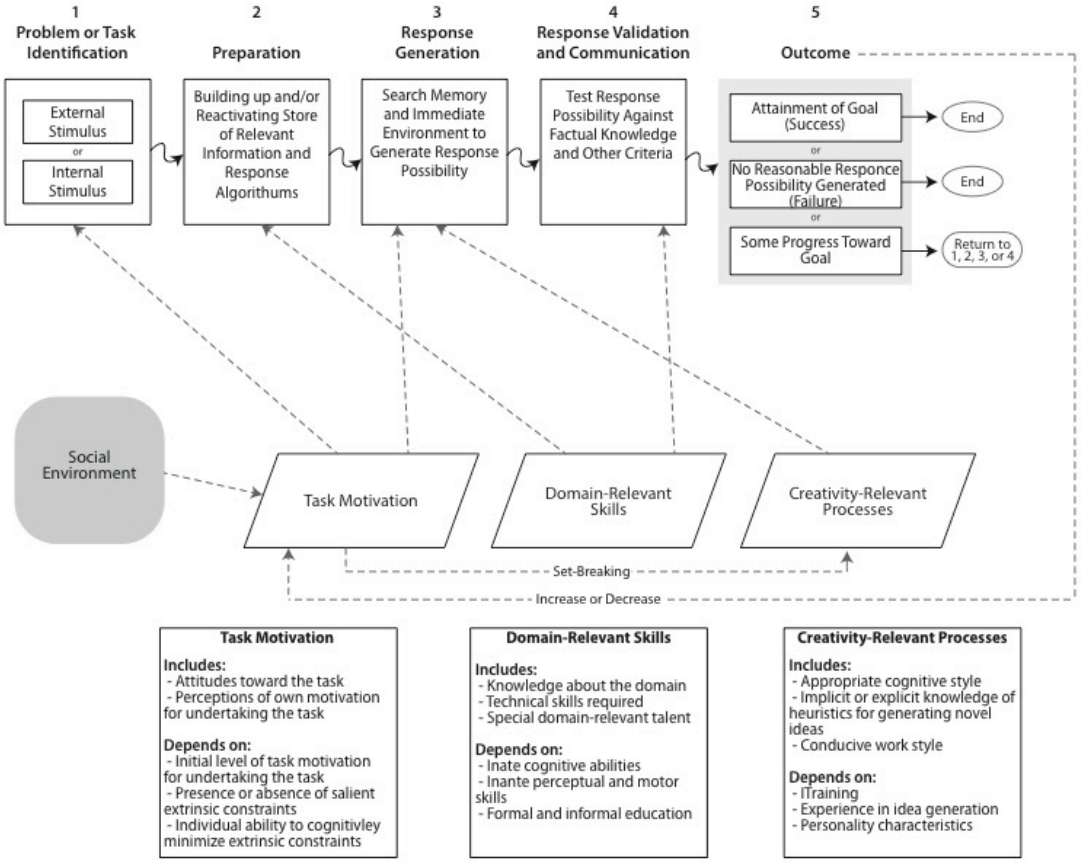
Creativity In Groups and Collaboration Between Arts and Sciences

Several researchers have pointed out that most creative products are not the result of a lone genius but some form of explicit or implicit collaboration (Csikszentmihalyi, 1996, 1988; Farrell, 2001; Feldman, Csikszentmihalyi, & Gardner, 1994; Sawyer, 2007). Amabile (1983, 1996) has focused her research on understanding creativity in social contexts, developing a framework for studying the social components of the creative

process. Her *Componential Theory of Creativity* (see figure 1) identifies the individual, social, and environmental elements that support or create barriers to creative work. Her model also acknowledges the iterative process of creative work; she conceptualizes these different stages into five progressive steps. Steps 1-5 relay the decision-making process within the creation of a product. Although each step generally builds on the previous, teams may return to a previous step as well. Once an outcome is reached the team has three options. It may: 1) determine whether the goal is attained, 2) chose to move through another iteration, or 3) terminate the project. Additionally, Amabile pinpoints *task motivation, domain-relevant skills, and creativity-relevant processes* as three characteristics that are critical for producing creative outcomes.

Her framework serves as a model for understanding how teams manage collaborations to achieve desired results, an insight that is especially relevant to the sustainability research context. Sustainability collaborations not only strive to collect more information but integrate that information in novel ways that bring about scientific and social innovations. For this reason, understanding how artists and scientists can collaborate is a fundamental objective of this research. It is the link that facilitates the emergent possibilities of art-science research (Edwards, 2008; Root-Bernstein et al., 2011; Siler, 1995, 2011).

Figure 1: Componential Theory of Creativity (Amabile, 1996)



Components and Conditions for Creative Collaborations

Unlike individual creativity, team creativity is compounded by the interactions members engage in to produce an outcome. These interactions are complex and emergent (Hackman, 2012; Harrington, 1990) which requires consideration for both individual and group conditions and interactions necessary for desirable outcomes. As previously mentioned, Amabile (1983, 1996) identifies *domain-relevant skills, creativity-relevant processes, and task motivation* as individual characteristics members should possess for a successful creative[23] outcome. These elements will be briefly discussed below.

[23] Amabile has defined a solution creative as one that is both novel and appropriate for addressing the proposed problem (Amabile, 1983, 1996).

Individual Components

For novel solutions to also be appropriate each team member must have a firm grasp of the current state of his/her discipline. If not, the solution may be novel but fail to be useful. For example, solutions may appear novel and appropriate, but due to the team's lack of knowledge in the respective fields they may produce a redundant product, i.e., a solution already arrived at by other researchers. Hence, one necessary condition is *domain-relevant skills.* This includes factual knowledge of a particular domain, technical skills (laboratory or studio art skills), and "talents" (Amabile, 1996). Relevant skills can be innate (i.e. cognitive, perceptual, kinesthetic, etc.) as well as formal and informal training.

Domain skills provide the fodder but the information must be organized in non-formulaic ways. This requires what Amabile has described as *creativity-relevant processes.* These skills are primarily associated with a particular *cognitive style* when working. *Perceptual and cognitive* set-breaking that consists of reorienting problems, looking at them from different angles, moving towards complexity versus simplifying ideas, and delaying resolution of a problem by maintaining an openness to multiple ideas, suspending judgment of ideas, and keeping categories broad to more easily identify counterintuitive relationships between ideas. This delaying of consensus is what Hackett (2005) has labeled as the "essential tensions" necessary for providing space for the production of creative research.

Finally, the ability to identify how new information may fit in unexpected ways and/or putting disparate ideas together allows for creative perception (Amabile, 1996), often times in what others may see as average situations or events. The combination of

these methods creates a toolbox of heuristics that allows for continuously fresh explorations for producing innovative ideas and products.

Central to Amabile's individual components is *task motivation.* Specifically, she identifies the necessity of intrinsic motivation, "in which the creative act is an end in itself." (Amabile, 1996, p. Kindle Location 2151). While extrinsic motivation can be exerted to accomplish a task, most often it becomes a barrier to producing creative work (Koestler, 1976). Amabile designates two forms of extrinsic motivation, what she calls synergistic and non-synergistic. However, she only distinguishes them in terms of how they increase or decrease intrinsic motivation. In effect, the focus returns to intrinsic motivation for the production of creative work. Task motivation is the final component that becomes the deciding factor between what a person is capable of and what he/she is willing to do (Amabile, 1996). An individual may be a domain expert and also highly creative, but without the necessary energy to produce something of interest to him/her, the product is likely to be less creative than it might be under intrinsically motivated conditions.

Group Conditions

Hackman (2012) acknowledges that focusing on conditions for collaboration does not guarantee team success, but does set them up for a potentially higher rate of success. From a complex adaptive systems[24] approach, which Hackman takes, conditions provide the necessary flexibility and structure for creative teams. He proposes 6 conditions

[24] Computer scientist and complex systems researcher, Melanie Mitchell defines a complex adaptive system as "a system in which large networks of components with no central control and simple rules of operation give rise to complex collective behavior, sophisticated information processing, and adaptation via learning or evolution." (2009, p. Kindle Location 319).

necessary for team success: (1) real teams, (2) a compelling purpose, (3) the right people, (4) clear norms of conduct, (5) a supportive organizational context, and (6) team-focused coaching.

Some of Hackman's ideas overlap with Amabile's components. For instance, a *compelling purpose* parallels the necessity of intrinsic motivation; individuals in the team must pick problems that matter to them. The *right people* would be individuals with the expertise and creative skills necessary for productive work. Hackman does add collaborative skills to this; without them individuals may not easily gel or share ideas. *Clear norms of conduct* create an agreed upon environment for working together and promote consistent and well-tuned awareness of the team's tasks and interactions. This is critical to artist-scientist collaborations since norms can vary and this provides even grounding for both disciplines. A *supportive organizational context* was impossible to control for in this study but it definitely affected outcomes[25]. Organizational/Institutional reward structures and resources can steer members in particular directions, without this support, teams will struggle to produce beyond mediocre work.

Although Hackman places *real teams* first, his approach suggests that this development most likely comes after the conditions mentioned above are met. *Real teams* are defined as, "intact social systems whose members work together to achieve a common purpose. They have clear boundaries that distinguish members from nonmembers. They work interdependently to generate a product for which members have

[25] Within the study I was able to provide participants the necessary working resources to accomplish the task, but I was not able to control for the pressures felt in regards to the various responsibilities that had as graduate students. Their school and research responsibilities, especially for the scientists, at times were at odds with this research project. Often times they remarked that they were too busy to dedicate sufficient time to the Tres Rios project because of their other responsibilities.

collective, rather than individual, accountability. And they have at least moderate stability, which gives members time to learn how to work well together" (Hackman, 2012, p. 437). Individuals with a shared compelling purpose and appropriate skill sets would have reason to form. They would then confer on appropriate norms of conduct. A supportive organizational context would reinforce their motivation for working together, which at that point would meet the criteria as defined by his "real team."

Finally, *team-focused coaching*[26] provides a correction process for teams from a more collaboratively experienced individual outside the team that can assess the group more objectively. Hackman places this condition last on the list because, while useful, if the other conditions are not met team-focused couching will do very little.

Considering the Collaboration Interactions

Initial conditions, like those mentioned by Amabile and Hackman, set the foundation for moving forward, they are the prerequisites to success. Still, once teams begin working together dynamics related to their interactions and goals of the collaboration continue to evolve. They relate more to how the teams reason together, develop ideas, and ultimately settle on a desired outcome. These factors consist of, (1) the different approaches scientists and artists may use when addressing the same problem, (2) methods for blending interdisciplinary ideas and (3) the role of dissent/conflict in producing creative outcomes.

[26] I mention this last condition since it's part of Hackman's 6, however, because the following study is investigating how art-science teams collaborate, I refrain from using any type of coaching that could alter their interactions.

Creative Scientists Versus Creative Artists

Scientists and artists need to be creative to push boundaries in their fields but creativity expresses itself in multiple ways. Two factors from the Big Five personality inventory (one of the most accepted personality inventories in psychology), show high correlation with creativity (Kaufman, 2009). Artists and scientists who score as more "inventive/curious" over "consistent/cautious" on the "openness to experience factor" rated as more creative. However, artists and scientists diverge on the conscientiousness factor; being "efficient/organized" versus "easy going/careless." Creativity in the arts correlated strongly with being more "easy going/careless" than non-artists. Scientists scored higher on "efficient/organized" than non-scientists; but they did not score higher than less creative scientists (Feist, 1998)[27].

These results suggest that the process by which artists and scientists (working on the same collaborative team) approach a problem may differ. For example, artists may want to delay the development of specific solutions or plans of action while they openly explore the broader implications and meanings of a particular idea. Scientists, however, are more likely to explore an idea quickly, and move to potential research design processes and outcomes. It's often assumed that, as an artist, if you know what the outcome of your project will be then it's not art but rather an execution of techniques. Yet, as a scientist, unless you have a well-articulated idea that can be tested, with a clearly identified array of predicted outcomes, then the project is treated as an incomplete idea. What this means is that not only will artists and scientists differ in epistemology and

[27] Psychologist, Gregory J. Feist, conducted a meta-analysis consisting of 89 different studies with a total of 13,167 participants investigating the potential differences in personality characteristics between creative scientists and creative artists.

ontology but in the manner that they frame and approach a challenge. The fact that artists-scientists teams may not share a common process for approaching a problem is thus a unique challenge for them. As Kurtzberg and Amabile point out that, "The more that individual team members differ with respect to problem-solving approaches, the harder it can be for the team to work together toward common goals" (2001, p. 287). Divergent views about who is supposed to do what part in the research or problem solving, and when or how it should be done, can therefore make high-level collaboration difficult, and in some cases, perhaps even impossible (Kurtzberg & Amabile, 2001).

Boundary Objects, Metaphors, and Analogies

A salient approach to overcoming potentially conflicting working styles is finding a theme or object that all team members can take interest in. Objects, abstract or concrete, can be powerful tools for connecting individuals with varying perspectives. Geographer Paul Robbins points out that the use of objects is a productive method for bridging the interdisciplinary divide, especially between artists and scientists. He adds, "This revelation is made possible because the sociability of scientists (or artists, or writers, or actors…) is not only with one another, but with the objects of the world" (Robbins, 2012, p. 62). These objects, which help bridge divisions, can be considered *boundary objects*:

> "Boundary objects are objects which are both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use, and become strongly structured in individual-site use. They may be abstract or concrete. They have different meanings in different social worlds but their

> structure is common enough to more than one world to make them recognizable, a means of translation. The creation and management of boundary objects is key in developing and maintaining coherence across intersecting social worlds" (Star & Griesemer, 1989, p. 393).

These objects can often take on metaphoric or analogous roles for connecting disparate ideas by creating relationships. In her study, Halpern (2011) noted that boundary objects served as visual metaphors for connecting ideas. Analogies and metaphors may be considered common tools for artists, but as psychologist Kevin Dunbar (1995) points out in his study on scientific reasoning, science labs that used analogies versus those that didn't when discussing their work were more likely to have research breakthroughs.

Analogy use is a tool set that can be associated with Amabile's creativity relevant skills (1983, 1996), in that it's a method for set-breaking. Dunbar (1995) points out that analogies can be categorized as *local, regional,* and *long-distance*, each serving a different purpose. His study of scientists in cellular or molecular biology labs found that local analogies are often used when there is a specific (and often technical) problem. Scientists attempted to borrow techniques from other similar studies, hoping to resolve the issue. Regional analogies were employed for developing new hypotheses. These analogies often made connections between different disciplines making connections that were more difficult to see than the connections used in local analogies. Long-distance analogies were used for explaining ideas. The two concepts were not connected in any practical sense but could more easily generalize an idea so that interdisciplinary groups could have some collective clarity.

We can see that Halpern's use of boundary objects in her study parallel two specific types of analogies. First, existing objects were used to express concepts and ideas, mimicking long-distance analogies. Second, ad hoc objects were created to help pairs better understand the relationships between the arts and sciences. Finally, appropriated objects were used to create new meaning for artists and scientists (Halpern, 2011), which parallel how regional analogies were used in Dunbar's study. In effect, the objects were used as tools to leapfrog potential barriers to ongoing dialogue, create common ground, and open new pathways. The use of boundary objects becomes a method for opening dialogue around an idea or theme open to pluralistic interpretations and making connections that are often difficult to see.

Minority Dissent, Appropriate Conflict, and Team Diversity

Addressing the differences between creative approaches for artists and scientists and the use of boundary objects as mediational mechanisms is a preliminary condition for formulating teams; it sets the stage for the group interactions. Once the stage is set, the focus moves to the types of interactions teams engage in. One of the most critical concerns is how team members work thorough the idea generation and validation process. The outcomes of these interactions are heavily influence by minority dissent, types of conflict, and the composition of the teams.

Minority dissent has been closely linked to divergent thinking, which contributes significantly to creativity (De Dreu & West, 2001; Nemeth, 1986; Nemeth & Staw, 1989; Van Dyne & Saavedra, 1996). Dissent can come from a member within a homogenous team but more often will arise when there is a diversity of ideas or methods in a team.

Minority dissent has proven beneficial when a group or organization needs to increase its adaptive and innovative capacity during times of crisis or rapid change (Nemeth & Staw, 1989). Van Dyne and Saavedra point out that "exposure to minority viewpoints causes group members to consider more aspects of a situation, evaluate more alternatives, and re-examine their premises" (Van Dyne & Saavedra, 1996, p. 152). Even when the minority perspective is incorrect, dissent can force a re-examination of the problem that aids in detecting correct and novel solutions (Nemeth, 1986; Van Dyne & Saavedra, 1996). The caveat is that while dissent can enhance creativity in teams it is buffered by the level of participation in those teams (De Dreu & West, 2001). Without high levels of participation the dissent can be interpreted as a threat to the cohesiveness of the team (Van Dyne & Saavedra, 1996). There needs to be a level of trust in the team that even the dissent is in service of the project.

A central characteristic of minority dissent is the development and resolution of conflict (Moscovici, 1980; Van Dyne & Saavedra, 1996). One of the reasons teams may fail to perform well is a premature movement to consensus on a group task (De Dreu & West, 2001; Hackman & Morris, 1975) when they have a desire to escape the ambiguity and tension that comes with dissenting perspectives. As historian of science Thomas Kuhn pointed out, "The ability to support a tension that can occasionally become almost unbearable is one of the prime requisites for the very best sort of scientific research" (Kuhn, 1977, pp. 226-227). Sociologist Edward Hackett (2005) extends this sentiment of essential tensions to research groups. There is a need to hold or oscillate between a multitude of dynamics regarding identity, control, and risk in research and these dynamics keep a group performing well while opening new research pathways. Hackett's

research has been conducted on scientific groups, but this tension is common with artists as well. Terri Kurtzberg and Teresa Amabile (2001) address the role conflict has in team-level creativity in a similar fashion, concluding that conflict has to be of a particular type and amount in order to increase creative process and outputs. Without the right balance, teams can perform worse than individuals.

Much of this work is grounded in the idea that a diversity of ideas, expertise, experiences, and epistemologies are important for creativity, but too much diversity makes working together nearly impossible (Kurtzberg & Amabile, 2001). For example, if there is no way to connect the work from the multiple perspectives presented, it will be nearly impossible to create a coherent piece. A critical role for a member in the team to take on may therefore be that of a bridger or connector among the other members' ideas, someone who can help connect the dots when ideas don't seem to fit (Farrell, 2001; Kirton & Kirton, 1994).

Many of these collaboration dynamics, moreover, have curvilinear relationships; the variables produce positive results to a certain point and hinder team performance as they move out of a particular balance. Extroverts on a team can boast performance and creativity but too many extroverts will diminish team performance (Barry & Stewart, 1997; Kurtzberg & Amabile, 2001). These curvilinear relationships are also experienced in the development and resolution of conflicts (Kurtzberg & Amabile, 2001). The difficulty in studying these dynamics resides in the fact that teams operate best when the tension is "just right."

There is agreement that bounded conflict – i.e., conflict in a particular amount, type, and under certain conditions – enhances creativity in teams but that anything

outside of that balance becomes detrimental to their performance (James, 1995; Kurtzberg & Amabile, 2001; Van Dyne & Saavedra, 1996). Conflict is often parsed into affective/interpersonal, and substantive/task based (Guetzkow & Gyr, 1954; Jehn, 1997). Research has shown an inverse relationship with affective conflict and creativity, and curvilinear relationship with substantive conflict on complex tasks (Jehn, 1997; Jehn, Northcraft, & Neale, 1999; Kurtzberg & Amabile, 2001). This implies that teams need moderate levels of substantive conflict and low levels of affective conflict to support diverse perspectives and alternative pathways that lead to creative outcomes.

Returning to the premise (discussed earlier) that sustainability challenges are wicked problems, and that emergent problems necessitate emergent solutions, it is not always possible to predict what these teams might create. If by definition emergent problems consistently evolve, then creative solutions to these problems are not recognizable at the onset of any project. This implies a shift in what Kagan, referencing Capra (2002) identifies as "emergence for sustainability" (2011): science dealing with emergence is now shifting from a focus on structures to a focus on process in these systems. Therefore, addressing the mechanisms, dynamics, and heuristics used for these collaborations may be our best option.

Addressing Complexity in Social Creativity

The interactional dynamics involved in *distributed creativity*, the collective generation of a shared creative product by a team (Sawyer & DeZutter, 2009), are very complex. These interactions are so complex, in fact, that controlled studies lose their ability to give us an understanding of how emergent interactions unfold (Dunbar, 1995; Sawyer & DeZutter, 2009). Researchers have therefore expressed the need for *in vivo*

studies that can help us better understand working dynamics (Farrell, 2001; Kurtzberg & Amabile, 2001; Sawyer & DeZutter, 2009). Responding to this call, I aim to identify potential conditions that must be met for artists-scientists collaborations to productively function, and how interaction approaches, (i.e., creativity skills (Amabile, 1996)), can create opportunities for conceptual change, such as reframing ideas or concepts that allow teams to generate creative solutions to complex problems.

In line with this framing, psychologist David Harrington compares the complexity of these collaborations to the dynamics of ecosystems (1990). An ecological concept that Harrington finds of particular relevance to distributed creativity is "biochemical demand." He finds a parallel between this concept and the psychosocial demands that need to be met for creativity to flourish. These demands act as thresholds; if met, they create the necessary conditions for creative work. In addition to addressing the necessary working conditions and individual components (e.g. boundary objects, resources, individual skill sets in expertise and creativity), I have identified variables that critically impact team performance. I focus on the role trust and task conflict play in the development of projects and how analogies and clarifying questions aid in overcoming false assumptions about what artists and scientists do and triggering insights for the teams.

Variables of Interest

Trust and task conflict are two variables that are required in particular amounts for collaborations to flourish. Farrell has discussed the importance of trust when sharing ideas with others, which he identifies as *instrumental intimacy* (2001). He notes that members "In this state … openly borrow one another's ideas, sympathetically criticize

one another's work in progress, and in other ways establish interdependence in their cognitive processes" (Farrell, 2001, p. 160). This type of trust allows members a freedom to share and critique ideas openly. Along with instrumental intimacy, Kurtzberg and Amabile (2001) have identified task conflict as a critical condition for highly creative work. Team members must believe that each member has valid knowledge that can be applied to the project (expert trust) and the project task must challenge (task conflict) the team as well. Therefore, if trust and task conflict are in short supply or out of balance the results will be mediocre at best. If they are operating at optimal levels, the conditions will be ideal for teams to begin collaborating and generate very creative ideas and products.

