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Ecological Innovators: A Multiple Case Study Approach to Explore the Influencing Factors and Conditions Upon the Lives of Young People Who Innovate to Save the World

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DEDICATION

For my sons.

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ABSTRACT

This multiple case study aimed to identify and describe factors and conditions that influence the lives of young people who become innovators of solutions that help the environment. This study involved three unique case studies of ecological innovators, two individuals and one paired team. Each participant had designed, prototyped, or patented an environmental innovation before the age of 30 years. The four primary participants, recruited by word of mouth and snowball sampling, were comprised of one American (U.S.) middle-school girl, one American-Israeli man in his 50s, and the team of a Palestinian man and an Israeli woman, both in their 20s. Each case also included interviews with auxiliary participants, such as parents, teachers, and mentors, who shared their perspective on their primary participant. Data collection for the criterion-based case studies included interviews, observations, published materials about the participants and their contexts, supplemental documents, and artifact collections such as prototype sketches.

Results indicate the eco-innovators in this study (1) had sustained, immersive, and tactile exposure to scientific exploration in and out of school; (2) internalized beliefs and perspectives over time that oriented them towards stewardship of the earth and environmental sustainability; (3) benefitted from relationships with mentors who invested in their development and inspired and challenged them; (4) engaged in activism; (5) maintained a stance of optimism and hope in the face of suffering or witnessing others' suffering; (6) participated in team-based iteration applied to a concern for an environmental problem; (7) assumed responsibility for things beyond themselves; (8) experienced self-directed engagement with creative problem solving and design;

(9) had at least one seminal experience that ignited their motivation to solve or overcome an ecological problem; (10) participated in innovation-focused programs, camps, or school courses; and (11) had lives that indicated the presence of three intertwining, integrated pathways towards eco-innovation: scientific exploration, positive relationships, and an empathetic and empowered response to vulnerability.

Implications and suggestions are provided for educational leaders, teachers and educators, and parents, guardians, and adults who invest in children.

Keywords: eco-innovation, eco-innovator, ecological innovation, environmental innovation

CHAPTER 1

Introduction

I am concerned about our planet's ecological systems and how, with human interference, they break down, threatening the wellbeing of numerous species, including humanity. As an educator of science teachers and as someone steadfast in my desire to be an integrative thinker, I habitually wonder about how to empower current and future generations to collaboratively solve the intractable problems facing our world—problems such as the 165 million tons of plastic litter swirling in the gyres of our world's oceans that simultaneously starve and poison sea life and birds who mistake the plastic for food (Cirino, 2017); the death of giant portions of Australia's Great Barrier Reef, which supports an interconnected system of ocean and human life—a demise caused by the human-influenced rise in ocean temperature (Cave & Gillis, 2017); the declining bee population, upon which we depend for global food sustainability (Sass, 2015); climate change, the foreboding shift in our biome that threatens to unleash a cascade of deleterious consequences, including increasingly powerful climatic events such as flood-bearing typhoons, hurricanes, and tornadoes, and an increase in mosquito-transmitted illnesses such as the zika, dengue, and chikungunya viruses (Bender et al., 2017; Easterling et al., 2000; Monaghan et al., 2016); and food sources that, due to increased carbon dioxide in the atmosphere, are shifting to contain more carbohydrates and fewer vital nutrients such as proteins, vitamins, and minerals (Evich, 2017). Despite these ominous circumstances, humans still have the ability to innovate—to tinker our way out of a problem and into a solution. As former President Barack Obama (2009) said in his remarks to the Educate to Innovate campaign, “We live in a world of unprecedented perils, but also unparalleled potential.”

Given our human need to survive the “unprecedented perils,” I am interested in learning how to support the “unparalleled potential” by finding out how to promote the development of young people who are drawn to the compelling work of finding long-range solutions to our ecological problems. If reports in the popular media are any indication, then it is clear that I am not alone in my motivation to support the upcoming generation with foundational experiences that kindle their sense of wonder and promote a problem-solving attitude that might help them outwit and survive the precarious global circumstances they are inheriting. Examples of these media articles written in the past 6 years include “5 Ways to Encourage Kids to Grow up to be Innovators” (Morgan, 2014), “5 Ways You Can Encourage Your Kids to Become Innovators” (Stillman, 2016), “Why the World Needs Innovators and How Your Child Can Become One” (Tripp, 2013), and “How to Turn Your Kids into the Innovators of Tomorrow” (Glangchai, 2017).

In addition to articles targeting parents who want to set up their children to be innovators, employers seeking sustainable practices are putting out the call that more innovation is needed (Choi, 2017). As these articles, along with many others, steep the culture with the idea that innovation is a necessary component of our children’s future, a growing number of youth eco-innovators are responding. These young ecological innovators, motivated by science fairs, makerspaces, and other opportunities in their schools, homes, and communities, are grappling with these problems and taking their solutions public. Some broadcast their ideas on YouTube, participate in TED Talks, or showcase their creations at Maker Faires.

Through this research, I aimed to determine what experiences, developmental factors, and conditions contribute to such young people becoming ecological innovators—the *why* and *how*. I sought to identify and understand the pathway or pathways to becoming an ecological innovator. The drive motivating this study was my desire to give our youth a fighting chance at overcoming the trajectory of our planet's multifaceted, system-linked demise.

Through this study, I researched the experiences of four people who had created (or were in the process of creating) an innovation to mitigate or ameliorate some aspect of ecological crisis. Prior to working with the study participants, I searched in popular media for models of the type of participant I sought for this study. I found Boyan Slat, a Dutch man in his 20s who developed a method to clean plastic from the ocean by iterating a prototype as a science project (Venema, 2014); Chaitanya Karamchedu, an Oregon teenager who determined how to turn salt water into potable water cheaply and easily by taking a perspective no known scientist had taken before (Bolduc, 2017); and Aidan Dwyer (2011), an American boy who at age 13 designed solar panels in the shape of an oak tree to gather the sun's energy throughout the day.

This study aimed to determine what factors and processes in the lives of qualifying participants supported their emergence as ecological innovators and to provide this research-founded information to educational leaders for the purpose of supporting and cultivating ecological innovators.

Throughout this dissertation, *ecological innovator* is defined as a person who has created or is in the process of creating a solution of some sort to mitigate or solve an environmental or ecological problem. The solution may be an invention, process, or system, as long as it is a novel approach to solve a problem affecting the earth's natural environment, including land, water, or air, and improves the quality of life for the species who make their home in the given environment.

Statement of the Problem

As evidenced by the international climate strike of March 15, 2019 that involved youth from around the world (Glenza, Evans, Ellis-Peterson, & Zhou, 2019), today's youth are growing up in a context where they are aware of humanity's negative impact on the environment—in a world with repeated references to genuine systemic ecological problems and an increasing realization of the consequences of climate change. Simultaneously, innovation as a means to engage with real-world problems is taking hold as an increasing thrust in the culture. Numerous articles in the popular media offer advice on developing innovators (Morgan, 2014; Stillman, 2016; Tripp, 2013). The presence of these articles suggests a broader cultural understanding of the need to prepare our children to leverage innovation to effectively respond to the global context they are inheriting. The intersection of the climate crisis with innovation is the niche of interest for this dissertation inquiry, which led to the following problem statement: There is a lack of understanding of the factors and conditions that influence young people to become ecological innovators.

Purpose of the Study

The purpose of this study was to discover if there were any consistent themes or common experiences within the developmental life experiences of ecological innovators that motivated and enabled them to become ecological innovators. The overarching goal of this study was to deepen the researcher's awareness of the multiple pathways that ecological innovators traveled to create their ecological innovations. Through a multiple case study design, this research documented key experiences, factors, and conditions present in their lives, challenges they faced, challenges they overcame, and factors they suggested to increase ecological innovation among their peers. This study aimed to address the following research questions.

Guiding Research Questions

1. What do people who have produced ecological innovations, and others associated with them, report as the critical experiences, factors, and conditions in their development as ecological innovators?
2. What factors and conditions do ecological innovators suggest can inspire ecological innovation among their peers and young people?
3. What pathways towards ecological innovation and common experiences, factors, or conditions emerge from the stories of ecological innovators?

Theoretical Framework

The epistemology of this research came from a bricolage of frameworks. Maxwell (2013), who pulled from the French anthropologist Claude Levi-Strauss (who coined the term in 1968), defined a *bricoleur* as one who "adapts to the situation, creatively employing the available tools and materials to come up with unique solutions to the problem" (pp. 42–43). Like Maxwell, my philosophical position underlying this study was critical realism, a bricolage of two blended perspectives "that have often been seen as logically incompatible: ontological realism and epistemological constructivism" (p. 43).

Ontological realism defines the belief that there is a real world with its own set of realities and systems that does not bend to our subjective beliefs. The foundation of ontological realism maintains that the "world doesn't accommodate to our beliefs; believing that global warming is a hoax will not keep the Earth from warming" (Maxwell, 2013, p. 43). *Epistemological constructivism* holds that our conception of reality is inevitably our construction and therefore, subjective. From this standpoint, all conclusions are an "incomplete attempt to grasp something about a complex reality" (p. 43).

This foundation of *critical realism*, the blending of ontological realism and epistemological constructivism, undergirded three influential concepts that shaped my thinking regarding this research study. The first concept was a model of the developmental and contextual factors that comprise an innovator in general (not necessarily an ecological innovator), as Wagner (2012) developed and published in his book, *Creating Innovators.* Wagner proposed a "framework for developing the capacities of young people to become innovators" (p. 58). This framework situated innovation within a culture of "teamwork, interdisciplinary problem-solving, and intrinsic incentives" (p. 58), noting the key incentives of "exploration, play, and empowerment" (p. 58). Within that culture, Wagner placed innovation at the nexus of expertise, creative-thinking skills, and motivation. His framework for researching innovators guided the literature review and case study design as this study homed in on the more specific subset of ecological innovators.

Bloom's (1985) groundbreaking study, *Developing Talent in Young People*, framed the second concept in the bricolage. Bloom found that people who achieve excellence in their field share some common developmental experiences that cross disciplinary fields, as well as some essential developmental experiences that are domain specific. Bloom's study methodology suggested that the key information about one's formative development is not solely contained in the innovators' minds, but also held in the memories and understanding of those who influenced the innovators, such as parents, teachers, and mentors. Bloom's research, therefore, informed the design of this study, which used a case study methodology to identify key developmental influences.

Positive deviance, a concept established by Pascale, Sternin, and Sternin (2010), served as a foundational principle for this study. As a supposition, positive deviance maintains that the solution to a problem may already exist within the context but has yet to be implemented on a broad scale because the innovator is not connected yet to social or political forces that would enable widespread implementation. Furthermore, Pascale et al. identified individuals within a community who stood out as exemplars of a desired behavior or phenomenon as *positive deviants*, also called *bright spots* (Heath & Heath, 2010; Pascale, Sternin, & Sternin, 2010). For this study, I used Pascale et al.'s (2010) framework to identify subjects who had achieved the status of an ecological innovator. These bright spots yielded information that helped identify factors and conditions that influenced their path and led them to ecological innovation.