Another variable of interest is the use of analogy. Analogies can be a powerful way to communicate and conceptualize ideas in groups. Dunbar expressed the importance of local and regional analogies for scientific breakthroughs (Dunbar, 1995), and the use of what he termed long-distance analogies as communication tools for cross-disciplinary teams.

In this study, I propose that even though scientists may engage with each other in local analogies, it will seldom happen between artists and scientists. Instead, I predict that long-distance analogies will be employed more often (especially in the beginning) between artists and scientists, since they will need to relay what they do and how they see the project pieces. In addition, I believe that teams that engage in high numbers of regional analogies will record more creative events; it seems to be fertile ground where ideas that are both novel and appropriate solidify.

In addition, I am also interested in the way clarifying questions can help individual or team ideas develop. Dunbar (in a video presentation for PopTech) (Spivack,

2011) and Woolley et al. (2010) have identified two phenomena that I relate as looking for clarity and understanding. The search for clarity is expressed in Dunbar's study where he identified a gender difference in how scientists dealt with unexpected results. He mentions that male scientists who encountered an unexpected result would automatically assume they knew why the result happened. Female scientists, on the other hand, would go back and check their work or rerun the experiment, a behavior I associate with searching for clarity. Additionally, Woolley et al. found that females scored better on collective intelligence but attributed it to their high scores on the social sensitivity scale (2010). The social sensitivity scale measures how accurately individuals can read emotional attributes of others just by looking at images of eyes. Higher social sensitivity scores would imply an increased ability to empathize. This attribute combined with the finding that an equal distribution of conversational turn taking increased collective intelligence (Woolley et al., 2010) would imply not only that those with higher social sensitivity may read others better but that they allow them the opportunity to speak so that collective understanding is higher. Furthermore, Dunbar found that when scientists were presenting their research, questions from their colleagues often produced research insights for the presenters (1995). Their findings illuminate the role clarifying questions play in breaking down assumptions for the group and revealing new insights on problems they are addressing; two critical components for dealing with the diversity of artist-scientist teams. Therefore, studying the use of clarifying questions could be identified as a variable that affects the number of insights a team has and breaks down false assumptions about what they do as artists or scientists. These questions are of a particular type; my assumption is that clarifying questions will increase insights and the ability to

synthesize ideas versus critical questions where the speaker has to defend himself/herself, which will stall progress.

Artists-Scientists Collaborations for Tres Rios Wetlands Signage

Sustainability challenges have been identified as wicked problems (see chapter 1 for a full discussion). Bryan Norton has nested the ten criteria of wicked problems originally proposed by Rittel and Webber (1973) into four subgroups organized by a set of diagnostic criteria: (a) the difficultly of problem formulation, (b) noncomputablity of solutions, i.e. no identifiable single best outcomes, (c) nonreapeatablility, i.e. no one-size-fits-all solutions, and (d) temporal open-endedness, i.e. there are repercussions to actions that will be difficult to fully identify (2005, 2012). With these criteria in mind, I set out to design a study that could simulate a design problem that has characteristics of a wicked problem. Though smaller in scale, I identified the signage development project at the Tres Rios constructed wetland site as a space and problem that could operate as a boundary object for this type of simulation. Again, the use of a boundary object was critical to providing artist-scientist teams a space/opening for interdisciplinary discussions that required each member's expertise.

Tres Rios

Tres Rios is a constructed wetland in Phoenix, AZ that captures water from the 91st Avenue Wastewater Treatment Plant and then empties into the Salt and Gila River. The site is considered "an urban wetland in a desert ecosystem" (School of Sustainability, 2013). The Wetland Ecosystem Ecology Lab in the Global Institute of Sustainability at Arizona State University conducts research at the site, which includes investigations in

biogeochemistry, ecohydrology, ecosystem ecology, information and ecosystems theory, sustainability science, urban ecohydrology, and wetland ecosystem ecology (Childers, 2013). These wetlands provide ecosystem services, such as nutrient regulation, flood control, and wildlife habitat. The City of Phoenix has opened most of the site as a recreational area to the public and, as a result, was interested in developing interpretive signage for multiple locations at the site. The interpretive signage was intended to educate and bring awareness to visitors about the flora and fauna, the wetland ecosystem they were visiting, and the engineering involved in the development of this site, which began in 1994.

Image 26: Satellite image of Tres Rios Wetland

Image 27: On site at Tres Rios in July

The goal of this project was to develop a mockup of the signage that extended beyond education by aiding visitors in appreciating the space and to help them learn about the broader ecological context. K-12 students are the target audience, but adults (and birders, in particular) visit the site often so the signs would ideally also be of interest to a range of public audiences. The signage could include interactive, educational, aesthetic, and empirically focused designs that engaged visitors in dynamic ways.

Tres Rios was a suitable study site for this project. While it itself does not qualify as a wicked problem, development of the signage was certainly an open-ended decision problem that approximated the criteria set forth for wicked problems. For example, there was no clear problem formulation: we knew the site but there were no set ways to approach the signage project. There were numerous possibilities for the design of the project and yet no real way to say which was really the best. Although we could pick criteria that let us identify a preferences, like accessibility of scientific information or interactivity, those preferences could not be considered the single best outcome. Also,

the ideas the teams created may suit this site, but moving to another site would require teams to develop new ideas for that site. Finally, the general public will be able to engage with the finished project, and while we can make educated guesses about potential uses, there is no way to identify the full implications of the project.

The Present Study

The majority of previous studies on these types of creativity-focused collaborations have been either retrospective or prospective case-comparison studies (Farrell, 2001). For this reason experimental or quasi-experimental evaluations of artists-scientists collaborations are a new, desirable, and promising direction for investigating the interactions, outcomes, and unintended outcomes of interdisciplinary teams (Hall, Feng, Moser, Stokols, & Taylor, 2008; D. Stokols et al., 2008). By employing a mixed-methods, qualitative and quantitative approach in this *in vivo* study I aim to not only understand how artist-scientist teams collaborate but how new technologies – coupled to survey and observational methods – can be incorporated in enhancing our understanding.

To provide context for the project, participants were brought out to Tres Rios for an initial site visit and then, over the course of four meetings, worked together to develop designs for interpretive signage. During each of these meetings, data were gathered via sociometric badges, surveys, and ethnographic observation. The objective of this data collection was to establish a rich understanding of individual and group factors that hinder or foster group creativity, an objective achieved through the triangulation of quantitative data, observational data, and self-report.

The teams were asked to be creative and to be expansive about what this signage project could look like. They were provided with questions to serve as primers for aiding in their exploration of ideas: What other aspects, aside from those mentioned by the city, might they include? What do they envision the site looking like? What educational, aesthetic, and/or scientific features would they like to propose? Is there a way that the final product can be of use to all ages? I provided these primers as a method for accelerating their initial meeting progress. Providing them questions to explore ahead of meeting time and also allowing them to revisit these questions in their meetings kept them focused on pushing ideas forward.

Method

Harrington points out that unlike ecologists, creativity researchers must "examine the subjectively experienced ecosystem as well as the "objective" ecosystem." (1990, p. 153). The variables addressed previously were primarily measured via a survey, which addressed participant perceptions of the collaboration dynamics, and observational analyses. I also collected data from sociometric badges, wearable sensors that collect speaking, movement, and interaction data (Olguin Olguin & Pentland, 2007, 2008; Pentland, 2008). Sensor data is not dependent on participant or observer perceptions of the dynamics but collects audio, movement, and proximity data from a wearable device outfitted with a microphone, accelerometer, infrared, and Bluetooth. While most questions revolve around perceived notions of working dynamics, I also wanted to explore these dynamics via sociometric badges because they give us a higher resolution image of the interactions in two particular areas of interest: 1) they will tell us how balanced or imbalanced conversational turn-taking is and how that affects perceived

notions of participation and authority; and 2) how amplitude coincides with higher ratings in creative events.

Study Participants

This study is specifically focused on how these collaborations apply to sustainability challenges so participants with close connection to sustainability or environmental scholarship were recruited. The study included 9 ASU graduate student participants in the Tres Rios Project. Participants were split into three interdisciplinary triads. Team one consisted of two ecologists and a ceramicist; team two consisted of a ceramicist, an intermedia artist, and an ecologist; team three consisted of two ecologists and a printmaker. Each team consisted of two females and one male. All participants were recruited via a convenience sample.

Procedures and Materials

Prior to team assignments, participants were given a two and one-half hour tour of the Tres Rios site by a liaison from the city of Phoenix. This allowed them to orient themselves with the site and ask questions about the project. After this initial orientation, participants were assigned to a group based on two criteria: (1) the need to have at least one scientist and one artist on each team, and (2) availability for scheduling meetings. Over the course of six months, each team met a total of four times for a period of one to three hours. With the exception of the initial visit to Tres Rios, all meetings were held in classrooms on the Arizona State University campus. I observed and video recorded each meeting. Additionally, participants documented their experience via a modified KEYS survey and wore a sociometric badge to collect quantitative data (described below).

Participants were provided with a suggested timeline and a variety of office supplies (easel, post-it notes, markers, pens) to facilitate their discussions. With the exception of the timeline and materials, the meetings were largely unstructured in terms of content and duration.[28]

Measures

Sensors: Sociometric Badges. Sociometric badges are wearable sensors (worn on a lanyard around the neck) about the size of a smartphone. They collect time-series data, which engineer Sandy Pentland has identified as behavioral "signals" (2008) at a rate of one-tenth of a second. These signals are measured by the badges ability to sense face-to-face interaction via an infrared transceiver, motion from a 3-axis accelerometer, speech frequency, duration, volume, and patterns via a microphone, and proximity and location via a radio frequency transceiver and a Bluetooth module (Olguin Olguin & Pentland, 2008). *Sociometric Datalab* software, bundled with the devices, analyzes the data and exports a Microsoft Excel file with a matrix of the selected measures for each team.

The variables of interest for this study were the number, duration, amplitude, and distribution of speech episodes. I identified individual patterns of participation in teams by analyzing the number of times each participant spoke, the number of successful and unsuccessful interruptions, who interrupted whom, the length of the speech episodes, and amplitude of those episodes.

Survey: KEYS Questionnaire. I used a modified version of the KEYS survey instrument, which is based on Amabile's (1996) *Componential Theory* of *Creativity*. The KEYS was "designed to give an organization or group within an organization a clear

[28] A protocol for these meetings is provided in appendix D

assessment of those aspects of the work environment that relate to creativity" (Amabile, Burnside, & Gryskiewicz, 1999, p. 1). Specifically, the KEYS measures how participants perceive individual and team cooperation, motivation, creativity, and meeting productivity. The questionnaire was adjusted to make it more suitable for the small team collaborations I was studying, which included adding seven items addressing group efficacy modified from a general self-efficacy scale (Schwarzer & Jerusalem, 1995). This efficacy inventory was added to assess perceptions of competence for successfully accomplishing the project; i.e. the level of trust members had in each other's expertise. I included 46 seven-point Likert scale questions and seven open-ended questions focused on outcomes from each meeting. It was used to measure the affect, rewards, creativity level, and motivation of participants. Questions addressed each of these measures at the individual and team level. Individuals filled out this questionnaire at the end of each meeting. Their responses were then coded so that categorical ratings could be applied to levels of motivation, conflict, and if, during the meeting, he/she or the team experienced any event that could be judged as creative.

Participatory and Ethnographic Observations. I attended all team meetings to collect ethnographic notes that aided in contextualizing the answers given on the KEYS and data from the sociometric badges. The purpose of these data was to provide a richer understanding of the interactions. The sociometric data provided a high-resolution analysis of the team interactions and the KEYS provided each participant's perception of the team interactions. The observational data aided in interpreting the other two data sources in answering questions like, "Does the high energy response from the badges

relate to excitement or frustration in team interactions?" Additionally, the quality of the conversations could only be judged by knowing what was said in the meetings.

Video Recording. I also video recorded all meetings. Ethnographic notes provide rich contextual data but recording the meetings allowed me to reanalyze data in light of new findings or themes that emerged through analysis. I could then synchronize time-stamped video recordings with the badge data, KEYS responses, and ethnographic notes.

Analytical Plan

My approach to addressing how teams reasoned together, validated ideas, and ultimately produced a creative conceptual design is three pronged. First, I begin by broadly describing all three teams with a focus on quantitative analysis. In this section I draw heavily from badge data and survey items that pertain to individual and group satisfaction and efficacy. The purpose of this first section is to provide a snapshot of variation between teams, to synthesize key findings and to explain what the badge variables measure. Since I use badge data in the ethnographic analysis familiarity with the variables is essential.

The second stage is analyzing the performance of each team via rich descriptions of their performance over four meetings. I also incorporate badge and survey data to support relevant findings at the team level. The final stage of this analysis is thematic findings that are better addressed by comparing dynamics across teams. This is heavily focused on badge and survey data.

The purpose of such an approach is to identify characteristics that pattern across groups as well as explore unique characteristics within groups that may or may not have

contributed to their creativity. By coupling these methods I provide a more holistic and dynamic understanding of these collaborations.

Aggregated Results

Table 1: Aggregated team results

		Badge Data						Survey Data		
Gender	Discipline	Speaking	Successful Interruption	Overlap Average	Amplitude Average*	Amplitude Deviation*	Total Group Deviation from the Average*	Individual Satisfaction	Team Satisfaction	Team Efficacy
Team 1										
F	Scientist	36%	66%	0.5233	12.16	1.74	6.17	4.88	4.21	3.75
M	Scientist	45%	66%	0.5081	11.78	1.35		4.75	5.25	5.43
F	Artist	19%	47%	0.4736	7.34	-3.08		5.79	6.08	6
Team 2										
F	Artist	37%	86%	0.5158	6.55	0.78	1.56	6.25	6.08	5.25
M	Artist	38%	74%	0.4942	5.43	-0.34		6.5	6.46	5.99
F	Scientist	25%	71%	0.4908	5.34	-0.44		5.33	6.63	5.29
Team 3										
F	Scientist	26%	49%	0.5033	12.13	-0.43	1.34	6.04	6.63	6.21
M	Scientist	35%	46%	0.5094	12.31	-0.24		6	6.38	5.64
F	Artist	39%	52%	0.5041	13.22	0.67		6.13	6.67	5.96

* E-03

Table 1 contains data for each team, aggregated across all four meetings. The *speaking* column is the percentage of uninterrupted speaking time for each participant. *Successful interruption* is the percentage of "successful interruptions" out of total interruptions. Interruptions are counted when one team member interrupts the current speaker. An interruption is successful if the interrupter speaks for more than 5 seconds out of 10 once the interruption has begun; it is unsuccessful if the interrupter speaks for less than 5 seconds. Overlap average is the average time for the length of interruptions at 1-second intervals. This is calculated by summing for each member all the moments where at least two team members are speaking simultaneously and averaging those events. Since the badge collects data at 1-second intervals, each overlap event is averaged from 1-second events (sum of overlap time in seconds/# of overlap incidents). *Amplitude average* is the average amplitude (volume) absolute value for an individual during a

meeting. The amplitude is measured from 0 to1 for the badges. The *amplitude deviation* measures how far from the group mean each individual's mean is. The *total group deviation from the average* calculates a variability score by summing the absolute value of the difference of each member's score from the group mean, the higher the score the more significant the deviation between members.

In team one the artist speaks significantly less than the other team members. Successful interruptions are consistent with speaking outcomes, successful interruptions being equal for the two scientists and the artist with the lowest percentage. Again, the artist scored lower on overlap average than the other two team members. Though she appears to participate less and appears to have less success when she tries to participate, she rates the team performance higher than her peers do.

Team two had more balanced interactions but the minority member[29] still had the lowest speaking percentage. However, her successful interruptions were fairly similar to the male artist. This percentage combined with a low overlap average suggests that, while she did not speak as often, when she did speak the other two members were quick to listen. Survey scores indicate high and consistent levels of satisfaction with the team.

Team three speaking percentages were very similar to team two, however the member with the highest percentage is the minority member. Successful interruption percentages were the lowest for team three, this is not necessarily negative, and I will elaborate on this shortly. Overlap averages were very similar for each member suggesting a consistency in their interactions. Survey scores were high as well for each member.

[29] As referenced in chapter 4, the member who solely represents his/her discipline is the minority member in the group. In team 1 and 3 it is the artists. In team 2 the scientist is the minority member.

These scores give us insight into the role equal participation may play in team performance with disciplinarily diverse participants. The team with the lowest satisfaction, as identified by the survey, is also the team that has the highest badge metric disparity between its members. The *total group deviation from the average* was notably different for team one than for team two or three; team one displayed more variability between their scores. Team two's minority member spoke less than the other two but her successful interruptions, being higher, indicate that while she may not speak often she is listened to. Again, team three had the most balanced scores in relation to each other; they had the lowest variability, which suggests balanced interactions may be more critical than specific scores.

Team Observational Analysis

The survey and badge data provide us with interesting quantifiable measures. There are clear differences among participation patterns for each team but it is unclear what the meetings were about or how teams reasoned and decided on outcomes simply by looking at that data. Contextualizing the data via ethnographic observations provides a foundation for understanding the complementary quantitative measures in this study. The qualitative data will be discussed in terms of dynamics within each team. Since context is critical to understanding member responses it makes sense to use the team as the unit of analysis.

Team One Results — Two Ecologists and One Ceramicist

Team one develops a couple of habits early in meeting one that prove challenging for them to overcome as they moved on. The two scientists attempt to engage the artist

early in the meeting but as the meeting progressed they moved towards interacting with each other in the ecosystem processes they believed were most relevant to signage. They ask the artist, on two separate occasions, what she found most interesting about the site, in an effort to understand how a new visitor might interpret the site. The artist notes that the water release site from the treatment plant and the EPA testing site before the water returns to the Salt River really stood out to her. Each time the female scientist points out that these areas are closed off to the public. The artist does not press the idea on how these specific locations could be addressed in the signage and the group moves on. This interaction is a clear example of a lack *creative perception* (Amabile, 1996; Koestler, 1976), the ability connect seemingly disparate ideas in novel ways. The team misses the opportunity to spark a discussion on how sensory input could be used to engage the public in the space and how the unseen aspects of the space could be communicated in compelling ways.

The two scientists move quickly to developing a plan of action about ecological processes. They discuss where the water is coming from, types of plants, and habitat, commenting at times how the artist may be able to aestheticize the concepts or illustrate the science, versus getting her input on what she thinks. They also take turns sketching ideas on the whiteboard about system processes, making it difficult for the artist to participate. This activity is not malicious, they regularly ask the artist questions, but they appear over-eager to make the process work. They would ask the artist simple questions and if she hesitated to answer they would interrupt to assist in finding an answer. The male scientist points out in his survey that he felt the need to fill up quiet moments in their sessions. The speaking percentage from the badge data shows this disparity in

speaking balance as well. The male scientist accounted for 46% of the total speaking time during the meeting, the artist only 20%. Moments that appeared to increase awkwardness, tension, or confusion in the meeting quickly became opportunities to move towards a solution that could be applied to signage development versus exploring potential ideas.

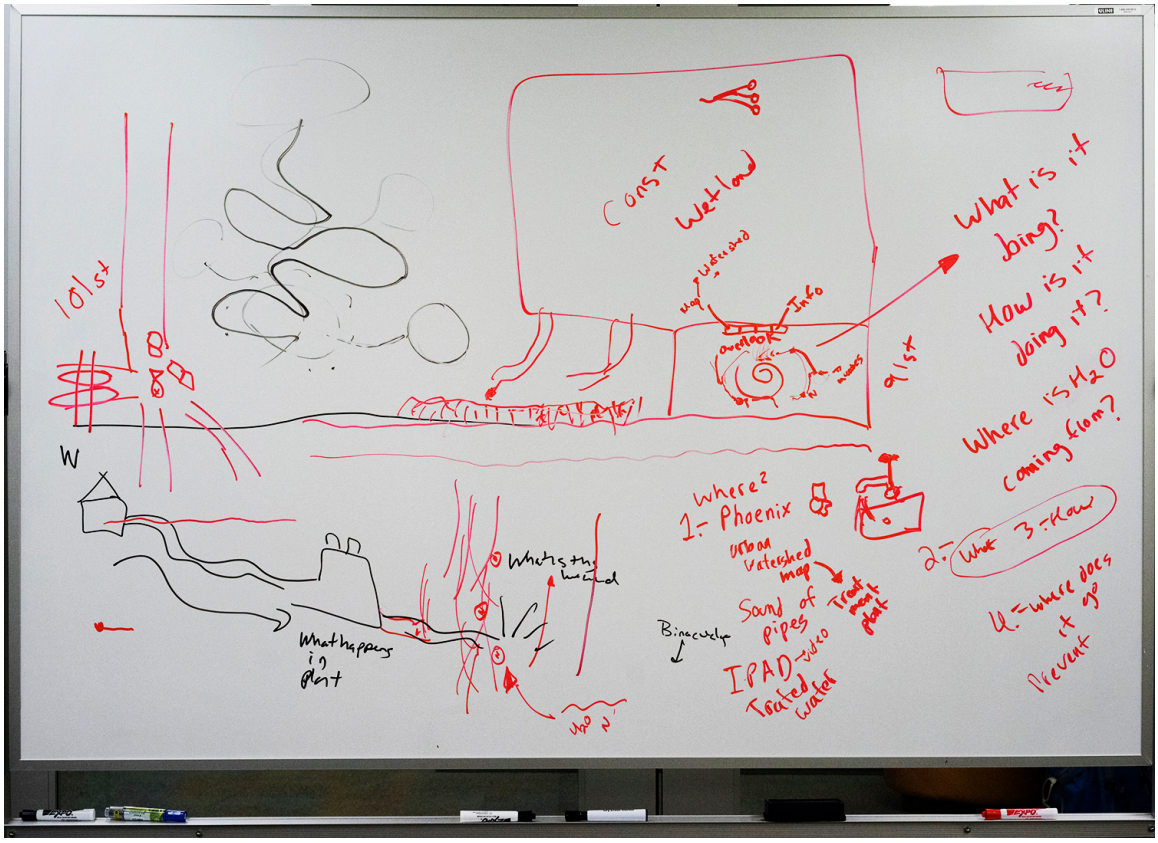


Image 28: Sample of team one signage design process

These habits continue into the following meetings. Early in meeting two, as the team is revisiting ideas from the previous meeting, the artist mentions how the noise of the rushing water drew her attention. The two scientists acknowledge her observation then continue with ecosystem processes. The artist is not very assertive; again they miss an opportunity to potentially engage visitors in sensory information that can make ideas about place more visceral. The two scientists position themselves facing each other with

the artist seated further from the whiteboard, creating an unintentional physical separation. This seems to reinforce the interaction where the two scientists discuss the work and look to the artist to give a "fresh" perspective similar to what a newcomer to Tres Rios might experience.