To synthesize, Wagner’s (2012) framework for what makes an innovator was used as a guiding model for what factors and conditions to consider influential in the lives of ecological innovators. Hence, Wagner’s framework contributed to guiding the subject areas for the literature review. Bloom’s (1985) work on talent development in youth informed this study in two foundational ways: (a) as a base for the assumption that there are formative factors and conditions in the lives of those who become ecological innovators and (b) for the idea that the important data about these developmental influences are vested in the ecological innovators, as well as those who influenced the innovator. Thus, Bloom’s work informed the specific way the case study methodology was applied to this investigation. Finally, Pascale et al.’s (2010) method of looking at positive deviant exemplars to determine why and how bright spots excel served as a foundation for the motivation, purpose, literature review, sampling method, and instrument design for this research.

Definition of Terms

Anthropocene. Anthropocene refers to our current epoch in the context of geological world history (Zalasiewicz et al., 2008). This proposed epoch, succeeding the Holocene, is marked by the effects of human impact on Earth’s geology and ecosystems, exemplified by anthropogenic climate change and other human-caused changes. These changes include geological shifts from terraforming and fracking and irreversible changes to the Earth’s rock stratification due to detonation of nuclear weapons or changes in the chemical composition of our air and in oxygen levels in the ocean (Willow & Wylie, 2014; Zalasiewicz, Williams, Steffen, & Crutzen, 2010).

Auxiliary participant. An auxiliary participant is an informing participant who provided case-relevant information about a primary participant (e.g., the primary participant's parent, mentor, or teacher).

Climate. For purposes of this study, climate refers to the earth's natural climate involving long-term weather systems and temperature.

Eco-. As a prefix, eco- modifies a term to be in relationship with or focused on some aspect of the environment and the life it sustains.

Ecological. This term modifies the noun paired with it, placing it in relationship with or focused on some aspect of the environment and the life it sustains.

Eco-innovation/Ecological innovation. These interchangeable terms refer to the process or product created by an eco-innovator. This object or process must in some way aim to mitigate or ameliorate detrimental environmental conditions or promote the survival of living creatures in context of their natural environment. It can also refer to the larger body of ecological innovation work. This term may refer to the ecological innovation domain, which includes all innovative efforts to mitigate or ameliorate the detrimental effects of human influence on the earth. For the overarching domain definition, this research looks to a definition by Rennings (2000, pp. 319–322): "Innovation processes toward sustainable development," with sustainable development described as containing "an ecological, economic and social dimension."

Eco-innovator/Ecological innovator. For purposes of this study, these interchangeable terms refer to a person who has created or is in the process of creating a solution to mitigate or solve an environmental or ecological problem—an innovative or inventive steward of the natural environment. For instance, an eco-innovator may have created an invention or innovative response to an ecological or environmental problem, such as plastics in the ocean, lack of potable water for people in a geographical region, the deleterious rise of carbon in the atmosphere, or a threat to a species due to environmental conditions.

Ecosystem. In this research, ecosystem refers to the classical scientific definition, which specifies an interconnected web of living organisms, including plants, animals, fungi, Protista, archaebacteria, and eubacteria, and their interactions with each other and with nonliving environmental elements such as water, rocks, land, and air.

Environment. In this study, environment refers to the natural world and the systematic factors involved in the natural world, including climate, geological features, ecosystems, and food webs, and the interaction of these features and systems.

Primary participant/Primary subject. A primary participant or subject is a person who served as the focus of a case or, in the instance of the third case in this study, shared the focus. These participants are, by the requirements and definitions of this study, eco-innovators.

Sustainable practice/Sustainability. There are many conceptions of this term, especially as related to different domains and different cultures. For purposes of this research, sustainable practice or sustainability refers to the practice of intentionally behaving responsibly in one's existence on the earth in terms of how one's waste, transportation, consumption, and construction affect ecological systems on the planet. A sustainable practice keeps in mind that human action affects the interconnected system of living things and takes measures to minimize the deleterious consequences. Sustainability refers to efforts to maintain Earth's ability to sustain all life on the planet.

Significance of the Study

This study investigated the formative experiences, factors, and conditions that influenced ecological innovators to develop solutions to ecological problems. This inquiry documented factors within the lives of four people (three cases) who innovated ecological solutions to ameliorate or mitigate anthropogenic environmental problems or support human life with sustainable design. Results from this study add to the ever-growing corpus of research geared towards supporting long-term sustainability for life on this planet. Further, it informs stakeholders, including educators—particularly science and interdisciplinary educators, school leaders, curriculum and instruction designers, policy makers, after-school program educators, summer camp designers, innovation and makerspace facilitators, science-educator preparation programs, educational researchers, environment-oriented community organizations, parents, environmental education funders, and eco-sustainability organizations and entrepreneurs.

For those in the field of education, this research may inform educators' understanding of the elements to have present in the learning environment that will likely foster students' potential to become ecological innovators. The understanding yielded from this study could potentially influence the opportunities educators and education leaders provide students, because this study may inform education leaders on how to allocate funding, school time, and school structure.

People who work in supplemental educational fields, such as after-school programs, camps, makerspaces, and outdoor education programs, may find this study useful to inform program design, as well as to apprise them of the web of experiences (past and ongoing) young people bring to their programs.

Education researchers may find the identified contributing factors and conditions or the suggestions for further research compelling enough to launch further study.

Environmental organizations and funders may find the contributing factors, conditions, and practices this study identified worthy of informing their missions.

For parents interested in environmental issues and raising their children to be ethical environmental stewards of the planet, this study may provide insights and practices to consider regarding issues and opportunities that support ecological innovation.

Delimitations

Because this was a criterion-based study, the criteria used to select the primary participants also served as the delimitations. The selection criteria clearly demarcated who would be considered valid potential candidates for the study, and who would not. Chapter 3 details the criteria for selection and exclusion of potential primary participants. Briefly, to be considered viable primary participants in this study, participants must have given consent (and parental consent also given in the case of a minor); started working on their first eco-innovation before the age of 30 years; spoken English fluently; engineered a novel process or product to solve, ameliorate, or mitigate an environmental problem; and not made their eco-innovation for an employer or client, but from their own motivation or during a time of academia.

Auxiliary participants must have been suggested by the primary participant (or by the primary participant's parent in the case of a minor), fluent in English, willing to participate and consented to do so, and, according to the primary participant, contributed to the primary participant's development into an eco-innovator in some way.

Research Base

The literature review aimed to gather a broad perspective of the interdisciplinary landscape involved in ecological innovation. That review started with an exploration of the role of context as it relates to ecological innovation by considering Gladwell's (2008) concept that the context and timing of one's birth plays a role in success, because when and where one is born delimits the phenomena to which one is exposed and the knowledge and tools to which one has access. This contextualization led into the exploration of three exemplar ecological innovators from the mainstream media. From a brief analysis of these three model eco-innovators, the following domains of literature were selected for review: (a) nurturing excellence, (b) motivation, (c) ecological education, (d) creativity, (e) the maker movement, (f) mentoring, and (g) educational leadership.

Nurturing Excellence

The literature review section on nurturing excellence overviewed Bloom's (1985) study of the development of talent in young people, which yielded evidence that "no matter what the initial characteristics (or gifts) of the individuals, unless there is a long and intensive process of encouragement, nurturance, education, and training, the individuals will not attain extreme levels of capability in [their] particular fields" (p. 3). Bloom found that different fields indeed required different specific qualities for success, which brought to question what specific qualities would be pertinent to the field of ecological innovation. Additionally, that section touched on the motivation experienced by exemplars of excellence, which led to an exploration of the literature on motivation.

Motivation

The review of the literature on motivation explored Bandura's (1977, 1982, 1997) work on self-efficacy; Deci, Vallerand, Pelletier, and Ryan's (1991) work on self-determination; Deci and Ryan's (2000) work on intrinsic motivation; Dewey's (1893, 1902) work on self-realization, which led to including Maslow's (1943) work on self-actualization; Csikszentmihalyi, Abuhamdeh, and Nakamura's (2005) concept of flow; and Nakamura and Csikszentmihalyi's (2003) research on the connection between motivation and creativity.

Ecological Education

Resourcing literature on ecological education, the literature review included work from the noted ecological educator, David Orr (1992), who challenged humanity to head towards a sustainable planet. Orr provided two concepts to help people do so—ecological competence and ecological literacy. The review included work from Louv (2009), who surveyed American culture and named the collection of its symptoms—childhood obesity, hyperactivity, and distractibility—"nature-deficit disorder" (p. 24); Krasny and Monroe (2016), who listed challenges involved in providing environmental education; and Daloz (2004), who proposed that people need to develop the capacity for systemic thought and must include the environment in the concept of sense of self because we are dependent upon the environment for survival. This section also included Lieberman's (2013) seven major categories of human impact on the earth. A large subheading within this section explored systems thinking, drawing from the work of Wilson (2016), Senge (1990), and McDonough and Braungart (2002, 2013).

Creativity

From the body of literature on creativity, Csikszentmihalyi's (1996) work was explored and used as a launching point for further study. In his work on the psychology of discovery and invention, Csikszentmihalyi proposed that "a person who wants to make a creative contribution . . . must learn the rules and content of the domain," as well as have the motivation to contribute (pp. 47–48). Other literature on creativity included were Goerner's (2007) concept of *learn or die*; Lubart and Guignard's (2004) findings that creativity development can be supported by both home and school environments and that at least domain-specific creativity could be taught; Csikszentmihalyi's (1999) model for the systems view of creativity; Csikszentmihalyi's (1996) paradoxical dimensions of creativity; Runco's (2004) assertion that anyone can be creative and that creativity can be cultivated; Richards's (2007) suggestions for how adults can nurture or squelch creativity; and Eisler's (2007) claim that love is a foundational force for nurturing the development creativity and that "our most urgent creative challenge is building a sustainable future" (pp. 261–262).

The Maker Movement

Anderson (2012) summarized the recent history of innovation to contextualize the maker movement. Martinez and Stager (2013) presented the work of the maker movement's founder, Seymore Papert, as a foundational framework for the movement. Papert developed a teaching theory based on progressive, child-centered, inquiry-based pedagogical models he named *constructionism* (pp. 21, 71). This section included Papert's "eight big ideas behind the constructionist learning lab" (cited by Martinez & Stager, 2013, p. 73). Papert's first makerspace sparked the maker movement with help from *Make Magazine*, created by Dale Dougherty and Tim O'Reilly (Corcoran, 2008). This magazine inspired a community of makers to create physical workshops called *makerspaces* and to convene at expos called *Maker Faires*. Thus, this section of the literature review included Dougherty's (2012) understanding of unbridled innovation as informed by Maker Faires, as well as works by Smay and Walker (2015), Fleming (2015), and others who described how schools and libraries are becoming a part of the maker movement and creating makerspaces. Mentoring in makerspaces was covered, with references from Roslund and Rogers (2014), Dougherty (2016), Fleming (2015), and Papert and Caperton (1999). This exploration of mentoring in the context of makerspaces flowed into the literature review section on mentoring.