The conversation continues with the female scientist taking the lead on developing content. If the artist interrupts, it tends to be to confirm an idea from one of the scientists. For instance the female scientist mentions that she doesn't enjoy reading signs and prefers visuals, the artist affirms with, "yes, something visually interesting" but doesn't follow-up with suggestions. The male scientist, half joking, asks, what if the signs were purely visual? "Or just no signs at all?" He continues, perhaps a trail with questions that culminate at the end with answers, a way to encourage exploration. The two scientists continue this dialogue for a while and decide it could be a very good idea. This is a moment of insight for both scientists and the female scientist quickly begins sketching out how the ideas could work (see figure 2). She finishes the sketch and comments, "that's all I have." The male scientist takes over and starts discussing how the signs could communicate how nitrogen moves through the system. They turn to the artist again as a sounding board. Would she prefer if the sign mentioned that the process removes nitrogen from the water or that the process cleans the water? Though they have a productive meeting, it primarily takes place between the two ecologists; they miss the opportunity to engage the artist in a thoughtful discussion about how she might imagine the signage operating. They have attempted to include her but the process seems difficult for both the ecologists and the artist. The female scientist notes in her survey that she wants to include the artist in these conversations but is uncertain how. The male scientist

considers it a success because the artist asks for vegetation samples at the end. This indicates, to him, that the artist is interested in what they are doing. The artist comments that the scientists are really knowledgeable regarding the wetland. She doesn't mention it but the interactions express a submission to the scientists based on their expert knowledge of the site.

The artist brings in some of her plant cell inspired ceramic sculptures to share with the team during meeting three. They spend a few minutes commenting about how interesting they are but they don't ask her any questions about them. The female scientist revisits her notes and shows the team a mockup she designed in Keynote to visualize what the site might look like with the signage in place. She comments that she's not artistically skilled but wanted to provide something to help them move forward. According to her survey, she has put in approximately 90 minutes of work into the project since the last meeting. As they move on, the two scientists work to draw consensus on the content they previously developed with the male scientist primarily providing affirmation for the ideas the female scientist is putting forward. They ask the artist what she thinks. Does the order look good? Is there anything missing? Could anything be simplified? She mentions the system map is necessary but she doesn't elaborate so they move on. The male scientist asks if the soil system should be included and the artist comments that maybe they shouldn't complicate the system too much. Both scientists ask the artist a few more questions about what she thinks is aesthetically appropriate regarding what they have already built; they don't appear to be looking for new ideas. They seem genuinely interested in engaging the artist but don't seem to know how to really go about it. Thirty minutes into the meeting the female scientist is asking

about meeting again and at 43 minutes the meeting has concluded. The energy for this meeting has been the lowest out of the three; the female scientist mentions the low energy level in her survey comments.

Six weeks pass between meeting three and four. It takes them fourteen minutes to revisit what they have done since the previous meeting and get on track for what they hope to do this meeting. The male scientist begins sketching signage layouts on sheets of paper, the female scientist provides him with the ideas they have discussed from previous meetings. The artist addresses a couple of the aesthetic choices the scientists are making and says she can help design visuals for those sections. The female scientist has comments that the final conceptual mockups are out of her technical expertise and asks the artist if she will be able to assist with the final designs. The artist confirms that she can make the final concepts in Photoshop. The female scientist would like to make multiple designs as an iterative process for picking the best final; the male scientist seems more intent on putting the group effort into one design.

Tension increases as they try to work through what they should do with a deadline quickly approaching. The male scientist decides they should revisit content and the female scientist redirects mentioning that content has been agreed upon and the priority is a coherent design. She mentions repeatedly that she does not have adequate design skills and is looking to the artist to help develop the finished signage. She also is firm on the fact that she is not able to view the project in its entirety on small sheets of paper and needs to visualize the design in a poster-sized context. I agree to go grab a role of butcher paper for them so they can sketch out the entire project. The artist reiterates the design pieces the female scientist has been discussing and asks for confirmation on the direction

the group is moving. The male scientist remarks that he doesn't need to see the design fully laid out but if that's what the female scientist needs then so be it. He is disengaging further, the female scientist apologizes but says that she cannot get clear on what is working and what is not working until she sees it in a manner that allows her to process through the decision making systemically. The meeting continues in this manner with the three members realizing they will not get resolution on a final design by the end of the meeting. The female scientist asks the artist what she will need to produce the designs; she appears tense even asking. The male scientist asks if she will do it in Photoshop, on sheets of paper, or on the butcher paper; working style has become a common point of tension. The artist has remained fairly quiet throughout the meeting, which also seems to increase tension for the female scientist. She is looking to the artist for her technical abilities and so is hoping to get confirmation from her that she can get the project done. The artist confirms that if she gets all the necessary content she should be able to create the designs. The meeting ends with all three members looking frustrated.

Qualitative Findings

As I discussed previously creative scientist dispositions can vary from artists in terms of conscientiousness (Feist, 1998; Kaufman, 2009) and this appears to play out for team one in terms of quick consensus (De Dreu & West, 2001; Hackman & Morris, 1975) and lack of creative perception (Amabile, 1983, 1996; Koestler, 1976). The two scientists take early control of the design content. By meeting two they have agreed on what the signage will include. Quick consensus is most visible in their interactions with the artist. They ask the artist for her opinion but most often look for a response that makes them feel like they are moving forward in accomplishing the task of building a

design. The need to keep moving forward also blocks potentially creative ideas. Rather than exploring the ideas the artist presented about the water release site, the EPA site, or the sound of the rushing water they discount them as unusable concepts. All three are opportunities to potentially reveal to the public hidden aspects of the constructed wetlands. To just explore a couple of possibilities, the artist's ideas could have been developed to express ideas about the amount of water used in the city, how water is tested before reaching the Salt River, or the sensory experience of water in the desert. In meeting three, when the artist brings in her plant cell sculptures, the scientists have the opportunity to ask the artists how she sees the work fitting into the signage concepts; a way to connect her work to the current designs or new designs. The desire to find an outcome early in the meetings created an issue in the end.

Sociometric Badge

The Sociometric badge and survey data supplements the dynamics discussed in the ethnographic observations. Team one expresses patterns of interest most clearly related to high-energy events and balanced participation. Because they are the team that experiences the most volatility, threshold patterns are expressed more clearly than the other two teams.

Amplitude[30] and Energy. When focusing on potential thresholds I calculated the variability of amplitude between members in their group. Woolley et.al. (2010) addressed

[30] Note that all 3 teams scored differently on amplitude. This can be attributed to louder teams and/or environmental factors. Some rooms may be louder than others due to size, building materials, or ambient noise. I was not able to fully control for these factors, however, when taking a meeting as an independent session, all members are equally affected by these factors. More important than an absolute amplitude value is the variability between members, hence, the noise they may equally experience may be normalized for the session.

how equal distribution of turn-taking during speaking events correlated with collective intelligence. The reason I turn to amplitude is that speaking time does not indicate the energy for the meeting. The badge element that records speaking may show balanced interactions but does not indicate the prosody of the speaking event. This is expressed most clearly in meeting four for team one where speaking appears to be high for the male scientist; however, his *amplitude patterns* vary from his previous scores as compared to the female scientist. The difference can be seen when comparing figure 2 with figure 3. This variability indicates that their interaction is different from previous meetings. As I will discuss in the next section, and the survey data supports this premise, that this is a frustrating meeting for the two scientists.

There are other potential indicators, such as the female scientist's *successful interruption* and *average overlap* scores that hint at a dynamic change in the meeting. The scores for her meeting 4 are higher than her scores for previous meetings (For example her rate of successful interruptions from meeting one to meeting four are up from 56 % to 80%, and her average overlap is up from 0.495 to 0.586) indicating that she became more assertive when expressing her ideas.

Figure 2: Speaking Patterns

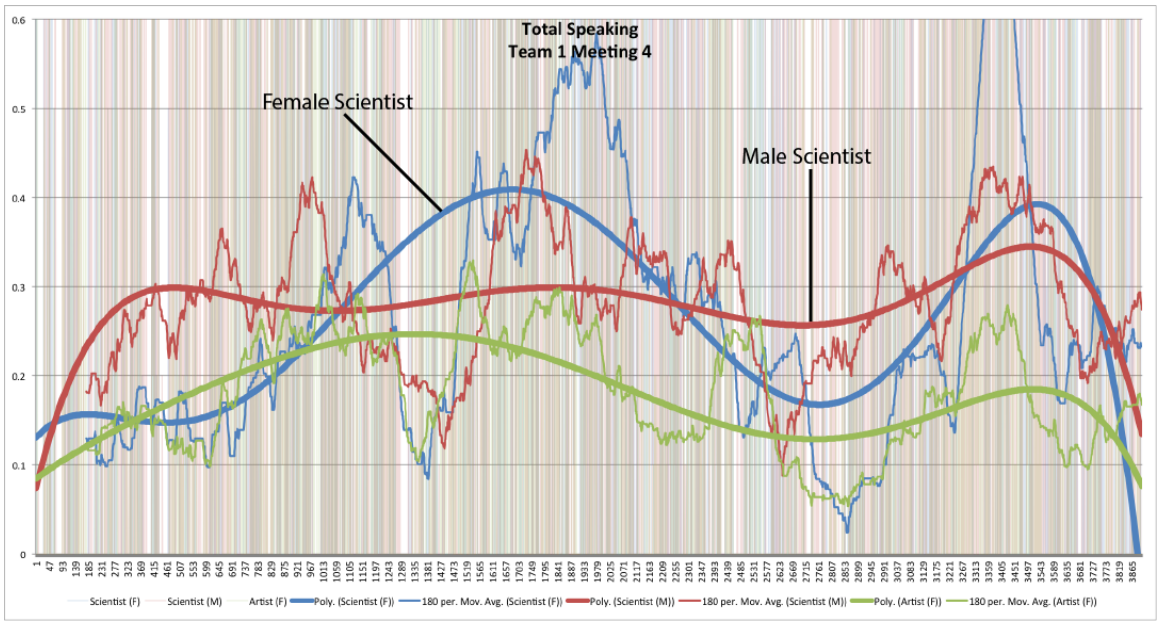
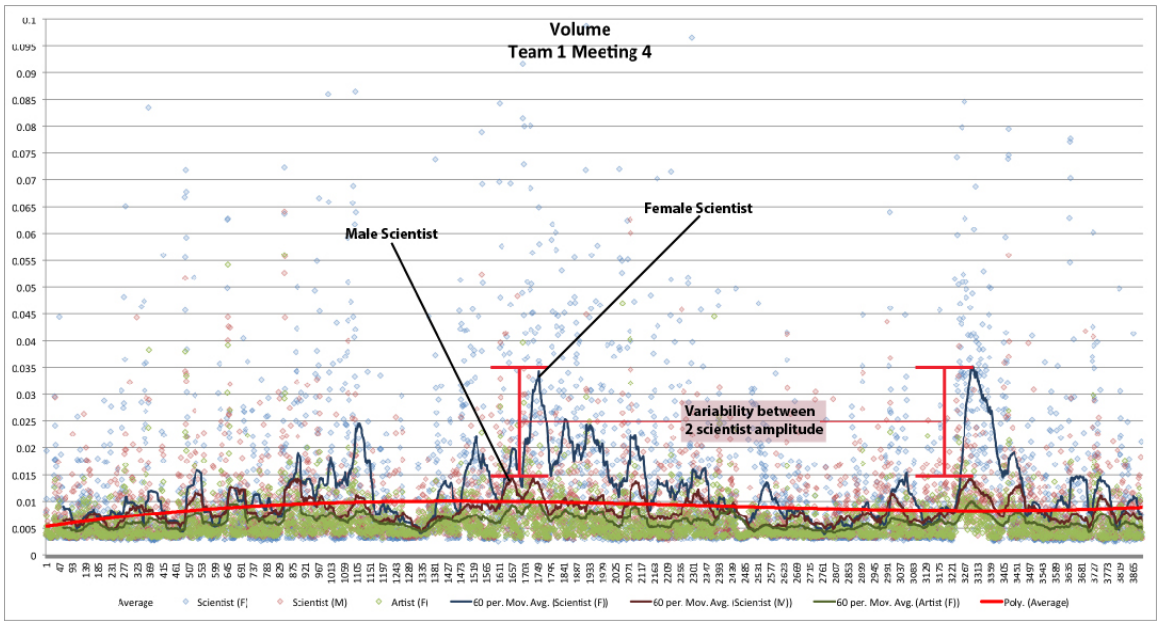


Figure 3: Frustration Event Measured Through Amplitude

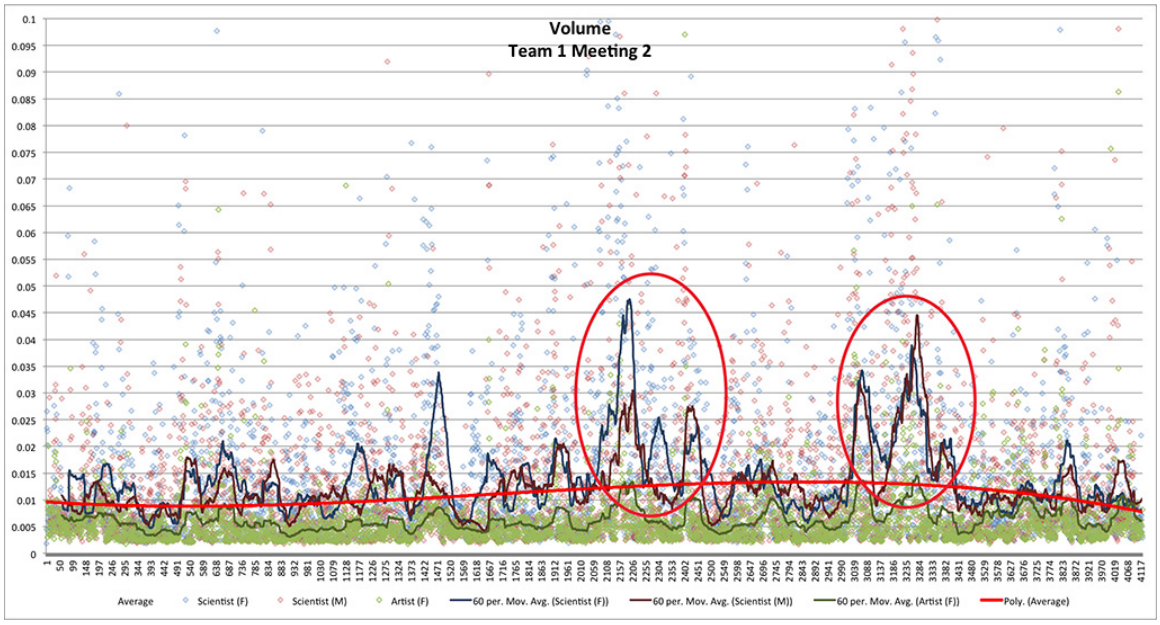


Thresholds being surpassed. Based on the previous section I used amplitude variability for the teams (per meeting) as a measure of equal participation.

Team one experiences the crossing of potential thresholds twice, in meeting two, where they generate the majority of their creative ideas, and meeting four, a highly frustrating meeting for two members. It's also worth noting that team one has the highest variability in participation (as express by *total group deviation from the average*) of all teams.

Meeting two for team one has the highest amplitude deviation for all teams with a score of 9.21E-03. Both scientists control the meeting from the beginning, directing the potential pathways for signage design. At about 30 minutes the male scientist presents the idea of exclusively visual signs, which sparks multiple ideas for both scientists. As the meeting continues, the average amplitude continues to rise for both of them at a higher rate than the artist. Both scientists score this meeting the highest on individual and team satisfaction, as well as team efficacy.

Figure 4: Creative Event Measured Through Amplitude



Meeting four for team one (figure 2) is their second highest amplitude deviation meeting with a score of 6.20E-03. Variability between member scores progressively increases with the male scientist and artist maintaining low scores and the female scientist's score continuing to spike and fall. Twenty minutes into the meeting tension began to rise regarding the ability to produce a mockup with a cohesive idea by the acknowledged deadline. The artist scores the meeting a 6 on the 7-point survey measures for individual and team satisfaction, and team efficacy. The female scientist scores the meeting very poorly; *individual satisfaction* a 2.5, *team satisfaction* a 1.83, and *team efficacy* a 2, indicating very little confidence that the team is capable of producing a sign mockup. The male scientist scores the meeting; *individual satisfaction* a 3, *team satisfaction* a 3.33, and *team efficacy* a 6. The artist identifies the female scientist as the team leader in her survey comments, interpreting her resolve as taking a stand in the direction the team should go. Both scientists acknowledge the inability to move forward in their survey comments, the male scientist being unhappy with the female scientist's inability to be flexible with working methods, and the female scientist feeling frustrated that members seem to be misaligned with what the end product should look like and how each member should contribute.

Team Two Results – One Intermedia Artist, One Ceramicist, One Ecologist

Team two was good about engaging all members on the team. After introductions the male artist took on a facilitative role. He asks each member for their experience of Tres Rios and begins writing his ideas and member responses on post-it notes to share on the whiteboard. The female scientist asks if it's worth thinking about what the story of

Tres Rios is. This sparks a conversation on what the multiple stories of the site might be. They discuss the history of water in the area, the waste treatment plant, and ideas about how water quality is interpreted. The female artist mentions she finds it interesting that water needs to pass an EPA quality standard before it returns to the river but is simply contaminated by farm runoff once it leaves Tres Rios. They continue sharing ideas regarding the ecological, social, and historical components of the area. Each member is willing to ask for clarification on ideas from team members, both to illuminate ecological processes and art making processes. The female artist comments that they should get at "questioning", the female scientist confirms that asking questions about water in the desert is an interesting direction. The male artist asks the female scientist for clarification: Is she interested in getting visitors to ask questions about water in the desert? She responds, "I'm more providing a ladder for them to get through." The male artist extends the idea, mentioning that it would be good to have visitors contemplating water in the desert even as they were driving home. The team is comfortable with this type of discourse, asking each other for clarification of their ideas, responding and building off one another's ideas, and sharing what they know. While the female scientist speaks the least, accounting for 26% of total speaking time, she engages actively with the 2 artists, not only answering questions and correcting misconceptions about the ecological processes of the site, but also offering ideas about what they might explore, from understanding how natural systems work, how constructed systems share similarities and differ, and the potential interactions of a wetland system situated in a desert system. As they conclude meeting one the male artist asks each member to brainstorm ideas for the

next meeting regarding how the signage might operate, i.e. as a sculptural object, text, imagery, web presence.

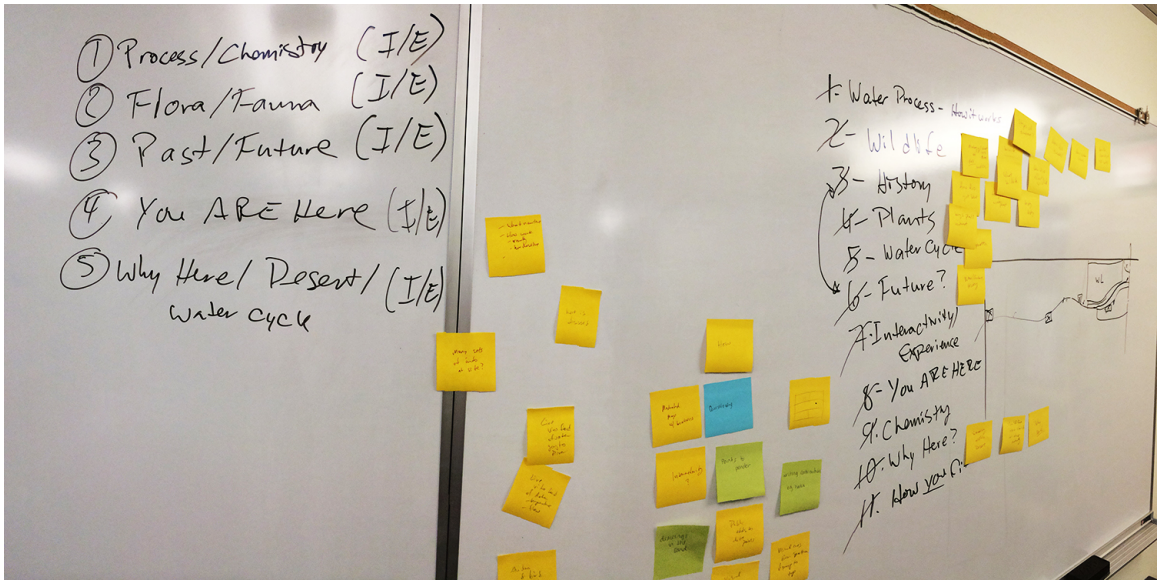


Image 29: Sample of team two signage design process

The team begins meeting two by quickly revisiting what they did in the previous meeting. The female artist begins placing last meeting's post-it notes on the board to review. This gets them up to speed quickly and they begin generating new ideas. They explore how technology could mediate the experience, what experiential components could be included, sound and colored lights, that communicate particular functions of the system like water temperatures and water cleanliness. They interact well as they generate ideas, going back and forth, asking clarifying questions, and building on each other's ideas. Again, the female scientist doesn't speak much, accounting for 17% of speaking time, but the quality of her interactions really serves the team well. The team plays with the idea of live video or audio feeds for the site. The female artist suggests potential areas

of interest, like audio feeds of birds. She wonders if they could attribute a "sound" to water temperature eliciting ideas of synesthesia and the female scientist picks up on it mentioning how the movie "Mr. Holland's Opus" translated music into color. These moments express the willingness of members not only to engage in each other's ideas but also to draw parallels to other information. This happens regularly for all members during the meeting.

They perform well, managing the development of ideas. They began the meeting feeling a little hesitant about silent moments but as they continue they use those silent moments well to reflect on ideas and either build on them or work to find a structure for the ideas they have populated onto the board. Team two is silent for 57% of meeting two compared to team one at 40% and team three at 42%. These silent episodes provide team two space to think more deeply about the responses they have generated and creates an oscillation between generating ideas and validating which ones they want to move forward with before they begin to generate more ideas in a more focused manner.