Mentoring

The section on mentoring included literature from W. B. Johnson and Ridley (2004) that described mentoring as a relationship in which the more experienced person helps the learner grow in the knowledge and practice of their shared interest, and "is associated with positive and personal and career outcomes" (p. xv). This portion of the literature review delved into what, as W. B. Johnson and Ridley described, mentors do, how mentoring supports positive youth development, and what mentoring innovators involves. This section also pulled from Ensher and Murphy's (2005) *Power Mentoring*, in which the authors defined power mentoring and contrasted it to traditional mentoring. Additionally, this section followed Dweck's (2015) response to the broad influence of her "growth mindset" concept, as she emphasized the importance of coming alongside the student to help the student gain understanding. The literature review outlined the role of mentoring as an influence on positive youth development, as conveyed by Lerner, Napolitano, Boyd, Mueller, and Callina (2014), who purported that mentors who allow mentees to fail, build their mentee's capacity for future contributions. Following was a section on mentoring innovators, which incorporated Wagner's (2012) work, *Creating Innovators.* Through analyzing several cases, Wagner found that all his young innovators had a significant teacher or mentor who transformed their lives, and those mentors themselves were innovators in some way. Wagner suggested that mentors search for the vital spark of passion in their mentees and nurture it, because this would support their students' ability and likelihood to create the very innovations our world needs.

Educational Leadership

Education is the intended domain for this dissertation's contribution; therefore, this literature review concluded with an investigation into literature that dually related to educational leadership and to the themes and topics presented in this dissertation. Because schools are functionally responsible for nurturing students' potential, the first work in this section was Scheffler's (1985) conceptual framework for understanding human potential. Next, literature from school and organizational improvement leadership that provided applicable constructs for eco-innovation practice was reviewed. The remaining topics covered in this section included: 21st Century skills; civic engagement; standards, assessment, and accountability (SAA) in relationship to education for democracy; and supporting creativity, motivation, and innovation in schools.

From the domain of school improvement leadership, Bryk, Gomez, Grunow, and LeMahieu's (2015) plan-do-study-act (PDSA) cycle for educators to improve their schools using an iterative process could also be a construct to support the iterative process necessary for eco-innovation. As such, Bryk et al.'s PDSA cycle could directly support the adoption and trial of suggestions that may arise from this study's findings. It may also be used as an analogous model for educators to engage in an iteration cycle so that they can internalize the practice of iteration from which they can draw the understanding to create an environment conducive for serial iteration and innovation among their students. Similarly, from the field of organizational improvement leadership, Heifetz and Linsky's (2002) concepts of *getting up on the balcony* and technical and adaptive challenges for problem solving can help school leaders notice instances or patterns of school conditions enabling, thwarting, or ignoring innovation-oriented activity. These concepts can also provide cognitive constructs that serve educators in their deeper understanding of the need for ecological innovation, in their communication surrounding their school's readiness to make changes to support ecological innovation, and as concepts to pass on to their students to equip students to approach ecological problems with these constructs as part of their cognitive tool set.

Kay's (2010) framework for 21st Century learning to prepare students to succeed in stewarding the world they are inheriting was included. The literature review followed the work of Westheimer and Kahne (2004), Kahne and Westheimer (2006), and Westheimer (2015) through their framework for civic education in a democratic society. This led to a review of Levinson's (2012) examination of schools' use of SAAs as they relate to education for democracy.

Next, the review explored literature from different educators who proposed strategies for practically supporting students' creativity (G. W. Johnson, 2014; Kettler & Sanguras, 2014; Piirto, 2014). The literature review summarized Pink's (2009) 10 suggestions for schools based upon his recapitulation of Deci and Ryan's (1985) self-determination theory—that humans have three motivating drives: the drives for autonomy, mastery, and purpose. The final subsection explored the intersection of innovation and leadership. Isaksen and Akkermans (2011) studied how leadership in organizations can facilitate a creative atmosphere, which can serve as a lever for innovation. Their findings, discussed more thoroughly in Chapter 2, suggested that a leader who appreciates creativity will foster an ambiance that nurtures innovation.

Study Design

Research Design

A multiple case study method was used to gather information from four eco-innovators (three cases) and their auxiliary participants, including perspective holders such as their mothers, teachers, and mentors. Lawrence-Lightfoot and Davis's (1997) frame of portraiture influenced the inquiry and narrative structure for this multiple case study research, to achieve "a narrative that is at once complex, provocative, and inviting, that attempts to be holistic, revealing the dynamic interaction of values, personality, structure, and history" (p. 11). With this influence, the cases in the current study were documented with respect to context, because the only way for a portraitist "to interpret people's actions, perspectives, and talk is to see them in context" (p. 11).

As a multiple case study, this design required me to select more than one case to investigate the specific phenomenon of interest (Creswell, 2013; Zucker, 2009): what went into the lives of these eco-innovators that influenced them to become eco-innovators. According to Creswell (2013), the case study method is an effective approach for situations in which the researcher "has clearly identifiable cases with boundaries and seeks to provide an in-depth understanding of the cases" (p. 100).

In this study, the phenomenon of interest inherently required an in-depth understanding of the ecological innovators' lives leading up to the experience of innovating. Given this necessary understanding of their life stories, I used the case study method, "a robust research method" for situations in which "holistic, in-depth investigation is required" (Zainal, 2007, p. 1). To honor the authenticity of the participants' stories, I approached the work as one informed by the frame of portraiture, because it focuses on finding "the central story" achieved through "careful, systematic, and detailed description developed through watching, listening to, and interacting with the actors over a sustained period of time, the tracing and interpretation of emergent themes, and the piecing together of these themes into an aesthetic whole" (Lawrence-Lightfoot & Davis, 1997, p. 12).

For this study, it was predicted and found to be true that the eco-innovators did not have complete knowledge of the factors and conditions that went into their development; therefore, this inquiry used the case study method to gather information from the eco-innovators and from the people who knew them best in terms of their development and eco-innovation, such as their parents, mentors, and teachers who have nurtured their development as contributing members of society.

Data collection tools included an interview protocol designed to gain multiple perspectives (Appendix A), an initial questionnaire (Appendix B), recording devices, illustrations and notes generated during interviews or shared with the researcher after the interview, written communications between the participants and the researcher, supplemental artifacts such as content generated by or about the participant found on-line or in other published forms of media, and other artifacts as described in the Data and Tools section.

Participants

In seeking willing participants who met the criteria, I actively attempted to recruit participants through academia, nonprofit organizations, media searches, and social network connections. Outreach included contacting North American nonprofit organizations and university professors, especially those in the ecology or innovation fields (e.g., professors of environmental engineering), to ask for recommendations for potential participants. To network and meet ecological innovators, I attended a conference geared towards innovation; the Resnick Institute’s Young Investigator’s Symposium focused on innovation and sustainability at the California Institute of Technology; and a community lecture by an environmentalist university professor who spoke on a related subject, in hopes of finding connections at those events. I also conducted content searches on the Internet, particularly TED Talks and similar media that showcased outlier examples of ecological innovators similar to Boyan Slat, who gave a TED Talk about cleaning the ocean and then started the Ocean Cleanup Project. I also created a recruitment website and posted a referral message on both Twitter and Facebook that guided people to the recruitment website: https://eco-innovator.weebly.com.

This study combined the selection criteria with the snowball, or chain, sampling method. Being an ecological innovator was the essential criterion for participation eligibility. Other criteria for subjects to serve as a case in this study were twofold. First, the eco-innovators must have engineered, constructed, or developed a process that directly ameliorates or mitigates anthropogenic harmful effects on the planet or the life it sustains. Second, the innovators must have started making their first ecological innovations before the age of 30 years.

The chain sampling method involved asking each participating ecological innovator for leads to other ecological innovators, which proved helpful in finding other criteria-meeting participants (Creswell, 2013). This sampling method brought in five potential participants, and later were whittled down to the four primary participants who make up the three cases for this study. Because this study was open to eco-innovators from all over the world, the primary participants were: a middle-school girl from the United States, an Israeli man in his 50s who started innovating for the environment when he was in high school, and a team comprised of a Palestinian man and an Israeli woman, both in their 20s.

If participants had given a TED talk on their eco-innovation or the news or other media had covered their innovation, then they would be considered an extreme exemplar of the criteria (Creswell, 2013). Given that delineation, three of the four (all adult) primary participants were extreme exemplars of the criteria. Each eco-innovator designed something to ameliorate or mitigate environmental problems. The participants' innovations were at different levels of ideation or implementation—ranging from a science-project to international implementation.

The data acquired for each of the three cases included interviews with the primary participants, additional perspective interviews, follow-up communications, supplemental data such as a speech given by the eco-innovator, articles written about the eco-innovators, and other informational documents and artifacts such as innovation program descriptions.

The auxiliary participants who provided vital perspective on the eco-innovators were parents, mentors, teachers, and innovation partners. The primary participants suggested these auxiliary participants as significant contributors to their development as eco-innovators. These auxiliary participants were interviewed to glean their perspectives and further information about the primary participant.

Each participant and auxiliary interviewee received a thank-you email, along with an option to choose either a $25 gift card or a $25 donation in their name to a charity of their choosing. Additionally, each participant received an entry into a random drawing for a $100 gift card that was conducted and delivered at the conclusion of the data collection.

Participant Confidentiality

For each primary and auxiliary participant in this study, I attained expressed and written consent (Appendix C; Creswell, 2013). For the participant under 18 years old, I attained expressed and written consent from a parent (Appendix D), as well as from the primary participant. To maintain confidentiality and anonymity for primary and auxiliary participants, I changed their names, specific locations, and other identifying information. This introduced a small but addressable issue, in that some participants would have preferred for me to use their real names because they could benefit from the recognition or additional publicity for their work. I was clear from the initial communication that even if they wished it to be otherwise, all identifying details and locations would be protected for the purposes of this doctoral research. The participants understood and agreed to these terms. To honor that anonymity, I described some details about the innovations themselves only vaguely in this dissertation. To the extent possible, the sample included participants who represented the genders evenly: two females, two males; came from more than one ethnicity: one Asian-Caucasian American, one American Israeli, one Israeli, and one Palestinian; and whose innovations addressed a variety of environmental issues, including sustainability-oriented architectural innovation, solar-power innovation, and water innovation.

Setting

I interviewed each primary and auxiliary participant in a safe, comfortable setting suggested by the interviewee. Because these interviews were audio recorded, I suggested to the participants that the setting needed to be quiet so that the audio would be free of background noise. The settings included a hospital room where the adolescent eco-innovator’s mother was staying for extended antepartum bed rest, a café, the outdoor seating area at the primary participant’s innovation lab, two public libraries, a quiet indoor seating area in the vestibule of a university museum, and home living rooms. For three auxiliary participants at distant locations, phone interviews were used. Drawing implements, such as paper, colored pencils, and a mini white board with markers, were provided as tools for the participants’ use during the interviews. I conducted supplemental observations of the ecological innovators in different settings, including an informational meeting about an ecological innovation company at a poolside wine-and-cheese gathering, at a Panera Bread restaurant while the primary participant explained the innovation to a potential investor, and at an innovation lab.