This smoothness of interaction is also expressed during moments of tension for members. In her survey comments, the female artist expresses her "mixed feelings" about the direction the male artist was taking the team into. She mentions that, "she made herself stop reacting and really listen" so that she could see the "advantages and disadvantages" of current strategies and articulate her ideas in reassessing the direction the team would like to take. They build out the elements they want to include in the signage, into 10 main points, covering ecological processes, history, interactivity, and the purpose of the site. Once they have settled in on these elements the male artist asks,

"Does everyone feel good about this list?" The other two members agree it's a good list and then begin reassessing in an effort to pair down and further flesh out the list.

Meeting three is a natural progression of the previous meetings. As members revisit information from the previous meeting, they populate the whiteboard framing out how they feel the signs will be situated at each site and what each sign will entail. The female scientist continues to drill down on ecological processes in the system. The discourse is still rich with ideas and questions, however they are quicker at evaluating ideas as they move forward. They have decided early on that they will need to meet again since the project is not close to completion and they do want to provide a finished concept. Moving forward they pick ideas based on how well they can be communicated to a layperson and if they coherently fit with the list of five elements they have decided on. These include, (1) process/chemistry, (2) flora/fauna, (3) past/present/future, (4) you are here, and (5) why here/desert/water cycle. They understand they only have one more meeting so they focus on which ideas to select from the large number they have developed. If the idea can be communicated coherently and fits the framework they have developed it makes it to the second round, if it doesn't it's discarded. The team is dealing with a high cognitive load at this point, several complex ideas that need to fit together. They discuss other relevant ideas like the nitrogen fixation process of the wetland system versus desert system, the mosquito larva eating fish, and the potential use of wetland biomass as fertilizer and it not being used because it's currently cost prohibitive. The male artist mentions they are kind of on a tangent and the female artist comments that it all seems useful. It's potentially information that incubates and provides a clearer

direction, but at this point they don't intentionally include it. The meeting isn't super energetic, fairly even keel, but very smooth operation.

Nearly two months pass before they find time to meet again. A significant amount of momentum has been lost for the project and they have to spend time getting reacquainted with what they were working on in April. The female scientist mentions that she will not have the time to continue working on the project but can advise via email. As they continue working, they seem cordial but the dynamic has changed. The female artist is taking the lead on the whiteboard to organize ideas and the male artist is taking notes on his computer, a role reversal for the two. The male artist's speaking time has dropped to 29% from his average of 40% over the past three meetings. Consensus comes quickly on ideas and new ideas feel scattered as if they are simply going through the motions. The member survey comments perhaps reveal the most about the change in dynamic. The female artist mentions that she is excited about seeing the signs at Tres Rios, whether it's their design or designs from another team. The male artist comments (at length) on his frustration over the fact that he and the female artist have been left to finish the project. He mentions their effort to accommodate the female scientist but feels that the two artists will have to finish the project. He specifically expresses frustration about feeling that others "think that artists have open amounts of time to create designs, doing large amounts of the work while others don't have to put in the same amount of time, effort, or expertise." The female scientist identifies this meeting as a "positive experience," and that the only frustrating issue was the fact that funding has been cut for the majority of the project, allowing for the development of only a small number of signs. She continues, "Fortunately, my teammates did not seem frustrated by the news, and forged on without

skipping a beat to approach the changed goal of the work." Overall, the team works very well together but the final comments also express each member's ability to maintain a particular composure even if there are underlying tensions.

Qualitative Findings

Team two turns out to be lower energy but a consistent group. The team members are quick to ask questions and seek clarification, which proves valuable in developing ideas that integrate both the artists' and scientist's perspectives. Additionally, the scientist highlights how expertise and cognitive flexibility can trump speaking time. She provided critical components that held ideas together. The male artist facilitates and is good at connecting multiple ideas, a factor critical to creating a synthetic product (Farrell, 2001; Kirton & Kirton, 1994). Being highly inquisitive, the female artist created a dynamic that allowed the team to remain open to new ideas. The quality of responses, ability to manage ideas, and resist premature consensus helped them produce a mockup that expressed the complexity and socio-ecological relationships of Tres Rios.

Team two did have some challenges, however. Their ability to mitigate tension in the group and being overly ambitious hurt their design. Every team member was very courteous; making certain each member was heard. This created a momentum issue for them. They were able to explore several ideas and worked hard to connect them but at a pace that made it difficult to accomplish what they wanted in four meetings. I believe that if they had extended their project to six or more meetings they would have developed a very robust and visually compelling design.

There is one more condition that would have fostered their success, that is being more open about personal tensions they were experiencing. While task conflict is good

for creativity interpersonal conflict is detrimental (Jehn, 1997; Jehn et al., 1999; Kurtzberg & Amabile, 2001). The most explicit example of an interpersonal conflict was when the scientist excused herself from active participation in the completion of the project and the two artists continuing as if nothing was wrong. This particular event seems to have affected the artists' motivation to produce an aesthetically compelling design. Their design executes on the suggested concepts but lacks the aesthetic complexity of their ideas. The artists seem to lose motivation for continuing with the project. Both conditions – more time and resolving interpersonal conflict – would have to be met for a successful project outcome.

Team Three Results – Two ecologists, One Printmaker

The team begins much like the other two. They take turns discussing what they do for their art/research. They don't get up and diagram anything; they simply engage in open discussion. I mention that maybe they should discuss what their workspaces look like, what they do, and what they are working on. The female artist shares first. Once she finishes sharing her work and research the male scientist comments that, being a scientist at heart, it's interesting to see how her art practice parallels his research practice. Once they finish sharing backgrounds they begin discussing Tres Rios observations. The male scientist, who conducts research at the site, mentions that an often-unnoticed component of Tres Rios is the seasonal changes. The female scientist notes the contrast between the wet and dry bosques. The female artist ties in the human component and points out how residents have a hand in creating the wetland system, i.e. the municipal water system feeds the wetland.

As the discussion progresses they begin developing ideas about what is important. The male scientist notes the importance of water in the desert, the female artist acknowledges his point and notes the careless consumption of water in Phoenix. She adds that it's a completely unscientific view but residents need to become more aware of where their water comes from and how it's used. They begin to expand on two main ideas, a water narrative about where the water comes from, and a story about ecological processes. As they continue developing these two narratives they are all very receptive to presented ideas and piggyback on each other's comments as well as quickly drill down on what they know about the site and the ecological processes at play. They go back and forth a little. The female artist has taken the lead, the first minority member to do so. She asks about potential interactivity. The male scientist responds asking if she's thinking about something "hi-tech." It could be something as "low-fi" as a hole to look through, she replies; something "accessible, warm, and relational." The male scientist suggests a potential visit to the Audubon Center, which could provide examples for their signage.

They begin to discuss the approach they want to take; multiple signs, multiple sites, or selecting a specific area. As they continue to exchange ideas the female scientist mentions that a vantage-point sculpture from another site was interesting to her. This sparks a conversation about place-based structures. The female artist starts sketching out what a similar structure might look like at the site and adds that inserts could be interesting as potential interchangeable overlays with revisable dates and editions. These inserts could be made of Plexiglas and would have cross-sectional diagrams of ecological processes that align with the site. There could be another insert that diagrams the engineering blueprints of the constructed wetland; the female scientist adds that they

could discuss the system not only over space but through time as well by updating the inserts. They work really well at adding to each other's ideas as they flesh out this vantage point structure. Before they finish their session the male scientist shares his video animation of "Drippy," a droplet of water, traveling from the rivers in northeast Arizona and through Tres Rios. He has produced this video to give high school students a glimpse at water in Phoenix. In their surveys, all three members comment on the positive energy of the meeting and their ability to work well together. Interestingly, members in team three are the quickest to say what ideas they do or do not like. They also leave space for each person to defend their critiqued ideas and if the team believes the reasoning is valid they put the idea back on the list.

They begin meeting two by revisiting what they covered in the previous meeting. They spend the first 20 minutes playing with how ideas from the previous meeting can be structured at the site. The female artist worries some of the ideas may sound cool in theory but will not be feasible once they attempt to build signs. The female scientist focuses the group by noting that maybe they should concentrate on the water narrative first and go from there. They begin discussing where the starting point should be for the water narrative, how technical the language should be for the signage, and how the signs might lay out on site to create a cohesive image of water in the desert. The female artist begins to sketch out 10 panels for the signage on the whiteboard, each discussing components of the narrative relating to the geographic points in the water system. She returns to her idea of simple interactivity, a knob that the visitor could slide through the water system as they read the signage. The male scientist is excited by this train of thought and asks if there could be audio that relays ecological facts about the system at

critical points. They think about interviews and other stories on watersheds or history of water that people could press a button to hear; perhaps interviewing people about what water means to them as it goes through the system, i.e. what does water mean to a farmer, to an ASU hydrologist, an engineer, a Gila River community member, etcetera. They get excited about ideas and keep asking, "Do you think this is too much?" clearly not wanting to overextend what they will be able to accomplish in such a short timeframe. They continue to work on organizing information as a socio-ecological system. The female artist asks how the text on the sign will differ from audio. She asks about representing the diversity of the area. Will the audio contain perspectives from minority communities in Phoenix? The female scientist acknowledges the sentiment and continues down this path of inquiry. Whose voice will be representative of a Phoenix resident? Should they consider different age groups as well, a child perhaps? As they work through this process they discuss how long the audio should be. The female artist thinks visitors will listen for 15 seconds at a maximum; the male scientist asks about the use of QR codes over push buttons. The female artist comments that she strongly dislikes QR codes because she feels they are annoying to use and aesthetically unappealing; the female scientist concurs. The male scientist notes that it would allow for additional information about the site and visitors could listen to it even after they step away from the sign. The female artist feels he makes a valid point and places it on the list of potential options.

This has become a normal interaction for the team, i.e., being open about each other's likes and dislikes and being willing to entertain ideas and well-reasoned arguments. They begin to wrap up and decide on what needs to be done before next meeting. They each take on specific tasks that need to be accomplished when they meet

next. In their survey comments they acknowledge this constructive dynamic that pushes ideas forward; both the female artist and male scientist comment on the positive and organic nature of their collaboration. The female scientist notes, “I felt our group's ability to really critique in a positive but logical and beneficial way is really great.” In doing so, she specifically cited how each member responded to the idea of QR codes.

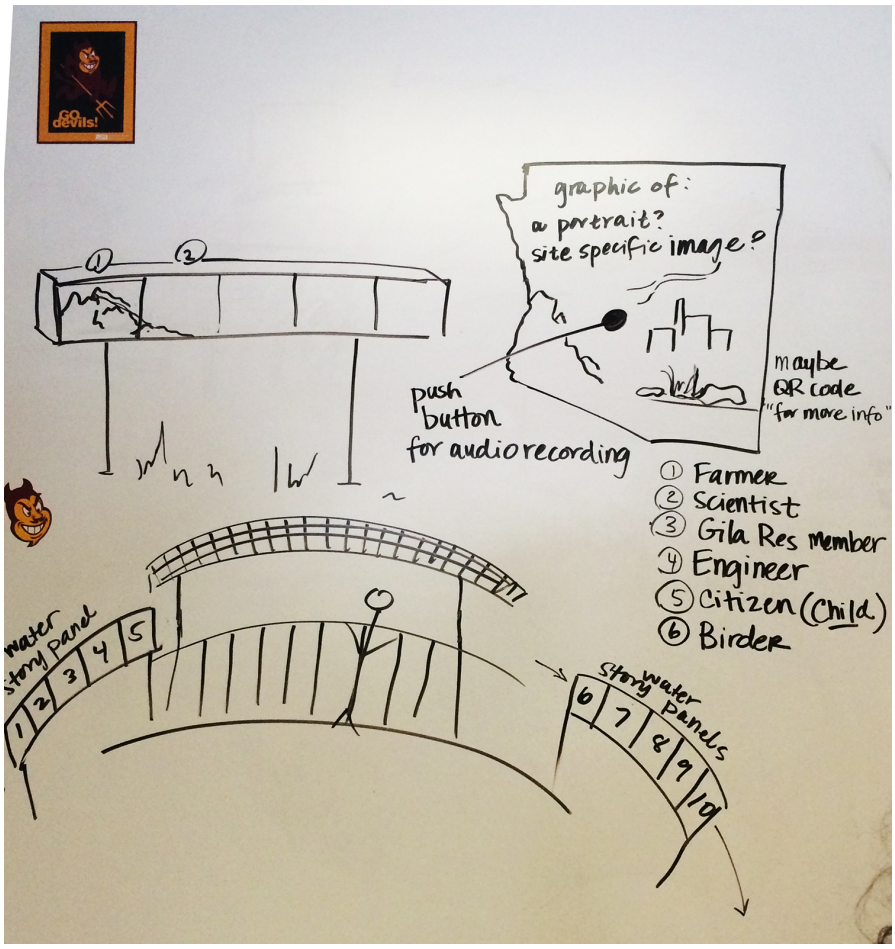


Image 30: Sample of team three signage design process

The team was very good about engaging each other’s ideas, validating them, and fleshing those ideas out. Member roles became more clearly defined during this meeting. The female artist has taken a clear facilitator/leadership role, with the male scientist

providing good ideas and expertise about the site, and the female scientist providing the critical bits of information that helps them get unstuck and connect related ideas. They have done well generating ideas and quickly making decisions on what direction they want to move.

Similar to the other two teams, early in the third meeting the team decides to meet again. The meeting is used to build consensus on which direction they will choose. Unlike the other teams, each member has spent time outside of this meeting preparing content; the female artist has spent four hours mocking up signage in Illustrator. After they share what they prepared the female artist asks what the team would like to accomplish today. The male scientist asks if they can prepare for the next meeting, working out ideas in Illustrator and making a list of supplies they will need to build physical mockups. They discuss how they want to contribute, both scientists mentioning they can develop content. The female artist agrees she can work through the graphics and mentions that once they develop text they can cut it out and move it around on the signage as a way to visualize the signage in different iterations. The female scientist mentions she really likes the idea. She hasn't spoken much but she does acknowledge ideas she thinks will work as they settle on specific outcomes they would like to see.

The female scientist asks about the scale they envision these mockups being. The female artist believes they can be much smaller and suggests making the 10 panels. The male scientist disagrees; he thinks they should focus on one or two signs. The female artist concedes and mentions signs around the ASU campus that she believes are successful examples to take note of. It's a nice pivot for the group, acknowledging the direction a member wants to take and build on it. She has continuously been very flexible

with ideas and simultaneously builds on ideas that move in directions that she hadn't originally intended. In their survey comments the female artist and female scientist note the male scientist's strong opinions on the direction they move in. They both agree he has made strong arguments for his ideas, which strengthen their project. It's an interesting dynamic; the female artist leads the team as a facilitator, however, if the male scientist expresses strong opinions his ideas are often integrated, even if they veer from the intended direction. It suggests the team is flexible and open to changing direction while simultaneously knowing how to focus once they choose a direction.

Meeting three is their lowest energy meeting. They really work to get a sense of what a mockup would look like as a physical object. It has been a decision making day, no work towards creative ideas, just getting the details handled, both for the signage and what they may want for the next meeting. I feel it was a productive meeting but simply for hashing things out, not developing anything new.

As stated previously team three uses their final meeting to build a mockup of one of the signs. The female scientist has spent nearly half the meeting preparing materials for the design to be pasted to. She has made all measurements and cut foamcore for the sign base while the male scientist and female artist work through the sign design. The decisions have been focused on specific product outcomes. At one point the male scientist suggests a couple new ideas; the female artist and male scientist then agree: no more new ideas. They stick to the plan, working through refining the text and imagery. They also decide how technical the language should be and how much or how little text is necessary. The female artist works through multiple processes to create a layout; drawing, scanning imagery, and developing the full design in Photoshop. The final

imagery displays the confluence of the Black and White Rivers into the Salt River; it is the mockup for where the water originates in the system (see Image 4). Once they have finished both assembling the foamcore pieces and printing the design they work together to finish the physical mockup. All members consider the meeting a success, having created a scaled physical representation of one potential sign for the site.

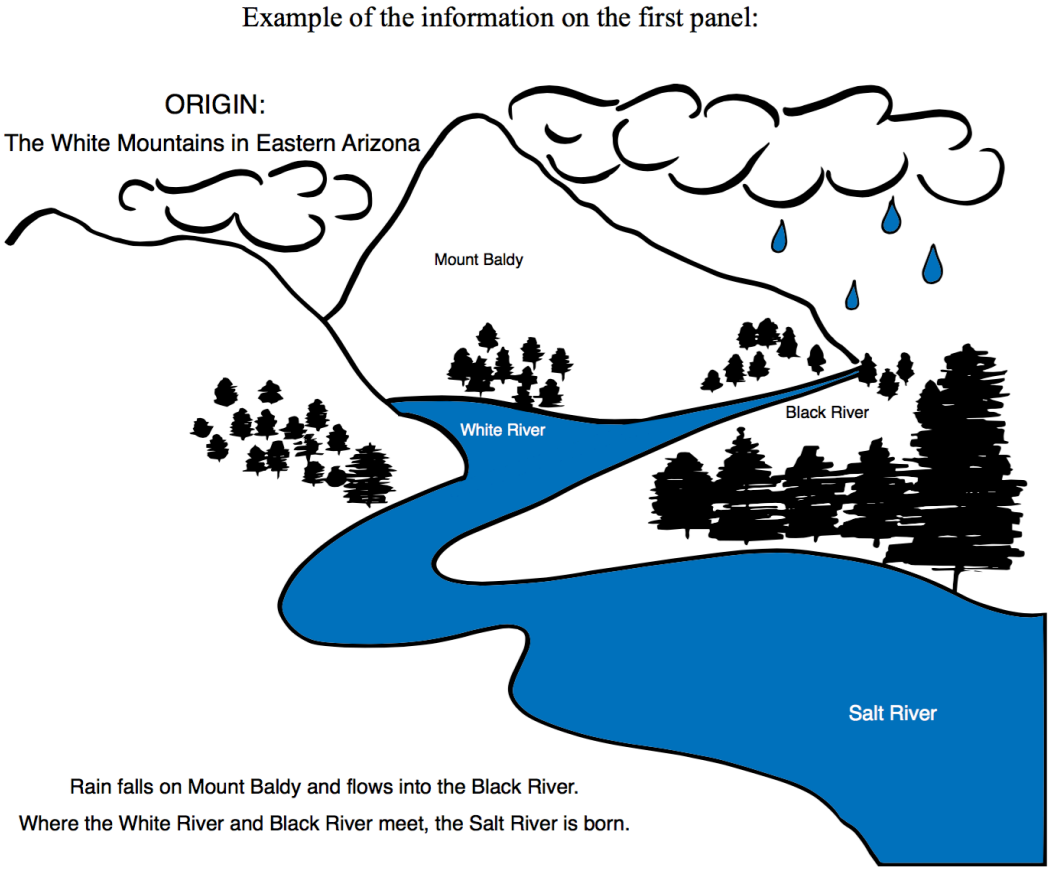


Image 31: Panel sample

Qualitative Findings

Team three has the highest consistent energy and most balanced participation of the three teams. They are very open to dissenting points of view and work through those

perspectives in a very constructive manner. Team members regularly presented ideas beyond disciplinary perspectives by commenting both on the design and content for the signage. Unlike the two other teams, the minority member (the single artist) takes an active lead in facilitating the team. She worked at the whiteboard throughout the sessions, not only writing the teams ideas on the board but also actively mocking up those ideas on sketched out signs. Additionally, she worked on the project for 4½ hours outside of meeting times signifying her commitment to the project; the two scientists combined worked on the project was 1½ hours outside of meeting time. This may suggest, that while active participation is desired of all members one highly motivated member can dramatically increase a team's effectiveness.

Team three engages in the behaviors typical of good creative teams. Most notable is their clear use of dissent and appropriate task conflict. As they grapple with ideas they remain flexible, entertaining different perspectives to produce better designs. This open negotiation of ideas displays a mutual respect between the members. This respect is indicated in their average team efficacy score of 5.94 on a 7-point Likert scale; the highest for all teams (team 2 average was 5.51 and team 1 average was 5.06). Additionally, having spent several hours on the project – outside of meeting time – displays a high level of motivation towards the project, which Amabile (1983, 1996) identified as one of the most critical factors to creative output.

Considerations for Interpreting Data

The two previous sections provide a method for contextualizing and analyzing art-science collaborations dynamics at the team level. The badge variables provide a general image of the equality of participation. The narratives give richer descriptions of

interactions in each meeting. However, there are 3 identified phenomena that are best expressed by comparing across all meetings for all teams. The 3 identified phenomena are:

1. Interaction effects between speaking time, successful interruptions, and overlap averages.
2. The nature of the meeting may change how the data is interpreted. Meeting purpose both first meeting and last T3 meeting
3. Quality is difficult to measure with any one method.

Interaction Effects Between Speaking, Interruptions, and Overlap

Individuals in teams can be expected to vary in speaking time. Some people speak more often than others, and taking on different roles may require some to speak more (Farrell, 2001). Therefore, speaking percentage cannot fully explain how the team values a team member or if members are participating in meaningful ways. The artist in team one and scientist in team two both spoke the least in their teams but the interaction between interruptions, and overlap shows a different pattern for the two individuals.

In all but the first meeting, the artist's percentage of successful interruptions is below 50% and her average overlap is 0.4736. The scientist averages 71% for successful interruptions while maintaining the lowest overlap average for her team at 0.4908. This difference between the two suggests that their status in their group is categorically different. Since overlap is a measure of two people speaking simultaneously, low averages suggest the individual is either winning overlap events by continuing to speak or losing them when he/she stops speaking when another member interrupts. In effect, the

scientist does not need to speak for very long before the other members give her the floor, indicated by her high percentage of successful interruptions. The artist, on the other hand, seems to submit to her team as expressed by low overlap with low successful interruptions.

There are two other possibilities for overlap and interruption interactions. A team member could have high overlap averages and low successful interruption percentages or he/she could have both high overlap averages and a high successful interruption percentage. In meeting four, the team one female scientist has both a high overlap average 0.5856 and a high successful interruption percentage at 80% but does not have the most speaking time. In this meeting, the female scientist was diligently working to finalize a design plan, which she expressed as a frustrating event due to the lack of progress. These 4 combinations can be expressed as a matrix (see figure 4):

Table 2: Interactions Between Overlap and Interruptions

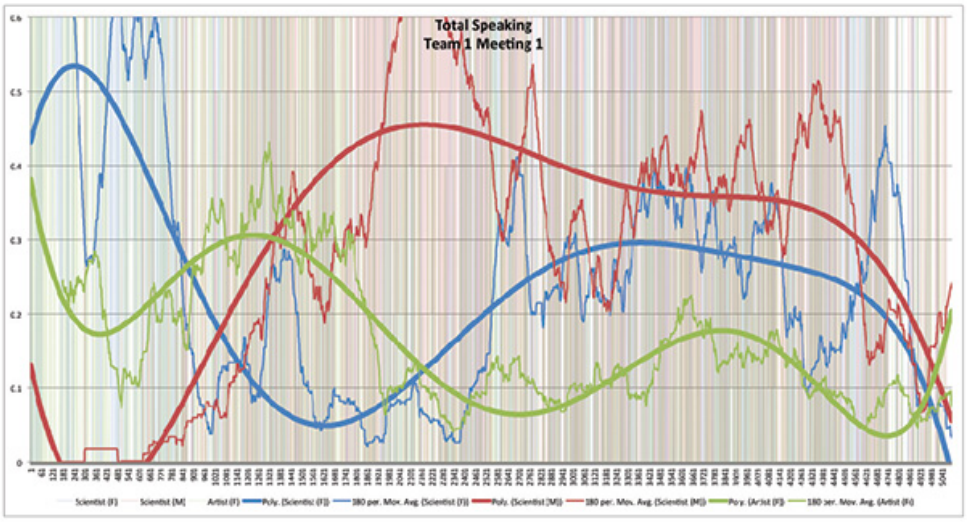
	High Interruption %	Low Interruption %
High overlap average	**Dominance** (Team 1 female scientist in meeting 4)	**Exclusion**
Low overlap average	**Deference** (Team 2 female scientist)	**Submission or Disengagement** (Team 1 female artist)

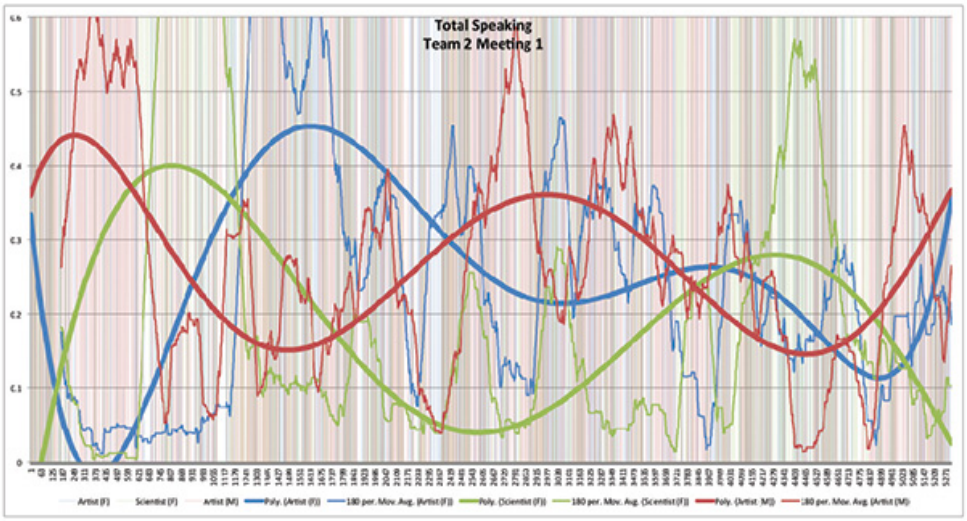
The Nature of the Meeting and Interpreting Data

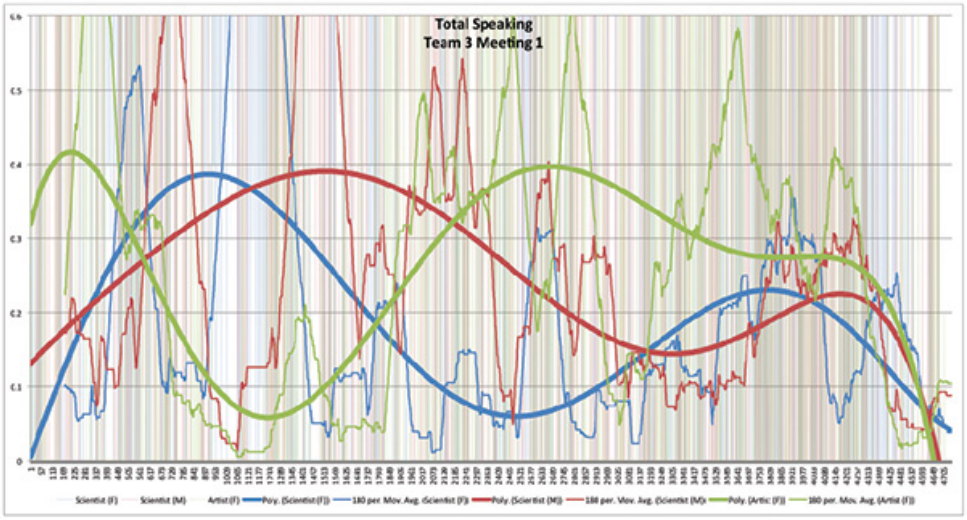
Survey and observational data have mechanisms for contextualizing information; this can be very difficult to do by exclusively depending on badge data. This was clear, both during the first meeting for all teams where introductions were a significant part of the meeting and members were first meeting each other, and during team three's final meeting. This meeting was used to create a physical mockup of a sign, which required members to oscillate between working individually, then in concert to finalize ideas, and actively constructing the mock up.

The introductory meeting patterned in similar ways for all three teams. This can be expected since introductions were formalized. Each team member shared what their work was about and what their lab, field site, or studio look like. They shared what tools/devices they used to solve problems/questions they were working on. This created long speaking segment events, which can be identified in the time-series visualizations. The pattern from the visualization can be read most easily from the smooth polynomial trendlines. The first line rises then dips as the second line rises, which dips as the third line rises, indicating long turn-taking events. At the halfway point the trendlines between the groups change patterns, signifying the teams have moved on from introductions. This is the only meeting where the team one artist has a successful interruption average above 50%.

Figure 5: Meeting 1 Speaking Pattern







The other meeting that conveyed different patterns was meeting four for team three. By the second half of meeting one, team three began developing a plan for creating interpretive signage and meetings two and three were focused on these processes. Meeting four was the resolving of ideas as well as building a physical mock up of one of the potential signs. According to the badge data, there is very even speaking time (male scientist 33%, female scientist 31%, female artist 36%), low successful interruptions for all members (male scientist 38%, female scientist 44%, female artist 45%) and a high amplitude deviation score of 5.29E-03. These patterns differ from the teams previous meetings and if interpreted in the same manner as previous meetings, suggest higher tension for the meeting; yet, members scored the meeting high on all three survey measures signifying a successful meeting. Additionally, their survey comments are all of a positive nature.

I believe the reason for this seeming incongruence is twofold: (1) the meeting is characteristically different in intention and (2) is held in a room with high ambient noise. The team used meeting two and three to develop their concepts and choose which ideas to put their energy into. Meeting four was used to execute the ideas they had already settled on. The female scientist began cutting materials to build the mockup and the male scientist and artist worked in Photoshop and with printmaking materials. As they worked to build a scale model they made choices on visual design and ecological content. They oscillated between working together and individually, processes that were not part of meeting two or three. An environmental factor that affected the data was the noise created by the air conditioner; this can be heard in the video and seen on their amplitude graph, the ambient noise is higher than all other meetings. Since the room was large and

members were working in different locations the noise could have affected each badge differently as well, not allowing for a good way to normalize speaking amplitude variance from ambient amplitude variance.

Accounting for the Quality of Ideas

All team members produced quality ideas for their teams, however team two was an interesting case because the significance of the scientist's contributions to her team is not clear from the badge data. As stated previously, there is reason to believe that she has status in her team indicated by high successful interruption percentage and lower overlap average. However, this does not fully reflect her contributions. In meeting one the scientist contributes by discussing what ideas they may want to pursue, however towards the end of the meeting her role has shifted towards providing more expert knowledge about the wetland system. The female artist engages her by repeatedly asking her questions about the system, which begins to shift how the team thinks about executing ideas for the signage. The quality of the scientist's comments proceeds on two fronts, (1) providing expert knowledge, and (2) engaging both artists in developing ideas that integrated their aesthetic sensibilities with the ecological phenomena unique to Tres Rios.

The female artist consistently asked questions about the biogeochemistry and both artists would work to integrate the scientist's recommendations into their own ideas. This created a dynamic where the scientist would regularly discuss what was unique about Tres Rios as a constructed wetland. Team one and three would often discuss what direction they wanted to take but the information the scientist provided the artists in team two would regularly shift the conversation providing new context and insights for moving

forward. One example of this situation is a discussion on nitrogen cycling in the wetland versus in a desert system. The scientist discusses how the wetland fixes nitrogen, contrasts this with how mesquite trees fix nitrogen in desert systems, expressing the uniqueness of these two systems being in such close proximity to each other. She continues to tie the biogeochemical processes and how they interact with flora and fauna in the broader system. This discussion shifts how the artists conceptualized how the signage would operate from discussing "traditional" ecological systems to how constructed systems might interact with "natural" desert systems.

Additionally, the scientist engaged with the ideas the artists presented. Both artists had been discussing live video feeds of the wetland system. The scientist offers what might be interesting as a live feed, like information of the water flows, audio feeds, and nutrient concentrations at different locations. She would work to connect this information with ideas that could be further presented as sound, color, or a combination of visual and audio representation.

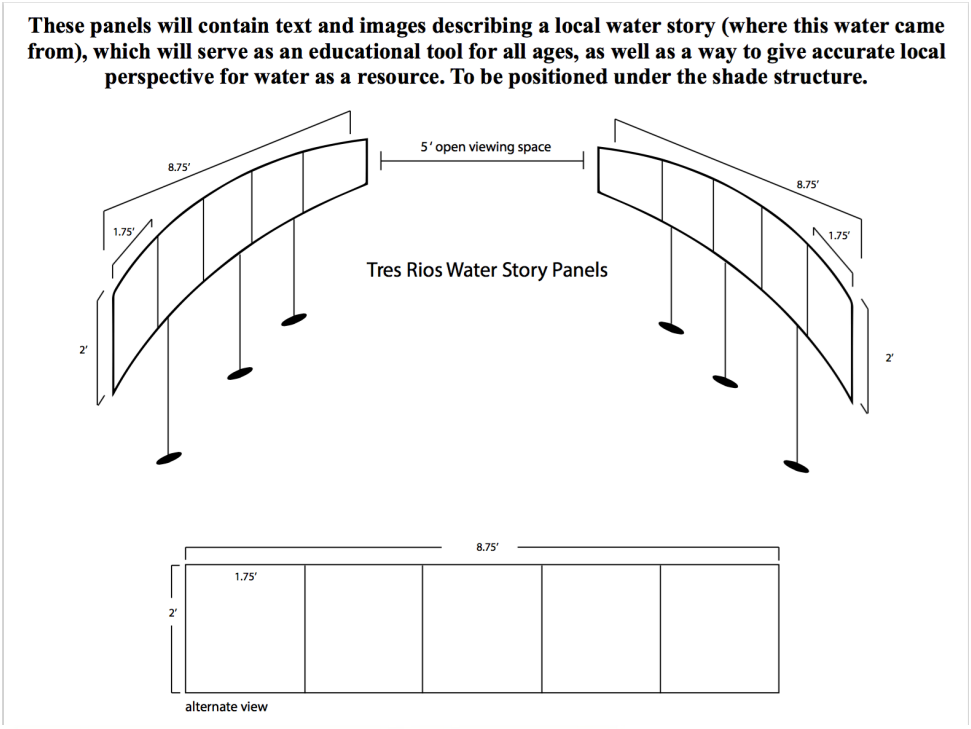
Design Outcomes

The purpose of this project was not only to investigate how artists-scientists teams collaborated but also if they produced something creative. Again, their goal was to produce signage for the Tres Rios wetland site that conveyed the uniqueness of the area. Each project was presented to stakeholders from the City of Phoenix, they commented on the uniqueness of each design but were not asked to rate the projects. There is no developed instrument for judging the creativity of art-science projects. My criteria for judging the creativity of the projects were to address the interdisciplinary complexity of each design. Was the signage ecologically accurate? Did the design integrate compelling

aesthetic components with the science or did it simply illustrate ideas? As a whole, does it extend the science and art beyond their disciplinary components? Although the ecological concepts can be viewed as correct or incorrect, judging if a project is aesthetically compelling can appear more subjective. An accepted method for judging social creativity is Amabile's (1983, 1996) *Consensual Assessment Technique*, which relies on subject experts to rate products as creative. Selecting ecologists and artists to judge the final products would have been a possible approach but is beyond the scope of this project. Additionally, I would be extending Amabile's method beyond its current uses since the desired goal would be the creative output of two integrated fields.

Instead, I used my own judgment as a trained artist-scientist to judge the projects. Rather than provide absolute scores I ranked the teams' level of success by their ability to produce signage that met the criteria previously stated, i.e. are the signage concepts both ecological accurate, artistically compelling, and do the two fields come together in a cohesive manner?

Team three produced the most creative signage designs. Their designs were ecologically informed, interactive, and connected to social components of the system. It was also the most refined project of the three. The team mocked up a 10-panel water narrative that begins in the White Mountains, travels into Phoenix, and then exists Tres Rios. Specific signs would be embedded with audio recordings of people connected to water at those specific locations in the narrative. The sign would potentially have a portrait for the person; a visitor could hear the interview by pressing a button on the sign.



Tres Rios Signage - Indiviuals Affected by Water and their audio story

Interactive signage will serve as a way to gain valuable perspectives on how everyone is affected by water, including key members of the community like:

- Gila River Indian Community
- Farmers
- Children
- Business Owners
- Ecologists
- and others!

When the blue button is pressed, a brief audio story is shared by the person pictured on the sign.

Signs may be positioned throughout the entire trail area.

Image 32: Team three design concept

Team two had the second most creative signage design. They were good about connecting ecological, social, and interactive components as well. Instead of focusing on one location they designed for five locations along the trail. Each sign would have sections for flora/fauna, process/chemistry, past/future/present, why here/desert section, and an overhead map with a location marker. Additionally, the signs would have QR codes that would connect visitors to the site-specific Instagram or Twitter account so they could post their visit to the area. They produced excellent content for the signage but aesthetically they were very straightforward. While they do best with content, they missed the opportunity to develop compelling signage that would draw visitors into the rich content.

Image 33: Team two design concept

Team 1 ranked last out of the 3. They produced signage for a single location and focused on the ecosystem processes of the site. They produced some interactive components like binoculars positioned at key areas for viewing birds in the wetland and a movable knob that visitors could move along the sign as they read about the processes water goes through as it travels from Phoenix to Tres Rios. The sign also went right to left for geographical accuracy.

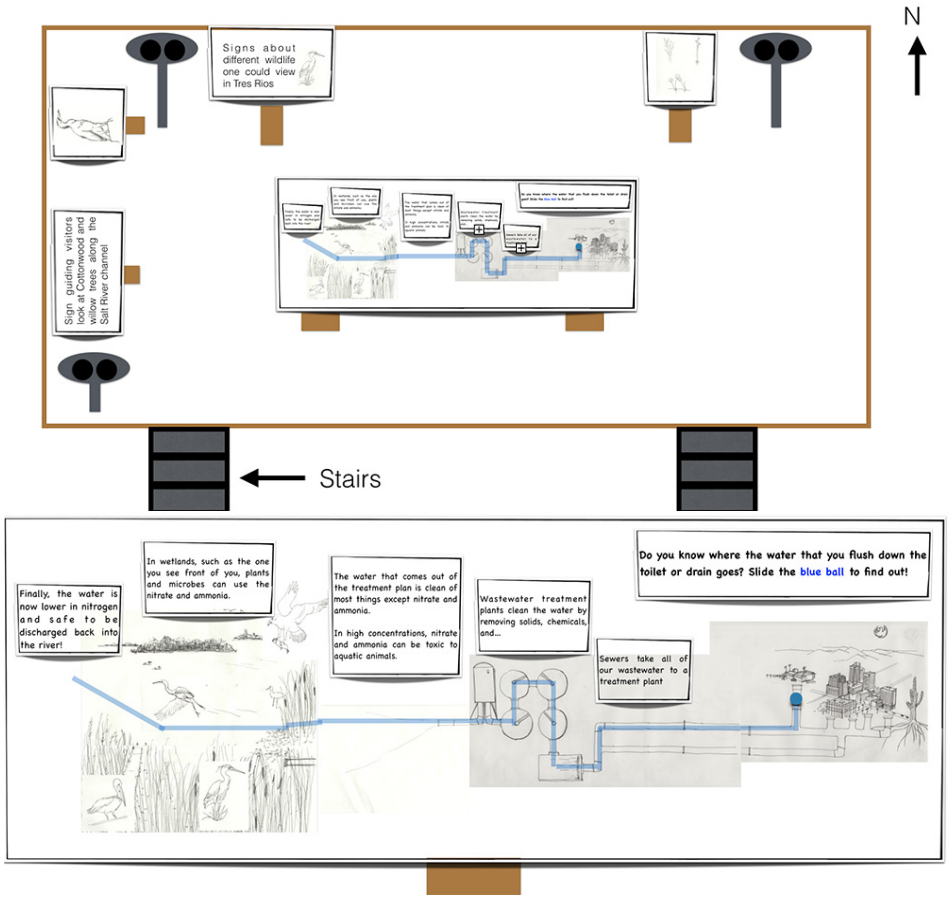


Image 34: Team one design concept

Discussing Relevant Conditions

As I discussed earlier, teams need particular conditions to improve their chances of successful outcomes. Some of these were easier to control for than others and I

attempted to improve chances of successful outcomes where possible. Amabile (1983, 1996) articulates three individual conditions that needed to be met; domain expertise, creativity relevant skills, and task motivation.

Doman Expertise

I actively recruited participants that would have domain expertise related to the site. I was able to recruit ecologists for the project that conducted research on aquatic systems. Team one and three each had an ecologist that worked specifically at Tres Rios. Artists were a little bit more general since they all work in different mediums. It may seem most logical that graphic designers may have been more suitable but the domain expertise I was looking for from artists was the ability to engage in the decision-making processes common to contemporary art practices. All four artists had worked on environmentally oriented projects and therefore were suited for grappling with the concepts they could develop for signage.

Creativity-Relevant Skills

Every team was able to engage in perceptual and cognitive set-breaking as they developed ideas. While there are moments of set breaking in every meeting it's primarily experienced in the second meeting for every team. The most significant variation between teams, in terms of creativity relevant skills is that of *creative perception*; identifying how new information may fit in unexpected ways and integrating ideas that may appear as mundane. It's experienced most noticeably in team one, when on multiple occasions the female artist presents experiential ideas about the site and both scientists do not find a way to integrate it into signage design ideas. It happens to team two as well in

meeting three but for a different reason. The female scientist has been presenting multiple ideas and they have worked to integrate those ideas into their signage design but as they continue the cognitive load seems to create a filtering process for the team. They work to connect old ideas. They don't shoot down new ideas, but they do stop engaging with them, considering them interesting tangents about Tres Rios. Team three picks up on ideas, primarily when members connect what they have seen at other sites. However, they also actively manage ideas by focusing on what they want to include and how much time they have to execute a product. By meeting three they engage less in this creative perception and more on idea validation and articulation.

What is most noticeable about managing creative perception is awareness of time constraints. Team three oscillated well between exploring ideas and then choosing a direction allowing them balance between being creative and completing a design by the end of meeting four. Team two was more open to exploring ideas, continuing to investigate new directions late into meeting three. This provided them with many interesting directions to move in but then time became a constraint, they were unable to execute on their ambitious ideas by the end of meeting four. Team one suffered from the opposite issue, that of quick consensus. By moving to quickly towards resolution of a design they missed several opportunities to include engaging concepts into their design.

Task Motivation

The KEYS does measure intrinsic and extrinsic motivation. Survey scores indicate high motivation, however, I found that time working on the project outside of meetings and the amount of meeting time was more indicative of the quality of project

outcomes. Table 3 displays the amount of time, in minutes, that each team spent working on the project. There is a significant disparity between team one and team two and three, especially on time spent outside of meetings. The disparity is even more significant if we look at how much time artists spent (630 minutes) outside of meeting versus scientists (210 minutes). Time spent outside of meetings appears to positively affect not just the interactions but also the outcomes of these collaborations.

Table 3: Task motivation and Time Spent on Project

	Meeting Time	Outside of Meeting	Total
Team 1	320	180	500
Team 2	390	300	690
Team 3	420	360	780

Supportive Organizational Context

As mentioned above, Hackman (2012) presented six conditions he felt are necessary for providing the necessary flexibility and structure for teams to perform. Again, they were: (1) real teams, (2) a compelling purpose, (3) the right people, (4) clear norms of conduct, (5) a supportive organizational context, and (6) team-focused coaching. While the degree to which these conditions were met for these teams is debatable, a supportive organizational context was clearly the most significant limiting factor. I attempted to account for several other conditions (e.g., the real teams, a compelling purpose, the right people, and clear norms of conduct conditions), through the convenience sampling and use of a protocol sheet that provided tips for working together. The final condition Hackman identifies – team-focused coaching –was not engaged in because its effects on the collaborations, would confound the data.

I found that a lack of a supportive organizational context (specifically the sense that all other projects took precedence over this one) directly contributed to a lack of task motivation. I provided teams with resources and financial support for the project; however, this was a voluntary project so their other projects often came first. Most often I found that scientists in each group had other meetings that created scheduling conflicts. They would often note that they had to work on other projects leaving minimal time to even think about the Tres Rios project let alone do work for it outside of meeting time. As the semester progressed time between meetings lengthened making it difficult to remember what they had been working on. More than six weeks passed between meeting three and four for team one and more than eight weeks for team two. Team three was the most consistent meeting approximately every two weeks, which showed in their ability to pick up quickly on ideas from the previous meeting.

Working cultures across the sciences and arts may also contribute to these issues. Since I am situated in both spaces I find that "extra-curricular" projects are treated differently in the two fields. Often the scientists treated Tres Rios as an interesting side project that provided a diversion from the "real work" they were doing. Artists treated the project as potential fodder for ideas they may want to incorporate into their own projects and often expressed an intrinsic desire to produce compelling signage. The male artist in team two expressed frustration when the scientist in his group dropped out to focus on her dissertation. He noted that they are all busy and prioritize projects. The female artist in team three was leaving for a summer project so she made certain that her team could meet before she left in an effort to finish. Perhaps the fact that the arts encourage exploration contributes to the artists being more motivated to contribute. This is not to

say that scientists don't care about anything but their research, but that pressure to direct attention on specific projects may differ in the arts and sciences.