Data and Tools

Data were collected using an interview protocol (Appendix A) and audio recorded (Chapter 3, Method, provides technical details). Additional data from the interviews, including illustrations created by the primary participants and observational notes I generated, were collected. Supplemental materials, such as internet videos featuring the participants, published materials about the participants including a book and newspaper articles, and related significant content such as webpages that described the innovation program or a camp a participant attended, were also used. Based on the new information, I conducted supplemental literature research that illuminated the primary participants' contexts. With the permission of all parties related to the communication, follow-up correspondence such as emails and phone calls that provided further details about the eco-innovator were also used (Creswell, 2013).

When interviewing the participants, all efforts were made to make the participant as comfortable as possible. The interviews started with a reiteration of the participant's right to skip any question or quit the interview at any time, and then I invited the participant to interview me for 10 minutes to let the participant learn more about me, to open an authentic conversation, and to reduce any sense of power differential. For the primary participants, I spoke the interview questions in the second person ("you") and aimed at opening their stories. When interviewing auxiliary participants, the questions were aimed clearly at learning more about the primary participant and the relationship of that auxiliary participant with the associated primary participant. Another tool for this study was the use of drawing materials during the interview so that the interviewees had the capability to draw their ideas for ease of communication. Interviewees were invited, but not required, to use the drawing materials. A digital camera was used to take digital photos of the participant's drawings. In one case, the participant sent digital copies of his initial innovation sketches. All data collected were stored and backed up with secure password protected technology. Each case had its own protected file for all its related data, which consisted of primary and accompanying auxiliary participant's audio interviews, diagrams, illustrations, and notes generated during interviews, surveys, observation notes, and any other supplemental materials (see Chapter 3 and Appendix E for more details).

Data Analysis

The eight-step data analysis used for this study is explained in Chapter 3. The data analysis process evolved over the course of the study. Because this is a multiple case study with three distinct cases to analyze as individual entities and as part of a whole, Stake's (2006) *quintain* concept was used to carry out the analysis. A quintain is "an object or phenomenon or condition to be studied. . . . In multiple case study, it is the target collection" (p. 6). For this dissertation, the phenomenon of the experiences, factors, and conditions that contributed to the participants becoming eco-innovators was the quintain. As such, this study was comprised of one quintain made up of three cases of eco-innovators, including two individuals and one team of two. This method let me seek targeted understanding from the whole of the cases while allowing the uniqueness and complexities of each individual case to inform the study. The balance of analysis between individual cases and the whole led to a dual analysis stream. Additionally, I used NVivo12 for Mac™ software (NVivo) to code and analyze the data and the case-writing analysis method to theme the data. By conveying the analysis process in eight steps, I explicated this emergent complex process. The three written cases, along with their emerged themes and the quintain analysis, appear in Chapter 4.

Chapter Outline

This dissertation comprises five chapters to convey the complete research study. Chapter 1 introduced the study and provided an overview of the entire dissertation. Chapter 2, Literature Review, grounded the study by connecting to its theoretical framework and provided a comprehensive review of the bodies of literature foundational for this inquiry. Chapter 3, Method, specified the research design and explained the research methods—including the researcher's role, participant recruitment, instrumentation development, and data collection and analysis methods. Chapter 4, Results: Cases, Quintain, and Findings, presented the data and analysis through three written case studies, their themes, and the cross-case quintain analysis. In closing, Chapter 5, Discussion, summarized the study, discussed the findings and implications, proposed areas for future research, and shared my final reflections.

CHAPTER 2

Literature Review

Introduction

Children alive today have grown up with unprecedented access to concerning information about the changing environment. They hear adult discussions, in which the adults wonder aloud about the reasons for unexpected changes in the weather as they, too, experience dramatic weather events and encounter headlines about the dangers facing the world. Noted ecological educator David Orr (1992) advocated for environmental improvements but also alerted innovators and activists to be mindful of how many intractable global issues people created trying to contribute something good or make something better. To head towards a sustainable planet, one in which humans do not further harm Earth but rather achieve a symbiotic balance with the planet, Orr challenged his readers to "think about the qualities people will need to build and maintain a durable civilization" (p. 181). Orr claimed the difference between a catastrophic dystopian future and a peaceable sustainable world is predicated upon the fortitude and public influence of people of a certain kind of virtue: "people motivated by a sense that their well-being is linked to that of others and to other life-forms" (p. 182).

One display of this type of virtue appears in profiles of *ecological innovators*, a term employed throughout this dissertation to describe people who have created a device or mechanism to address an ecologically related problem. This chapter includes brief accounts, based on media reports, of three youths who are exemplary illustrations of ecological innovators. To discern and glean a deeper understanding of key factors in their life experiences that may have contributed to their success as ecological innovators, this chapter took the factors evident in their stories (available through news articles and other media such as their TED talks) and looked to research literature to further explore those aspects of life experience from a generalized or theoretical perspective to gain a deeper understanding of those factors. Given Orr's (1992) diametrically opposed trajectories for humanity—either a dystopian wasteland or a sustainably maintained biome—how have individuals identified as ecological innovators developed into people who achieve the latter? This question drove the forthcoming inquiry.