Conclusion

The main interest of this study was to develop a better understanding of the collaboration dynamics for artist-scientist teams and the potential conditions that foster those collaborations. As an *in vivo* study requiring a novel, multi-method approach, replication is difficult. Collecting large amounts of multi-faceted data was essential for providing a rich analysis of these teams. Using observational data, perceptions of the collaborations (via the KEYS questionnaire), and wearable sensors provided me with qualitative and quantitative data, which could be triangulated for a more holistic analysis for team dynamics.

Each data collection method coupled with the other two, helped fill in gaps and produce a robust dataset. The observational data were ideal for contextualizing the meetings. The video recordings in particular worked very well with the badge data. Critical events witnessed in the badge data, like those experienced in Team one's second and forth meeting, could then be contextualized by revisiting the time-stamped video.

The survey data provided individual perceptions of team performance. The open-ended comments by individuals proved valuable for reevaluating the observational data. Team two was able to hide frustration well, without the survey comments that data would have been missed. Furthermore, the satisfaction scores on the survey correlated with levels of disparity in amplitude measured by the badges. Together they indicate if the high-energy event correlated with a creative of frustrating event.

The majority of studies conducted with Sociometric badges have focused on high-level interactions (Olguin Olguin & Pentland, 2008; Tripathi & Burleson, 2012; Waber, Olguin Olguin, Kim, & Pentland, 2008; Wu, Waber, Aral, Brynjolfsson, & Pentland, 2008). Woolley et.al. (2010) provide one of the few studies to date that used the badges for a small group collective intelligence study. The badges allow for high-resolution data sets but no context for that data. It begins to indicate how a team may be performing but fails to provide us with adequate reasoning for why they are performing well or poorly. It may give insight into potential participation but not the level of contribution from the participants. In effect, Sociometric badges complement observational and survey data. They may even serve as a diagnostic tool which signals when problems begin to arise, which then need further context-dependent analyses.

This pilot study creates some of the groundwork for building a stronger empirical foundation for collaborations that integrate knowledge in the sciences with knowledge in the arts. Understanding the organization, functioning, and accomplishments of these collaborations is vital to the development of conceptual frameworks and observational methods used to adaptively manage these interdisciplinary teams (Hackett & Parker, 2012). I believe this research advances our understanding of collaborative behavior in deeply heterogeneous groups with significantly different social practices focused on finding creative solutions to wicked sustainability challenges.

CHAPTER 5 CONCLUSION AND FUTURE DIRECTIONS

The acute problems of the world can be solved only by whole men [and women], not by people who refuse to be, publicly, anything more than a technologist, or a pure scientist, or an artist. In the world of today, you have got to be everything or you are going to be nothing. ~ Conrad Hal Waddington

As stated throughout this dissertation, solving sustainability challenges requires a focus on the problem versus the discipline (Clark, 2007) and a deep integration of the multiple components is critical. If sustainability challenges are historically, socially, culturally, technologically, and scientifically intertwined then sustainability scholars and scientists need to find ways to connect their work, contextualize the problems, and ask nuanced and relevant questions. This dissertation has been an attempt at rigorous interdisciplinarity, both in approach and content. Specifically, throughout this work I have linked the environmental humanities, photographic arts, and social sciences, with each chapter contributing to a larger program of art-science thought and practice for sustainability.

Chapter 1 framed the intellectual and disciplinary challenges for developing a sustainability aesthetic and practice, one that draws creatively from the arts, humanities, and social sciences. In Chapter 2, I contextualized and grounded this interdisciplinary intent by addressing how natural aesthetics frame decision-making, and how the integration of ecology, aesthetics, and ethics can shift the conversation in sustainability studies and science toward a more suitable and productive vision, one that isn't saddled by the limiting aesthetic and cultural traditions that have gripped wilderness-centric

environmentalism. Aldo Leopold's process of aesthetic-ecological-ethical integration was put forward as a model for developing a sustainability aesthetic and ethic that is tightly coupled with sustainability science. I also provided an argument for the necessity of art-science integration and proposed criteria for a more engaged, educated, and integrated sustainability aesthetic.

Chapter 3 tested this idea of an art-science integration by focusing on art practice for sustainability. It connected the analysis of American environmental thought (emphasizing the work of Leopold) in chapter 2 to the history and theory of contemporary landscape photography. Most significantly, the chapter presented in summary form my multimedia project *one hundred little dramas.,* which served as a proof of concept initially exploring the idea of a personal sustainability practice at the household level. This idea – heavily informed by landscape photography – evolved into an exploration of new directions within contemporary landscape photography and its contributions to both the field of photography and sustainability. It was important that my art practice was developed in concert with a scientific inquiry; simply discussing how the two fit together would not accomplish the goal of integrating the two practices. The process of synthesizing these two different cultures (i.e., art and science) – with different languages – was a time- and energy-intensive process. But this challenge was also an opportunity to find new ways to connect the arts and sciences.

Collaborative practices seemed like the next step, especially given that collaborations provide a process for shortcutting the expertise any one person needs to acquire. The challenge here is therefore to understand how interdisciplinary art-science teams could work together effectively in a sustainability context. Accordingly, chapter 4

provided the final component to constructing an art-science sustainability practice. Recruiting artists and scientists to co-create a project that required both ecological and artistic modes of production allowed me to investigate the challenges that made working together difficult – and the mechanisms that provided opportunities for the development of creative ideas. Additionally, as a pilot study, it raised questions about creating these art-science teams. For example, how long does it take for team members to become conversationally literate in each other's practices? What types of incentive structures allow for the creation and maintenance of these teams? It was clear that the meetings I documented primarily served as an introductory phase to the work. However, by providing team members this interdisciplinary experience, the expectation was that a familiarization with each other's epistemic cultures would illuminate not only the content in the field but the set of practices that make up each domain, and how each participant could contribute to the team. Furthermore, familiarization with scientific or artistic practice allowed team members to understand what it means to work as a scientist or artist and hopefully created new ways of seeing, approaching, framing, and problem solving in the world (Root-Bernstein, 2003; Root-Bernstein & Root-Bernstein, 1999).

Implications for Education

One of the goals of this dissertation is to encourage art-science work for sustainability education at the university level. It's an objective with a pragmatic as well as an aesthetic motivation: students who can grasp both artistic and scientific modes of thinking will be better suited for problem solving in their careers outside of academia. Aldo Leopold expressed this sentiment when discussing the art-science divide in his 1942

essay "The Role of Wildlife in a Liberal Education." He remarked out that this separation only worked in the classroom – "Step outside the campus and they [art and science] are immediately fused" (1991d, p. 302). It was a unity embodied his notion of "land ecology," which Leopold described as a process of "putting the sciences and arts together for the purpose of understanding our environment" (Leopold, 1991d, pp. 302-303). Although written more than seventy years ago, Leopold's words are just as relevant for training sustainability students today as they were when he originally addressed them to students in his ecology course at the University of Wisconsin. Among other things, Leopold's vision for an art-science fusion implies that sustainability students will need integrative training in the arts and sciences to more holistically address the problems they will face.

It is a challenging requirement. Although many students are often exposed to the humanities, arts, and sciences as distinct fields, the relationships and potential synergies among them are rarely made explicit. This more integrated approach can be accomplished in several ways. Perhaps the most familiar and efficient method is to require a distribution of arts, humanities, and science courses as part of any core undergraduate sustainability curriculum. Such a model could include co-taught courses by art and science faculty that could inform a sustainability subject from both perspectives. Team-oriented courses similar to the design-inspired course Innovation Space (https://innovationspace.asu.edu), in the Herberger Institute for Art and Design at Arizona State University (ASU), could be modified for sustainability curriculum. This course assembles student teams comprised of an engineer, business student, graphic designer, and industrial designer to prototype a product often for the private sector. This

style of course could quite easily also include students in the arts, humanities, social and life sciences focused on creating interdisciplinary solutions to a series of identified sustainability challenges.

I believe graduate students in sustainability would also benefit from interdisciplinary training in the arts and sciences. It's generally understood that graduate students must focus more intensely on a specific topic, a constraint making a broad, liberal arts curriculum not as feasible. But there are other opportunities to achieve more intense interactions among the disciplines. One possibility would be to require a number of semester hours spent in residence an art-science institute, which would provide students an opportunity to explore and engage ideas from both artistic and scientific perspectives. This institute would serve as a collaboration space for art and science students interested in sustainability questions and challenges to engage with each other on a regular basis. It would allow them to explore new ideas but more importantly, it would develop a familiarization within the mixed community of artists and scientists about the different modes of working and creating. Another, perhaps more radical, idea would be interdependent theses and dissertations. Similar to the Integrative Graduate Education and Research Traineeship (IGERT) Fellows in Urban Ecology at ASU who are required to co-author a chapter in their dissertation; graduate students in an art-science track for sustainability could co-author a chapter or develop interrelated dissertations. Students could choose a sustainability topic that would be better understood through both artistic and scientific investigations. Having a collaborator would ease the need to develop expert level skills in both fields but would develop their conversational abilities across disciplines.

Implications for Research

In addition to the development of interdisciplinary opportunities for university students, opportunities for academic researchers should be fostered. In general, researchers (artists included), have the investigative skills described in chapter 4. In order to be successful in their field they must have domain expertise, be able to approach problems creatively, and ideally focus on questions or problems that they are intrinsically motivated by. These valuable traits can have a compounding effect on art-science collaborations by combining the understanding in both fields in unique ways, but collaboration opportunities must be fostered between artists and scientists. Based on my work with and study of artists-scientists teams I believe that two factors, greater organizational support and continuous informal modes of contact, could (with relatively modest investment of resources) greatly increase number and success of these collaborations. By focusing on these two variables openings for serendipitous encounters will also be created, generating opportunities for sparking joint interests, either in connecting current projects, or in collaboratively following a new line of inquiry.

I have personally witnessed how these informal interactions create collaborative opportunities for researchers from different disciplines. I can even cite my own graduate studies committee as an example. My dissertation placed the arts and sciences on equal footing, and so I sought out co-chairs in each field: conservation scholar, Ben Minteer; and photographer, Mark Klett. They are both professors at ASU but until my committee had never found the opportunity to work together on a project. Through their intermittent yet continuous exchanges as my co-chairs over the years, however, they found topics

they were mutually interested in. This created opportunities for them to collaborate on interdisciplinary projects they found interesting and that they could both contribute to.

Likewise, forming continuous chance encounters for researchers could be the necessary link to recognizing topics they are mutually interested in. Since artists and scientists still belong to a tightly knit community within their own disciplines, I imagine that art-science projects would operate more as loosely connected nodes in a large network. Teams would form, disband, and reform around topics of interest, working on them until they experienced some resolution in their contribution. Composition of teams and interests would be fluid. However, these potential collaborations require that departments and the university at large provide organizational support for these collaborations. Specifically, I envision them providing artists and researchers the time to explore new ideas and office resources for collaborating. Given this organizational support, I see several potential options for creating fertile conditions for these interactions, including: (1) the use of "boundary themes," (2) co-location of office space (i.e., areas that house both artists and scientists), and (3) studio and lab visits/StudioLabs.

Similar to boundary objects, boundary themes are a way to begin a conversation that explores cross-cutting themes. The themes could be nested. For example, water in the desert could include specific ideas around water: natural riparian areas, engineered canal systems, agricultural practices, etc. A theme focused on built environments could include urban ecological systems, urban heat island, building density, and other topics. An environmental justice theme might include an array of issues, including food deserts, highly-polluted sites, transportation infrastructure, and so on. Such nested themes provide access points for discussions about how researchers are already connected to a particular

topic, including questions they may have and how they might approach a topic. These discussions open pathways for linking interests between artists and scientists.

Designating more office spaces that house both artists and scientists, too, would provide opportunities for continued chance encounters. One example of this strategy is ASU's School of Sustainability, which has built a space on the third floor for sustainability scientists and scholars to meet, have coffee, and converse. This is a good first step, but the space is often inconvenient for sustainability scholars (artists included) and scientists who hold primary appointments in other departments and thus are housed in other buildings. If artists and scientists want to meet they need to make the extra effort to schedule a time to come to Wrigley Hall. This may not appear to be a significant inconvenience, but as I mentioned in describing the collaborations between Minteer and Klett above, researchers and artists rarely decide on a collaborative project ahead of time. Housing them in the same space provides the necessary chance encounters that are critical to finding topics they may be mutually interested in. Granted, the School of Life Sciences has adopted a practice of housing philosophers, ethicists, and historians in the same building as their biologists, ecologists, and geneticists, as well as others. However, if there are no open spaces to congregate do to building layout and all it takes to exclude oneself from an interdisciplinary community is simply closing ones office door the potential for this serendipitous conversations will be drastically reduced. Therefore, when I propose these interdisciplinary offices, I am also calling attention to architectural designs that promote informal interactions.

I can imagine that some faculty may be hesitant to leave their disciplinary communities and want to maintain their offices in their departments. An alternative to

permanent interdisciplinary office spaces would be office residencies. Faculty could move to the interdisciplinary space for a semester or the year. This provides the needed contact between disciplines and allows for new faculty to continue rotating through the space. Connections would be built that could be maintained even after faculty returned to their respective departmental offices.

My final recommendation would be to have a practice of regular studio and lab visits including field site visits where some artists and scientists might collect data or produce work. I have found that some of the most insightful experiences artists and scientists have are the visits to each others working spaces. Workspaces illuminate much about the processes artists and scientists are involved in when they produce their work. For example, they can reveal how they think through a problem and what tools aid in the development of their ideas. Participants in the art-science collaboratives I have facilitated regularly commented on the usefulness of these visits. It helped them see parallels between artists and scientists and also dispelled biased or uninformed assumptions about what members of the other discipline did. Often times these assumptions are a significant barrier to working together, so removing them creates an open space to become curious and open with others.

Along these lines, a more ambitious idea to foster shared workspaces connecting artists and scientists addressing sustainability questions and challenges would be the creation of "StudioLabs." Similar to spaces like the Decision Center for a Desert City and the Decision Theater at ASU, the StudioLab would be a boundary space that allowed for the cross-fertilization of ideas between scientists and artists. It wouldn't only be an interdisciplinary meeting space but also a working space. Although studio and lab visits

can produce isolated moments of insight, StudioLabs would be an enduring project, a shared working space that would be the next step in blurring the institutional and performative line between art and science. It would help develop a shared language and third culture that dissolves the demarcations between art and science. Returning to a point made at the beginning of this chapter, it would focus, as Clark (2007) has proposed, on the problems rather than the disciplines in framing and investigating sustainability challenges – a reorganization and reorientation that will help provide more informed, creative, and durable solutions.

Future Directions

The rigorous integration of art and science for sustainability is still in its infancy. As such, there are a multitude of future directions that might be pursued. My work in this dissertation, however, leads me to conclude that three strategic paths are essential: (1) the development of a sustainability aesthetic and coupling this with a sustainability science, (2) the continued collaborative investigation of art-science topics related to sustainability, and (3) inquiry into the conditions and mechanisms that foster or block creative production from artist-scientist collaboratives.

Sustainability Aesthetics and Practice

Chapter 2 provided a reason to take aesthetics seriously in sustainability thought and practice and began to lay out – through an analysis of Aldo Leopold's writings – how aesthetics is intertwined with science, as well as considering which practice-oriented components are important in this relationship. Although it's generally understood that any sustainability aesthetic must be informed by the sciences, that active participation in

creating it is necessary, and that this sustainability aesthetic must be deeply interdisciplinary, it is not clear how to conceptualize the value of the outcome. This is not to say that it's not valuable, only that these integrative efforts have been so scarce that we lack the judgment to properly critique these products. Indeed, stating the necessity of a sustainability aesthetic implies that it will produce something *different* from other aesthetic ideals, especially traditional environmentalist aesthetics. I think this has implications for the kinds of products that are created.

Most critical to me is developing methods for situating the work without compromising the art or science. While an aesthetic product may be thought of as an artifact of some sort (e.g., a photograph, painting, sculpture, etc.), it still must coherently connect to the science. That's not to say that it shouldn't also stand alone as a work of art; rather, it's to make the additional point that, ideally, the art and science become integrative, a process that elevates both[31]. Ultimately, I think venues, physical and virtual, need to be created for connecting an aesthetic to science in a salient and compelling manner. The most readily available spaces I imagine are well crafted art-science books, natural history museums, science museums, and interactive online sites. They are the current modes for organizing information that is both factual in the scientific context and visually compelling. I believe this demarcation, with its fuzzy edges, will not happen solely by analyzing the aesthetic pieces but more likely through the consistent

[31] This can be a very challenging task since both art and science have developed "languages" that relate specifically to their disciplines. These languages situate the art and science products often within discipline-specific cultural relationships that connect ideas to representation (Klett, 2015). Klett (2015) further notes, similar to my comments in chapter 2, that choosing an audience that is prepared to receive can be difficult. A less burdensome task would be producing work that raises questions that are valid to both art and science.

developing of art-science projects that test the ideas of what integrating sustainability science and aesthetics looks like.

Artist-Scientist practice, whether individual or collaborative, will be the testing ground – therefore, it is the most critical component. The creation of new work, even if we have not fully elaborated this new aesthetic or found venues for the work, is a valuable method for thinking and navigating through this art-science practice for sustainability. Through my own practice I have realized that the work does not progress in an easily recognizable or predictable manner but takes form through the actual making process. I struggled in my attempts to integrate both practices, the most significant challenge being the development of a coherent body of work that expressed the artistic and scientific facets of my projects. At times it felt like the science and art making were in direct conflict and that some compromise was thus necessary – i.e., the project would either serve the art or the science, but not both. I realized that I treated the work as a solution rather than a container for contextualizing specific subject matter. By treating my work as an access point for engaging in topics that have both humanistic and scientific facets I was able to invite both fields into the topic at hand. These integration challenges revealed to me that art and science are primarily in discourse and that the work serves to invite others to join in the topic at multiple levels. Additionally, getting other's impressions on the work provided a deeper understanding for the way the work was interpreted. The process of understanding how aesthetics will be coupled to science will only be grasped through a continual engagement in an art-science practice, from the initial conception of an idea, to the formulation, editing, and exhibition of the work and, finally, to the publics' interpretation and critique of it.

Investigating Artist-Scientist Collaboratives

My chapter 4 study provides a window into artists-scientists collaborations and raises new questions about team size, composition, and length of collaborations. As I have discussed, these three factors may significantly affect dynamics and outcomes and should be studied.

Within my study, I found that three-person teams assigned the minority member as a discipline "expert" in their respective field, a move that led to the minority members' ideas rarely being challenged. The members with disciplinary counterparts, on the other hand, actively exchanged ideas and challenged each other, pushing the ideas forward. Four person teams could potentially enhance the creativity of outcomes by allowing for dynamic interactions for both artists and scientists. However, as size increases the dynamics change; there is a higher potential for members to pair off rather than working as a team.

But changing the size of teams not only affects the dynamics, it also impacts the roles members play (Farrell, 2001). To counter the potential of team members pairing off a fifth member could be advantageous. Rather than adding another artist or scientist the new member's primary role would be the connecting of presented ideas; in other words, a synthesizer. He or she would likely be proficient in both art and science practices, creating a stronger bridge for the artists and scientists on the team. We could then test, with a similar mixed-methods, qualitative and quantitative design, how team size affected member participation and the development of creative ideas. These studies could further explore if five-person teams have higher rates of creative perception and if their

outcomes exceed the interdisciplinary complexity and cohesiveness of three or four person artist-scientists teams.

In the Tres Rios collaborative project described in chapter 4, artists-scientists teams were originally scheduled for 3 meetings, but each team decided they needed one more meeting just to produce a rough mockup. After the iterative in-meeting process of generating ideas, deliberating on them, and determining which ideas to move forward on, there was not enough time allotted for reevaluating creations. Both art and science practices are implicitly iterative, working through "prototypes" of objects, hypotheses, and ideas. This often takes significant time and effort that was not allotted to this study. Longer collaborations, however, would provide teams time for iterations. Additionally, if there were deadlines for mockups every two months then teams would be on their third iteration at the end of a six month collaboration. If departments and the university administration implemented some of the previously proposed ideas for more consistent interactions the effort to maintain these more long-term collaborations would be minimized.

Conclusion

This dissertation research engaged environmental and photographic thought and history, an individual art-science practice, and a sociological investigation of a group collaboration experiment as a step toward exploring, and ultimately improving, art-science in service of sustainability. The potential benefits of an enhanced art-science practice are far reaching at both an individual and societal level and extend to a variety of settings. To move toward a consistently effective art-science practice, it is important to

understand the characteristics of an effective art-science practice or collaboration and, furthermore, how to create and maintain motivation for genuine participation.

In my first chapter I included a comment by sociologist and sustainability scholar Sasha Kagan. He remarked, "A meaningful assessment can only be achieved if the qualitative observation is engaging the researcher as a full person, and beyond the limitations of purposive consciousness…This is a collective, combined exploration that has to engage artists as well as (social and natural) scientists" (Kagan, 2011, p. 470). This suggested to me that the linking of art and science could not be fully realized unless the researcher was engaged in both art and science. This integration required going beyond simply explaining how it could be accomplished by focusing on *wh*y the integration was necessary, and by the development of a body of multimedia work and an empirical and conceptual understanding of how art-science research could operate in a collaborative setting. This dissertation has taken some initial steps in an exciting exploration on how to reconnect artistic and scientific investigations and the potential benefit they may provide for sustainability work.

REFERENCES

Aldo Leopold Archives (Producer). (1940, August 7). Aldo Leopold and Robert McCabe. [Still Image] Retrieved from http://digicoll.library.wisc.edu/WebZ/FETCH?sessionid=01-48585-846903169&recno=27&resultset=2&format=F&next=html/nffull.html&bad=error/badfetch.html&&entitytoprecno=27&entitycurrecno=27&entityreturnTo=brief

Alinder, M. S. (1998). *Ansel Adams: a biography*: Macmillan.

Amabile, T. M. (1983). The social psychology of creativity: A componential conceptualization. *Journal of Personality and Social Psychology, 45*(2), 357.

Amabile, T. M. (1996). *Creativity in context: Update to" the social psychology of creativity."*: Westview Press.

Amabile, T. M., Burnside, R. M., & Gryskiewicz, S. S. (1999). *User's Manual for KEYS: Assessing the Climate for Creativity*. Greensboro, North Carolina: Center for Creative Leadership.

Bargmann, J. (Ed.). (2013). *Troubled Beauty*. Charlottesville, VA: OpenGrounds.

Barry, B., & Stewart, G. L. (1997). Composition, process, and performance in self-managed groups: the role of personality. *Journal of Applied Psychology, 82*(1), 62.

Batchen, G. (1999). *Burning with Desire*. Cambridge, MA: MIT Press.

Bennison, R., & Aloi, G. (2009). In Conversation with Maja and Reuben Fowes. *Antennae*(10), 21-24.

Berthold, D. (1984). Charles Brockden Brown," Edgar Huntly", and the Origins of the American Picturesque. *The William and Mary Quarterly: A Magazine of Early American History and Culture*, 62-84.

Berthold, D. (2004). Aldo Leopold: In Search of a Poetic Science. *Human Ecology Review, 11*(3), 205-214.

Bright, D. (1985). Of Mother Nature and Marlboro Men: an inquiry into the cultural meanings of landscape photography. *Exposure, 23*(1).

Byerly, A. (1996). The uses of landscape: The picturesque aesthetic and the National Park System.

Callicott, J. B. (1994). The land aesthetic. *Ecological prospects: Scientific, religious, and aesthetic perspectives*, 169-183.

Callicott, J. B., & Freyfogle, E. T. (Eds.). (2001). *For the health of the land: Previously unpublished essays and other writings*. Washington D.C.: Island Press.

Cardenas, E. (2012). Como Lo Veo. Retrieved from http://comoloveo.tumblr.com/post/25649483546/did-i-already-post-this-either-way-had-to-post-it

Carlson, A. (Ed.). (2001). *Environmental Aesthetics* (1 ed.). New York, New York: Routledge.

Carlson, A., & Berleant, A. (2004). *The aesthetics of natural environments*: Broadview Press.

Cash, D. W., Clark, W. C., Alcock, F., Dickson, N. M., Eckley, N., Guston, D. H., . . . Mitchell, R. B. (2003). Knowledge systems for sustainable development. *Proceedings of the National Academy of Sciences, 100*(14), 8086-8091.

Center for Sustainable Practice in the Arts. (2013). The First International Summer School of Arts and Sciences for Sustainability in Social Transformation. Retrieved 7/26, 2013, from http://www.sustainablepractice.org/2010/01/24/the-first-international-summer-school-of-arts-and-sciences-for-sustainability-in-social-transformation/

Childers, D. (2013). Wetland Ecosystem Ecology Lab. Retrieved 10/31, 2013, from http://weel.asu.edu/WEEL/Home.html

Clark, W. C. (2007). Sustainability science: A room of its own. *Proceedings of the National Academy of Sciences of the United States of America, 104*(6), 1737-1738. doi: 10.1073/pnas.0611291104

Cole, T. (1836). Essay on American scenery. *American Monthly Magazine, 1*(3).

Cronon, W. (1996). The trouble with wilderness: or, getting back to the wrong nature. *Environmental History, 1*(1), 7-28.

Crutzen, P. J. (2002). Geology of mankind. *Nature, 415*(6867), 23-23.

Csikszentmihalyi, M. (1996). *Creativity: Flow and the Psychology of Discovery and Invention*: Harper Collins Publishers.

Csikszentmihalyi, M. (Ed.). (1988). *Society, culture, and person: A systems view of creativity*: Cambridge University Press.

De Dreu, C. K. W., & West, M. A. (2001). Minority Dissent and Team Innovation: The Importance of Participation in Decision Making. *Journal of Applied Psychology, 86*(6), 1191-1201.

Dieleman, H. (2001). Art & Sustainability: a research, educational and art production project. Rotterdam: Erasmus University Rotterdam.

Dunaway, F. (Ed.). (2013). *Beyond Ansel Adams: Landscape Photography in an Age of Environmental Crisis*. Charlottesville, VA: OpenGrounds.

Dunbar, K. (1995). How Scientists Really Reason: Scientific Reasoning in Real-World Laboratories. In R. J. Sternberg & J. E. Davidson (Eds.), *The Nature of Insight* (pp. 365-395). Cambridge, Massachusetts: MIT Press.

Edwards, D. (2008). *Artscience: Creativity in the post-Google Generation*. Cambridge, MA: Harvard University Press.

Edwards, D. (2010). *The Lab: Creativity and Culture*. Cambridge, MA: Harvard University Press.

Evans, W. (1935). Bud Fields and his family at home (pp. Family members posed, sitting in bedroom.). Eyes of the nation: a visual history of the United States: Library of Congress.

Farrell, M. P. (2001). *Collaborative Circles: Friendship Dynamics and Creative Work* University of Chicago Press.

Feist, G. J. (1998). A meta-analysis of personality in scientific and artistic creativity. *Personality and Social Psychology Review, 2*(4), 290-309.

Feldman, D. H., Csikszentmihalyi, M., & Gardner, H. (1994). *Changing the world: A framework for the study of creativity*: Praeger Publishers/Greenwood Publishing Group.

Fischer, J., Manning, A. D., Steffen, W., Rose, D. B., Daniell, K., Felton, A., . . . Lindenmayer, D. B. (2007). Mind the sustainability gap. *Trends in ecology & evolution, 22*(12), 621-624.

Flader, S. L., & Callicott, J. B. (Eds.). (1991). *The River of the Mother of God and other essays by Aldo Leopold*. Madison, WI: University of Wisconsin press.

Funtowicz, S. O., & Ravetz, J. R. (1993). Science for the post-normal age. *Futures, 25*(9), 739-755.

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., & MartinTrow. (1994). *The new production of knowledge: The dynamics of science and research in contemporary societies*. London: Sage Publications Limited.

Gobster, P. H. (1999). An ecological aesthetic for forest landscape management. *Landscape Journal, 18*(1), 54-64.

Guetzkow, H., & Gyr, J. (1954). An analysis of conflict in decision-making groups. *Human relations*.

Hackett, E. J. (2005). Essential Tensions: Identity, Control, and Risk in Research. *Social Studies of Science, 35*(5), 787-826.

Hackett, E. J., & Parker, J. N. (2012). Sensible Science: A Sociometric Approach to Collaboration in Synthesis Groups (pp. 16). Arizona State University: National Science Foundation.

Hackman, J. R. (2012). From causes to conditions in group research. *Journal of organizational Behavior, 33*(3), 428-444.

Hackman, J. R., & Morris, C. G. (1975). Group task, group interaction process and group performance effectiveness: A review and proposed integration. *Advances in Experimental SOcial Psychology, 8*, 45-99.

Hall, K. L., Feng, A. X., Moser, R. P., Stokols, D., & Taylor, B. K. (2008). Moving the science of team science forward: collaboration and creativity. *American journal of preventive medicine, 35*(2), S243-S249.

Halpern, M. K. (2011). Across the great divide: Boundaries and boundary objects in art and science. *Public Understanding of Science, 21*(8), 922-937.

Harper, D. (2012). The Online Etymology Dictionary. Retrieved 10/24, 2012, from http://www.etymonline.com/index.php?allowed_in_frame=0&search=aesthetic&searchmode=none

Harrington, D. M. (1990). The ecology of human creativity: A psychological perspective. In M. A. Runco & R. S. Albert (Eds.), *Theories of Creativity* (pp. 143-169). Newbury Park, CA: Sage Publications, Inc.

Hepburn, R. (Ed.). (1966). *Contemporary Aesthetics and the Neglect of Natural Beauty*. London: Routledge and Kegan Paul.

Hill, J. (2013). [Studio Visit].

Holst, L. (2014). A Brand-New National Monument: The Organ Mountains-Desert Peaks. Retrieved 6/19, 2014

Jacobs, C. D. (2015). *Jonas Salk: A Life*: Oxford University Press.

James, K. (1995). Goal conflict and originality of thinking. *Creativity Research Journal, 8*(3), 285-290.

Jamieson, D. (1998). Sustainability and beyond. *Ecological Economics, 24*(2), 183-192.

Jasanoff, S. (1996). Science and norms in global environmental regimes. *Earthly Goods: Environmental Change and Social Justice*, 173-197.

Jehn, K. A. (1997). A qualitative analysis of conflict types and dimensions in organizational groups. *Administrative Science Quarterly*, 530-557.

Jehn, K. A., Northcraft, G. B., & Neale, M. A. (1999). Why differences make a difference: A field study of diversity, conflict and performance in workgroups. *Administrative Science Quarterly, 44*(4), 741-763.

Jerneck, A., Olsson, L., Ness, B., Anderberg, S., Baier, M., Clark, E., . . . Lövbrand, E. (2011). Structuring sustainability science. *Sustainability Science, 6*(1), 69-82.

Kagan, S. (2011). *Art and Sustainability: Connecting Patterns for a Culture of Complexity*. Piscataway, NJ: Transaction Publishers.

Kahan, D. M., Peters, E., Wittlin, M., Slovic, P., Ouellette, L. L., Braman, D., & Mandel, G. (2012). The polarizing impact of science literacy and numeracy on perceived climate change risks. *Nature Climate Change, 2*(10), 732-735.

Kajikawa, Y. (2008). Research core and framework of sustainability science. *Sustainability Science, 3*(2), 215-239.

Kaufman, J. C. (2009). *Creativity 101*: Springer Publishing Company.

Kemmerer, A., Stilgoe, J. R., & Weinberg, A. D. (2001). Reinventing the West: The Photographs of Ansel Adams and Robert Adams: Andover, MA: Addison Gallery of American Art, Phillips Academy.

Kessler, W. B., & Booth, A. L. (Eds.). (2002). *Professor Leopold, what is education for?* New York: Oxford University Press.

Kinsey, J. L., Roberts, R., & Sayre, R. F. (Eds.). (1999). *Prairie Prospects: The Aesthetics of Plainnes*. Madison, WI: Univ of Wisconsin Press.

Kinzig, A. P. (2001). Bridging Disciplinary Divides to Address Environmental and Intellectual Challenges. *Ecosystems, 4*(8), 709-715.

Kirton, M. J., & Kirton, M. J. (1994). *Adaptors and innovators: Styles of creativity and problem solving*: Routledge London.

Kitch, S., & Adamson, J. (Producer). (2010, July 8, 2014). Values, Affect, Scale: Humanities for the Environment. [Video] Retrieved from https://www.youtube.com/watch?v=-rWLD06bErU

Klein, J. T. (2008). Evaluation of interdisciplinary and transdisciplinary research: a literature review. *American journal of preventive medicine, 35*(2), S116-S123.

Klett, M. (2015). [Dissertation Revisions].

Klett, M. (Ed.). (2014). *On New Topographics, Man-Altered Landscapes and Revolutions*: Art and Theory Publishing.

Klett, M., Manchester, E., & Verburg, J. (1984). *Second view: the rephotographic survey project*: University of New Mexico Press.

Knight, R. L., & Riedel, S. (Eds.). (2002). *Aldo Leopold and the ecological conscience*: Oxford University Press.

Koestler, A. (1976). *The Act of Creation* (second ed.). London: Hutchinson & Co.

Kuhn, T. S. (1977). The essential tension. Selected studies in scientific tradition and change. *Philosophy of Science, Chicago: University of Chicago Press,| c1977, 1*.

Kurt, H. (Ed.). (2004). *Aesthetics of Sustainability*. Boston, MA: Birkhäuser.

Kurtzberg, T. R., & Amabile, T. M. (2001). From Guilford to creative synergy: Opening the black box of team-level creativity. *Creativity Research Journal, 13*(3-4), 285-294.

Lang, D. J., Wiek, A., Bergmann, M., Stauffacher, M., Martens, P., Moll, P., . . . Thomas, C. J. (2012). Transdisciplinary research in sustainability science: practice, principles, and challenges. *Sustainability Science, 7*(1), 25-43.

Larson, B. (2011). *Metaphors for environmental sustainability: redefining our relationship with nature*: Yale University Press.

Lazarus, R. J. (2009). Super Wicked Problems and Climate Change: Restraining the Present to Liberate the Future. *Cornell Law Review, 94*(5), 1155-1231.

Leopold, A. (1966a). *A Sand County Almanac: With Essays on Conservation from Round River*. New York: Oxford University Press.

Leopold, A. (1966b). *A Sand County Almanac: With Essays on Conservation from Round River* (Kindle Edition ed.). New York: Oxford University Press.

Leopold, A. (Ed.). (1991a). *The Conservation Ethic*. University of Wisconsin press, Madison, WI.

Leopold, A. (Ed.). (1991b). *The Ecological Conscience*. University of Wisconsin press, Madison, WI.

Leopold, A. (Ed.). (1991c). *Land Pathology*. University of Wisconsin press, Madison, WI.

Leopold, A. (Ed.). (1991d). *Some Fundamentals of Conservation in the Southwest*. University of Wisconsin press, Madison, WI.

Leopold, A. (Ed.). (1991e). *A Tramp in November*. University of Wisconsin press, Madison, WI.

Leopold, A. (Ed.). (1991f). *Wherefore Wildlife Ecology?* University of Wisconsin press, Madison, WI.

Leopold, A. (Ed.). (1991g). *Wilderness*. University of Wisconsin press, Madison, WI.

Leopold Bradley, N., & Huffaker, W. (Eds.). (2002). *Forward*: Oxford University Press.

Levin, K., Cashore, B., Bernstein, S., & Auld, G. (2007). *Playing it forward: Path dependency, progressive incrementalism, and the "Super Wicked" problem of global climate change*. Paper presented at the International studies association 48th annual convention.

Levin, K., Cashore, B., Bernstein, S., & Auld, G. (2012). Overcoming the tragedy of super wicked problems: constraining our future selves to ameliorate climate change. *Policy Sciences, 45*, 123-152.

Lineberry, H. S. (2009). Defining Sustainability. In A. S. University (Ed.). Tempe, AZ: Arizona State University Art Museum.

Martineau, P. (2012). *Eliot Porter: in the realm of nature*: Getty Publications.

Meadows, D. H. (2008). *Thinking in systems: A primer*: Chelsea Green Publishing.

Meine, C. (1988). *Aldo Leopold: His Life and Work*. Madison, WI: University of Wisconsin Press.

Meine, C. (Ed.). (2015). *A Letter to the Editors. In Defense of the Relative Wild*. USA: University of Chicago Press.

Miller, T. (2012). Constructing sustainability science: emerging perspectives and research trajectories. *Sustainability Science*, 1-15.

Minteer, B. (2006). *Landscape Reform: Civic Pragmatism and Environmental Thought in America*. Cambridge, MA: MIT Press.

Minteer, B., & Pyne, S. (Eds.). (2015). *After Preservation: Saving American Nature in the Age of Humans*. USA: University of Chicago Press.

Mitchell, M. (2009). *Complexity: A Guided Tour* (Kindle ed.). New York: Oxford University Press.

Moscovici, S. (1980). Toward a theory of conversion behavior. *Advances in Experimental SOcial Psychology, 13*, 209-239.

Mueller, R. E. (1967). *The science of art: the cybernetics of creative communication*: Rapp & Whiting.

Nabhan, G. P. (Ed.). (1999). *Arts and Science: Between Imagination and Observation*. Madison, WI: Univ of Wisconsin Press.

Nash, R. F. (1982). *Wilderness and the American Mind* (4 ed.). New Haven: Yale University Press.

National Research Council. (1999). Our Common Journey: A transition toward sustainability. Washington D.C.: National Academy Press.

Nelson, R. R. (2003). On the uneven evolution of human know-how. *Research Policy, 32*(6), 909-922.

Nemeth, C. J. (1986). Differential contributions of majority and minority influence processes. *Psychological Review, 93*, 10-20.

Nemeth, C. J., & Staw, B. M. (Eds.). (1989). *The Tradeoffs of Social Control and innovation in groups and organizations* (Vol. 22). New York: Academic Press.

New York City Parks. (2015). Olmsted-Designed New York City Parks. Retrieved August 6, 2015, from http://www.nycgovparks.org/about/history/olmsted-parks

Newton, J. L. (2006). *Aldo Leopold's Odyssey*. Washington D.C.: Island Press.

Newton, J. L., & Freyfogle, E. T. (2005). Sustainability: a dissent. *Conservation Biology, 19*(1), 23-32.

Norton, B. G. (2005). *Sustainability: A Philosophy of Adaptive Ecosystem Management* (1 ed.). Chicago: The University of Chicago Press.

Norton, B. G. (2012). The Ways of Wickedness: Analyzing Messiness with Messy Tools. *Journal of Agricultural and Environmental Ethics, 25*(4), 447-465.

Norton, B. G., & Toman, M. A. (1997). Sustainability: Ecological and economic perspectives. *Land Economics, 73*(4).

O'Brien, B. (2012). Webinar: NEA Art/Science Grant Workshop. Retrieved June 20, 2013, from http://www.arts.gov/grants/apply/Art-Science-webinar.html

Olguin Olguin, D., & Pentland, A. (2007). *Sociometric Badges: State of the Art and Future Appications*. Paper presented at the IEEE 11th International Symposium on Wearbe Computers, Boston, MA.

Olguin Olguin, D., & Pentland, A. (2008). *Social Sensors for Automatic Data Collection.* Paper presented at the Proceedings of the Fourteenth Americas Conference on Information Systems, Toronto, ON, Canada.

Parker, J. N., & Hackett, E. J. (2012). Hot Spots and Hot Moments in Scientific Collaborations and Social Movements. *American Sociological Review, 77*(1), 22- 44.

Parr, A. (2009). *Hijacking sustainability*: MIT Press Cambridge, MA.

Pentland, A. (2008). *Honest Signals*. Cambridge, MA: MIT Press.

Porter, E. (1988). *The Place No One Knew*. Salt Lake City, UT: Peregrine Smith Books.

Ravetz, J. R. (2006). Post-normal science and the complexity of transitions towards sustainability. *Ecological Complexity, 3*(4), 275-284.

Rittel, H. W. J., & Weber, M. M. (1973). Dilemmas in a general theory of planning. *Policy Sciences, 4*(2), 155.

Robbins, P. (Ed.). (2012). *Talking Through Objects: Multidisciplinary Dialogues with "Things"* Tucson, AZ: University of Arizona Press.

Root-Bernstein, R. (2000). Art Advances Science. *Nature, 407*, 134.

Root-Bernstein, R. (2003). Problem Generation and Innovation. In L. V. Shavinina (Ed.), *International Handbook on Innovation* (pp. 170-179). Oxford: Elsevier Science Ltd.

Root-Bernstein, R., Allen, L., Beach, L., Bhadula, R., Fast, J., Hosey, C., . . . Weinlander, S. (2008). Arts Foster Scientific Success: Avocations of Nobel, National Academy, Royal Society, and Sigma Xi Members. *Journal of Psychology of Science and Technology, 1*(2), 51-63.

Root-Bernstein, R., Bernstein, M., & Helen, G. (1995). Correlations Between Avocations, Scientific Style, Work Habits, and Professional Impact of Scientists *Creativity Research Journal, 8*(2), 115-137.

Root-Bernstein, R., & Root-Bernstein, M. (1999). *Sparks of Genius*. New York, NY: Houghton Mifflin.

Root-Bernstein, R., & Root-Bernstein, M. (2004). Artistic Scientists and Scientific Artists: The Link Between Polymathy and Creativity In R. J. Sternberg, E. L. Grigorenko, & J. L. Singer (Eds.), *Creativity: From Potential to Realization* (pp. 127-151). Washington, DC: American Psychological Association

Root-Bernstein, R., Siler, T., Brown, A., & Snelson, K. (2011). ArtScience: Integrative Collaboration to Create a Sustainable Future. *Leonardo, 44*(3), 192.

Rybczynski, W. (1999). *A clearing in the distance: Frederick Law Olmsted and America in the 19th century*: Simon and Schuster.

Salk, J. (1973). *The survival of the wisest*: Harper & Row New York.

Salvesen, B. (2009). *New Topographics*: Steidl.

Sawyer, K. (2007). *Group Genius: The Creative Power of Collaboration*: Basic Books.

Sawyer, K., & DeZutter, S. (2009). Distributed creativity: How collective creations emerge from collaboration. *Psychology of Aesthetics, Creativity, and the Arts, 3*(2), 81.

School of Sustainability. (2013). Tres Rios Urban Wetland Lab. Retrieved 10/31, 2013, from http://schoolofsustainability.asu.edu/media/video/tres-rios

Schwartz, S., & Carpenter, K. M. (1999). The right answer for the wrong question: consequences of type III error for public health research. *American Journal of Public Health, 89*(8), 1175-1180.

Schwarzer, R., & Jerusalem, M. (1995). Generalized self-efficacy scale. *Measures in health psychology: A user's portfolio. Causal and control beliefs, 1*, 35-37.

Scott, R. H. (2014). *Sustainability in Photography can Change the World*: IGI Global.

Sherman, W. (Ed.). (2013). *Living the Art of Engagement: Art and Environmental Action*. Charlottesville, VA: OpenGrounds.

Siler, T. (1995). *ArtScience: Integrating the arts and sciences to connect our world and improve communication.* Paper presented at the Keynote Address, NAEA Conference, Houston, Texas.

Siler, T. (2011). The ArtScience Program for Realizing Human Potential. *Leonardo, 44*(5), 417-424.

Simon, H. A. (1983). *Reason in Human Affairs*. Stanford, CA: Stanford University Press.

Simon, H. A. (2001). Creativity in the arts and the sciences. *The Kenyon Review, 23*(2), 203-220.

Smith, D. D. (1998). Iowa Prairie: Original Extent and Loss, Preservation and Recovery Attempts. *Journal of the Iowa Acadamy of Science, 105*(3), 94-108.

Snow, C. P. (1960). *The two cultures and the scientific revolution*: Wiley Online Library.

Solnit, R. (2003). *As eve said to the serpent: On landscape, gender, and art*: University of Georgia Press.

Solnit, R. (Ed.). (2001). *Every Corner is Alive: Eliot Porter as an Environmentalist and an Artist*. New York, NY: Aperture Foundation.

Sontag, S. (1973). *On Photography*. New York, NY: Pan Books Limited.

Spangenberg, J. H. (2011). Sustainability science: a review, an analysis and some empirical lessons. *Environmental Conservation, 38*(3), 275-287.

Spence, M. D. (1999). *Dispossessing the wilderness: Indian removal and the making of the national parks*: Oxford University Press.

Spivack, E. (Producer). (2011, 12-28-2013). Kevin Dunbar on unexpected science. [Video] Retrieved from http://poptech.org/blog/kevin_dunbar_on_unexpected_science

Star, S. L., & Griesemer, J. R. (1989). Institutional Ecology, 'Translations' and Boundary Objects. *Social Studies of Science, 19*, 387-420.

Stokols, D., Hall, K. L., Taylor, B. K., & Moser, R. P. (2008). The science of team science: overview of the field and introduction to the supplement. *American journal of preventive medicine, 35*(2), S77-S89.

Stokols, D., Misra, S., Moser, R. P., Hall, K. L., & Taylor, B. K. (2008). The ecology of team science: understanding contextual influences on transdisciplinary collaboration. *American journal of preventive medicine, 35*(2), S96-S115.

Stott, W. (1973). *Documentary expression and thirties America*: University of Chicago Press.

The Metropolitan Museum of Art. (2006). Thomas Cole: View from Mount Holyoke, Northampton, Massachusetts, after a Thunderstorm--The Oxbow. *In Heilbrunn Timeline of Art History*. 2015, from http://www.metmuseum.org/toah/works-of-art/08.228

Thompson, P. B. (2007). Agricultural sustainability: what it is and what it is not. *International Journal of Agricultural Sustainability, 5*, 5-16.

Thompson, P. B. (2010). *The agrarian vision: Sustainability and environmental ethics*: University Press of Kentucky.

Thompson, P. B., & Whyte, K. P. (2012). What Happens to Environmental Philosophy in a Wicked World? *Journal of Agricultural and Environmental Ethics, 25*(4), 485-498.

Tress, B., Tress, G., van der Valk, A., & Fry, G. (Eds.). (2003). *Interdisciplinary and Transdisciplinary Landscape Studies: Potentials and Limitations*. Wageningen: Drukkerij Modern, Bennekom.

Tripathi, P., & Burleson, W. (2012). *Predicting creativity in the wild: experience sample and sociometric modeling of teams.* Paper presented at the Proceedings of the ACM 2012 conference on Computer Supported Cooperative Work.

Tsang, L.-C. (1998). *The Sublime: Groundwork Towards a Theory*: University Rochester Press.

van der Leeuw, S. (2014). Sustainability, culture and personal responsibility. *Sustainability Science, 9*(2), 115-117.

van der Leeuw, S., Costanza, R., Aulenbach, S., Brewer, S., Burek, M., Cornell, S., . . . Steffen, W. (2011). Toward an Integrated History to Guide the Future. *Ecology & society, 16*(4).

Van Dyne, L., & Saavedra, R. (1996). A naturalistic minority influence experiment: Effects on divergent thinking, conflict and originality in work-groups. *British Journal of Social Psychology, 35*, 151-167.

Vucetich, J. A., & Nelson, M. P. (2010). Sustainability: Virtuous or Vulgar? *Bioscience, 60*(7), 539-544. doi: 10.1525/bio.2010.60.7.9

Waber, B. N., Olguin Olguin, D., Kim, T., & Pentland, A. (2008). Understanding organizational behavior with wearable sensing technology. *Available at SSRN 1263992*.

Wainwright, C. (Ed.). (2014). *Squaring the Circle*: Art and Theory Publishing.

WCED. (1987). *Our Common Future*. London: Oxford University Press.

Westerbeck, C. (Ed.). (2014). *Robert Adams: The Ecology of Photography and the State of Nature*: Art and Theory Publishing.

Woolley, A. W., Chabris, C. F., Pentland, A., Hashmi, N., & Malone, T. W. (2010). Evidence for a Collective Intelligence Factor in the Performance of Human Groups. *Science, 330*, 686-688.

Wu, L., Waber, B. N., Aral, S., Brynjolfsson, E., & Pentland, A. (2008). Mining face-to-face interaction networks using sociometric badges: Predicting productivity in an IT configuration task. *Available at SSRN 1130251*.

APPENDIX A

IRB APPROVAL

ASU Knowledge Enterprise Development

EXEMPTION GRANTED

Edward Hackett
SHESC: Human Evolution and Social Change, School of
480/965-6561
ehackett@asu.edu

Dear Edward Hackett:

On 1/27/2014 the ASU IRB reviewed the following protocol:

Type of Review:	Initial Study
Title:	Understanding Collaboration Patterns in Artists-Scientists Teams
Investigator:	Edward Hackett
IRB ID:	STUDY00000527
Funding:	None
Grant Title:	None
Grant ID:	None
Documents Reviewed:	• Cardenas Consent Form.pdf, Category: Consent Form; • IRB_Cardenas_1_16.docx, Category: IRB Protocol; • Pretest.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Posttest.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Meeting Survey.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Debriefing.pdf, Category: Other (to reflect anything not captured above); • Tres Rios Protocol.pdf, Category: Participant materials (specific directions for them); • Cardenas Email Recruitment Script.pdf, Category: Recruitment Materials; • TresRiosVideo.pdf, Category: Recruitment Materials;

The IRB determined that the protocol is considered exempt pursuant to Federal Regulations 45CFR46 (2) Tests, surveys, interviews, or observation on 1/27/2014.

In conducting this protocol you are required to follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).

Sincerely,

IRB Administrator

cc: Edgar Cardenas
Edgar Cardenas
John Parker

APPENDIX B

CONSENT FORM

Consent Form: Understanding Collaboration Patterns in Artists-Scientists Teams

We are Edgar Cardenas, a graduate student in the School of Sustainability at Arizona State University, Ed Hackett, a professor in the School of Human Evolution and Social Change, and John Parker, a Barrett Faculty Fellow in the Barrett Honors College. We are conducting a research study on participation patterns in artists-scientists collaborations.

I am inviting your participation, which will involve approximately 1 ½ hours of your time for 4 meetings. During this study you will work with 3 other participants. The composition of teams will consist of 2 artists and 2 scientists. You will collaborate with team members on the development of design ideas for the Tres Rios signage development project. During this study you will be videotaped, observed by the Co-I Edgar Cardenas, and you will be asked to wear a small electronic device around your neck (sociometric badge), which gathers data on your speech and movement patterns. The device is similar, in size and weight, to what you could expect from wearing an ID badge on a lanyard. After the completion of each meeting, you will be given a brief questionnaire asking about your experience during the task. You have the right not to answer any question, and to stop participation at any time.

Your participation in this study is voluntary. If you choose not to participate or to withdraw from the study at any time, there will be no penalty. You must be 18 or older to participate in the study.

Possible benefits to your participation will be experience in collaborative settings, particularly in interdisciplinary collaborations that develop skills that will be useful in your academic or professional careers. The city of Phoenix is interested in implementing the ideas that are developed in this experiment, so you have the opportunity to collaborate on a 'real world' project that can be placed on your curriculum vitae or resume. Furthermore, you will have the option of leaving an email address on a separate sign-up sheet if they wish to be informed about the findings of the study. There are no foreseeable risks or discomforts to your participation.

Your responses will be confidential. In this study, you have been assigned a unique ID number. Data from your participation will be labeled only by this ID number. The file linking your name to your ID number will be stored on a password-protected computer in a locked office for the duration of the study. At the end of the study, this file will be deleted. The results of this research study may be used in reports, presentations, or publications, but your name will not be used. Please do not write your name or any other identifying information when performing study tasks.

If you choose to participate in the study, please do not share what you are doing with others outside of your team until the end of the study. The session will be video recorded and I will be observing the meetings. The session will not be recorded without your permission. Video records of your participation will only be used in ways to which you agree now and at the end of this session. **During the session, please refer to yourself, your group members, and any other individuals by first name only, in order to help preserve the confidentiality of all parties.** Video records will be stored on an external hard drive in a locked office, labeled only with your ID numbers, and only available to our research team. At the end of the session, if you or your group members decide that you do not want the video record analyzed by the research team, the data will be destroyed immediately.

With your permission, the video records will be analyzed by the research team. These data may be aggregated with data from other sessions and included in reports, presentations, and publications. Additionally, we are asking for your permission to show your recording at scientific

meetings, in scientific publications, and for future educational/research purposes. This means we could display part or all of the recording to illustrate our research. We will not tell anyone your name while showing the video records; however others may still be able to identify you. You may agree to be recorded and to have your data analyzed by the research team, but not to have your recording displayed in this way.

If you have any questions concerning the research study, please contact Edgar Cardenas (ecarden4@asu.edu). If you have any questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at (480) 965-6788.

Sincerely,

Edgar Cardenas, Ed Hackett Ph.D., and John Parker Ph.D.

1) "I agree to participate in the study above, and to have my speech and movement characteristics recorded by a sociometric badge during today's session"

_____	_____	_____
Participant's signature	Printed name	Date

2) "I agree to be videotaped during each session, and this video record may be analyzed by the research team for use in aggregate publications and presentations."

_____	_____	_____
Participant's signature	Printed name	Date

3) "I agree to allow video records of each session to be shown to others at scientific meetings, in scientific publications, and for future educational/research purposes"

_____	_____	_____
Participant's signature	Printed name	Date

4) "I agree to be observed during each session, and this record may be analyzed by the research team for use in aggregate publications and presentations."

_____	_____	_____
Participant's signature	Printed name	Date

APPENDIX C

STUDY SURVEY

Participant ID: _____

How much total time (in minutes do you think each member has spent on this project?

Name: Time:

Name: Time:

Name: Time:

Briefly describe the major work (if any) you did on the project today, or the major activities you engaged in that were relevant to the project.

How many minutes did you spend working on the project today? _____

What percentage of this time was spent working with other members of your team? _____
Which members did you work with?

Was there a team member you felt most engaged with today? (circle one) YES NO
If yes, who was it and why did you feel this way?

Rate the degree to which you agree with each of the statements below

	Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree	Not Applicable
Today, in my work on the project, I felt:								
I made progress								
My work was high quality								
Challenged								
Involved								
I did creative work								
I enjoyed my work								
Motivated by external pressure to work								
Motivated by my own internal pressure to work								
Motived by my own interest								
Motivated by the rewards I might earn								
Motivated by recognition I might earn								
Based on the team's work on the project today, I felt:								
Satisfied with the team								
The team did quality work								
The team was creative								
Frustrated with the team								
The team worked well together								
The team made progress								
Today, I felt that my team's work environment contained:								
Freedom or autonomy in the work								
Positive challenge in the work								
Sufficient resources available for the work								
Time pressure in the work								
Supportive interactions within the team								
Clarity of goals for the project								
Encouragement and support from other team members								
Positive interactions between the team and the researcher								
Fair evaluation of our project work								
Recognition and reward for creative work on the project								
Collaborative ideas flow across the team, concerning the project								
A conservative, low-risk attitude toward this project within the team								

Rate the degree to which you agree with each of the statements below

	Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
Today, overall, I felt:							
Relaxed							
Frustrated							
Happy							
Energetic							
Distracted							
Imaginative							

In terms of my teams ability to complete this project, I feel:							
We can always manage to solve difficult problems							
It will be easy to stick to our aims and accomplish our goals							
We can deal efficiently with unexpected events							
Thanks to our resourcefulness, we know how to handle unforseen situations							
We can solve most problems if we invest the necessary effort							
When we are confronted with a problem, we can usually think of a solution							
We can usually handle whatever comes our way							

What do you think each team member's contribution to the group will be? (include yourself)

My contributions are….
_____'s contributions are…
_____'s contributions are…

Briefly describe one event from today that stands out in your mind as relevant to the project (this could include: your feelings, your work, or your perceptions around how your team feels or your team's work).

Remember to specify **who was involved and **what** happened**
The event can be positive, negative, or neutral
Please write your answer below

How many individuals on your team were aware of this event? (circle one)

Just myself

Myself and _____ others. (fill in number of people)

How did the event take place? (Circle one)

Physical meeting (with badges)

By email

By phone

Chance encounter (no badges)

I was alone at my desk

I was at the Tres Rios Wetland Site

Other _____.

What was the approximate time of the event? _____.

Rate the effect of this event on each of the following

	Very Negative Effect	Moderately Negative Effect	Slightly Negative Effect	Neutral or No Effect	Slightly Positive Effect	Moderately Positive Effect	Very Positive Effect
Your feelings about the project							
Your work on the project today							
Other team members work on the project today							
The Project overall in the long-term							

APPENDIX D

TRES RIOS PROTOCAL

THE TRES RIOS PROJECT: OUTCOME SUMMARY

Where
The Tres Rios Restoration site is a constructed wetlands site that is connected to the wastewater plant and provides ecosystem services to the area including habitat formation for fauna. The site will also soon be used as a public park. Additional info will be made available via a shared Dropbox folder.

What
The city of Phoenix would like to share the restoration work they have done via interpretive signage with the public, so we are enlisting artists-scientists teams to develop ideas of what this could look like. They have funding for this project and would like your assistance in conceptualizing the signs. The target age group is 8th graders.
The city is particularly interested in relaying their work in developing the site and the ecological relationships between the various areas. Rather than considering this as the box you must work in, treat it as starting point to developing engaging, novel, and appropriate ideas that express Tres Rios' social and ecological complexity

Who
We will assign two artists and two scientists per team. This project is about giving equal voice to both artists and scientists. All members should be willing to express their ideas and understand they carry equal weight.

How
Including the field visit, you are expected to have 4 1.5-hour meetings though you may choose to meet more. At each meeting, in addition to project work, you should expect to:

- Agree upon a time for the next meeting
    - Be sure to include me in this information, I need to be present at all meetings to collect data
    - If possible, please try not to schedule meetings Tuesday between 7:30 am - noon
- Establish any tasks that need to be completed in the interim (research, brainstorming, etc.)
- Complete your survey as soon as the meeting is over!!!

Tips on working together:

- **Show vs. Tell:** Favor showing and giving examples over explaining. Even if you think you can't draw, sketch out ideas, use pictures, models, etc.

- **No cries, analogize:** Scientists and artists both use analogies in their work, at times to get unstuck, to communicate ideas to someone outside their field, or to unite ideas that don't initially seem connected. Feel free to play with analogies when working together.

- **Collaborating with others can be rewarding… but also challenging:** Collaborating can be hard even if you work in the same space. Bridging the divide between art and science may be difficult so please be patient with each other. If you don't understand something ask questions that help clarify ideas or points of view, don't assume you understand what others are thinking or contributing.

Above all, please have fun and be creative!

The following is intended to serve as a tool. You are not obligated to follow this structure if you feel it is not serving your process

Meeting One – The site visit

Observe, collect, engage, immerse: You will be getting a site tour and get a chance to explore Tres Rios. Note what you see and experience, how you can imagine people using the area, the questions they might have, things that you find interesting and how to bring others attention to this. Be sure to identify elements that you feel are critical to include in the final product.

Objectives

- Review the process being undertaken
- View the area and begin to formulating reactions to the space
- Meet potential group members

Meeting Two – Initial idea formation

Defining your team point of view: As a group, share out your discoveries from the wetlands. Identify your critical elements and consider how they may be compatible (or not). Develop a statement for WHAT your signs will accomplish (what will it give to people, in terms of: information, experience, feeling, etc.)

Objectives

- Share experiences and stories about the space
- Brainstorm on additional realizations/insights that emerged from group discussion
- Identify specific aspect that you're interested in and how to communicate them.

Meeting Three – Developing your idea

Idea expansion: In your previous meeting you established critical pieces from your experience at the wetlands, now begin to explore the way those conceptual pieces can be built out into an experience for participants.

Objectives

- Identify a variety of ways that the signage can be executed to give participants your "critical experience." (Will you find a way for them to interact with the space via made objects? Will something mediate the experience? i.e. QR codes for Internet access)
- Evaluate each idea in terms of effectiveness, appropriateness, and novelty.

Meeting Four – planning your mock up

Prototype: During this phase you should begin building out your idea so that it can be effectively conveyed to the City of Phoenix administrative team overseeing this project.

Objectives

- Clearly flesh out your ideas and ensure that there is a shared vision
- Establish how to present it to best allow the evaluators at the city to fully appreciate and experience this product (storyboard, PowerPoint, other)

APPENDIX E

SOCIOMETRIC DATA BY MEMBER AND TEAM FOR EACH MEETING

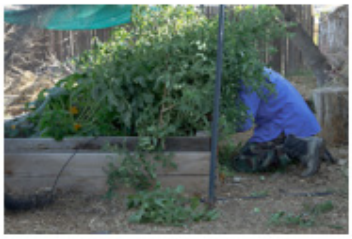
			Badge Data						Survey Data		
Team	Gender	Discipline	Speaking	Successful Interruption	Overlap Average	Amplitude Average	Amplitude Deviation	Total Group Deviation from the Average	Individual Satisfaction	Team Satisfaction	Team Efficacy
Meeting 1											
1	F	Scientist	34%	56%	0.49537	12.2	1.43	8.96	5.33	4.83	4
	M		46%	65%	0.53065	13.9	3.07		6	6	4.67
	F	Artist	20%	57%	0.45680	6.34	-4.46		6	6.17	6
2	F	Artist	34%	88%	0.52120	7.11	1.35	2.70	6.33	6.17	5
	M		40%	84%	0.47971	5.09	-0.674		6.67	5.83	6.17
	F	Scientist	26%	68%	0.49762	5.08	-0.684		5.33	6.67	4.83
3	F	Scientist	28%	60%	0.50952	11.7	-0.373	1.17	5.83	6.67	5
	M		35%	47%	0.52102	12.6	0.587		6	6.33	5
	F	Artist	38%	60%	0.51879	11.8	-0.214		6	6.83	4.33
Meeting 2											
1	F	Scientist	41%	69%	0.49626	14.0	2.99	9.21	6	5.83	4.67
	M		39%	63%	0.52681	12.6	1.62		5.17	6.17	5.17
	F	Artist	21%	43%	0.49048	6.42	-4.61		5.83	6.17	6
2	F	Artist	36%	88%	0.52455	5.17	0.526	1.60	6.67	6	6
	M		46%	73%	0.51271	4.92	0.273		6.5	7	6
	F	Scientist	17%	71%	0.49889	3.84	-0.799		6.33	6.83	4.5
3	F	Scientist	18%	53%	0.52589	9.59	-0.865	1.73	6.83	7	6.5
	M		43%	65%	0.52751	10.9	0.419		6.17	6.83	5.5
	F	Artist	39%	61%	0.52721	10.9	0.446		6.83	7	6
Meeting 3											
1	F	Scientist	33%	65%	0.50252	10.4	-0.572	2.62	5.67	4.33	4
	M		52%	73%	0.47992	12.3	1.31		4.83	5.5	6
	F	Artist	15%	45%	0.45635	10.3	-0.732		5.33	6	6
2	F	Artist	41%	79%	0.51507	7.77	1.08	2.17	5.83	5.17	4.67
	M		33%	68%	0.50150	6.00	-0.687		6.5	6.83	6
	F	Scientist	26%	73%	0.48538	6.30	-0.395		5.67	6	5.83
3	F	Scientist	24%	56%	0.46773	10.8	-0.0456	0.492	6.17	6.83	6.5
	M		29%	68%	0.50395	11.1	0.246		5.5	5.83	5.83
	F	Artist	47%	63%	0.47510	10.6	-0.200		5.5	6.17	6.67
Meeting 4											
1	F	Scientist	38%	80%	0.58566	12.0	3.10	6.20	2.5	1.83	2
	M		46%	61%	0.49331	8.27	-0.579		3	3.33	6
	F	Artist	16%	42%	0.48237	6.33	-2.52		6	6	6
2	F	Artist	36%	92%	0.50109	6.15	0.162	0.581	6.17	7	5.83
	M		29%	70%	0.49080	5.70	-0.291		6.33	6.17	5
	F	Scientist	35%	72%	0.47983	6.12	0.129		6.17	7	5.83
3	F	Scientist	31%	44%	0.50096	16.4	-0.423	5.29	5.33	6	6.5
	M		33%	38%	0.49605	14.6	-2.22		6.33	6.5	6
	F	Artist	36%	45%	0.49488	19.5	2.64		6.17	6.67	6.83

Amplitude Average, Amplitude Deviation, and Total Group Deviation from the Average are set at E-03

APPENDIX F

CONTACT SHEET OF ALL IMAGES FROM EXHIBIT



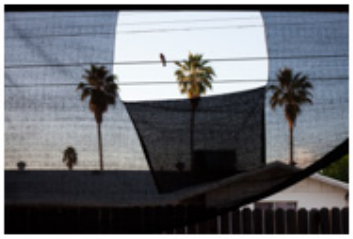

















May 17, 2012

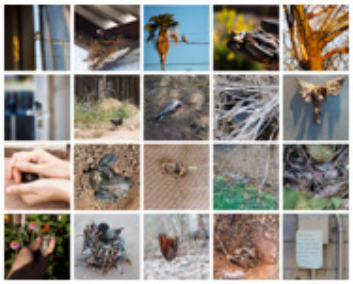
This is our palo verde tree from our first spring in our rental. The palo verde beetles have done a number on the tree though. They killed two of our palo verde trees and now this one producues very few leaves or flowers. Last night I dreaded it finally gave in to the Palo Verde Beetles.

January 19, 2011

For weeks, the neighbor's chickens would hop on fence and went in our Palo Verde for the night. One morning, I woke up to find one a ranch chicken huddling next to our chicken coop and another chicken outstanding in the yard. The neighborhood cats have access to plenty of food so killing this bird was simply an act of predation.

This cat punctuated this point by eating some of the bird. The neighbors came over to get their chicken and then returned 30 minutes later to inform us they were throwing the chickens away. We are vegetarian so we weren't going to eat it, but the feathers strewn throughout the yard showed the chickens struggle. We didn't want the chicken to have suffered and died in vain so I tookk it back to chase it. We couldn't find good instructions online for throwing a chicken. After an hour of sadly wrestling with the feathers, we ended up burying the chicken. We were at a loss about what to do. Were were we going to throw it if we couldn't even pluck feathers?

For the next week, when the sun set I would check into the fowl, pull the chickens out, and place them in our coop for the night. In the morning, I'd return them to the neighbor's yard. They have their own chicken coop now.



October 19, 2011

Pepino, one of our Chihuahuas, was sniffing intently in our trees and pointed out to a baby iguana that had fallen out of his nest. At first, the tiny Iookalectus body was cold and limp in my hands. As he absorbed my body heat, he grew warmer, lifting his little head high and supervising before collapsing back down.

As he grew more comfortable, we did not so we tried to figure out what to do for him (though we did pause to name him Henry). We couldn't reach the nest to put him back, but we did take him to Wild Wings Rehabilitation.

I have been wanting to return and see how Henry the Iguana is doing. I'm sure he is quite big by now.

May 9, 2011

I looked out the door this morning to see Henry our girl ball frozen on the rock. As I got closer, I realized he was standing next to some with a freaking sparrow. The bird wasn't hurt but was still trying to get itself to flying. We found a still sparrow, placed him/her

With a little peace and quiet I he got his wits about him and was on his way.