This chapter first looks to understand the current context in which youth are maturing and how the unique timing of their lives might play a role in their becoming ecological innovators. Following this contextualization, this chapter introduces accounts of three young people who have developed ecologically minded environmental solutions as exemplars of contemporary ecological innovators. Analyzing the three exemplar cases led to the following seven topics for the literature review because they appeared in the exemplar eco-innovators' lives and therefore may potentially support young people in becoming ecological innovators: nurturing excellence, motivation, ecological education, creativity, the maker movement, mentoring, and educational leadership.

Understanding Context

The context of one's birth plays a role in achievement in a particular field, as well as the knowledge and tools to which one has access. Gladwell (2008), in his book, *Outliers*, explored people who achieved extraordinary success in a field. Gladwell defined *outlier* as a person who achieves demonstrably above and beyond the norm in their field. Gladwell connected the phenomena of outliers experiencing extraordinary success to having received benefits created by the place and time of the outlier's birth.

Gladwell illustrated this point in a multitude of ways, including an exploration of the birth months of elite athletes, the birth years of the wealthiest people of all time, and the birth dates of present-day personal computing giants Bill Gates, Steve Jobs, and their contemporaries. For athletes, the month of birth strongly correlated to the level of expertise an athlete attains due to the league enrollment cut-off dates. The oldest among entry-level players performed best because they were the most developmentally mature. This developmental advantage translated to greater skill, which yielded more attention and more promotions, which led to opportunities for advancement to elite status. In terms of the world's wealthiest people of all time, 20% of the top 75 wealthiest individuals of all time were born in the United States between 1831 and 1840. That decade was perfect to be of an age to grasp opportunities the emergence of the railroad, industrial manufacturing, and New York's Wall Street created. Gladwell asserted that for magnates such as John D. Rockefeller and Andrew Carnegie, there was a "narrow nine-year window that was just perfect for seeing the potential that the future held" (p. 62). Prior to that window, people's mental constructs had been formed in the pre-Civil War era, and those born after were too young to seize the fortuitous moment. Similarly, timing was just right for Bill Gates of Microsoft, Steve Jobs of Apple, Bill Joy of Sun Microsystems, and Eric Schmidt of Google; all were around 21 years old when the first personal computer was made available to the public in 1975. Computer enthusiasts older than 21 in 1975 likely had already settled into careers at IBM, so they would not have jumped at the chance to take an entrepreneurial leap into personal computing. Those younger than 20 in 1975 would have still been in school and thus mismatched for the opportunity. The computer enthusiasts who were 20 and 21 when the personal computer came out in

January of 1975 were fit to embrace the personal computer and start fueling the computer revolution, which is why Bill Gates and Steve Jobs are household names to this day (Gladwell, 2008).

With respect to Gladwell's (2008) analysis of how the relationship between birthdates and contextual events primes people for success in a particular field, it made sense to explore our global context—noting current world events—to consider how the present-day environmental context might influence up-and-coming ecological innovators. The following two subsections explore two contextual aspects in young people's lives.

Today's Context: Climate Change

Many of today's youth are growing up in a context where the earth's climatic conditions and the importance of taking action to stop global warming are more than just a 1-day splash on the news cycle or a single unit of science curriculum in school, but part of the zeitgeist. These young people are growing up in a world with repeated references to genuine systemic ecological problems. The gyres of our world's oceans are swirling with 165 million tons of plastic litter that simultaneously starve and poison ocean life who mistake the plastic for food (Cirino, 2017). Giant portions of Australia's Great Barrier Reef, which has supported an interconnected system of ocean and human life, died due to the rise in ocean temperature (Cave & Gillis, 2017). Daily, people are reminded that climate change is intensifying and threatening to unleash a cascade of deleterious consequences. However, one truth about humanity is our ability to adapt—to create solutions to our problems—what former President Barack Obama (2009) termed "unparalleled potential."

Today's Context: The Maker Movement and Makerspaces

Another contextual feature of the world's societal landscape for today's youth is that increasingly greater numbers of youth have access to makerspaces. Stager (2016) noted that makerspaces are evidence of a "trend that is pushing its way into more schools" (p. 1). Stager explained that the educational and societal "shift to 'making' represents the perfect storm of new technological materials, expanded opportunities, learning through firsthand experience and the basic human impulse to create" (pp. 1–2). Stager described the potential for makerspaces "to make classrooms more child-centered: relevant and more sensitive to each child's remarkable capacity for intensity" (p. 2), and suggested the thrust behind the proliferation of makerspaces is that "making is predicated on the desire that we all have to exert agency over our lives, to solve our own problems" (p. 2). Democratizing experiential learning takes place in makerspaces where participants can engage in authentic real-world problem solving because they are provided "access to a vast range of experience and expertise" (p. 2). Schools, libraries, museums, and community centers are adding makerspaces to their offerings because makerspaces nurture human potential by bringing together young people and the tools, training, inspiration, and workshop-space they need to innovate. Makerspaces also foster open exploration where people can create anything from their imaginations ranging from art and costumes to innovative solutions to address the problems they see in the world.

Tim Bajarin (2014), a chronicler of Silicon Valley computer history, claimed the maker movement "has the potential to turn more and more people into makers instead of just consumers, and [he knows] from history that when you give makers the right tools and inspiration, they have the potential to change the world" (para. 5). Maker Faires, giant festival-like family-friendly expos marketed as “the greatest show and tell on earth” (para. 7), gather participants to share their creations, learn from one another, and showcase the latest fabrication gadgets, such as 3D printers, laser cutters, and computerized numerical control milling machines. These Maker Faires occur throughout the year, annually on all six populated continents. In 2016, there were 191 official Maker Faires in 38 countries with 1,404,000 attendees (Maker Media, Inc., 2017).

Morris (2015), a writer for *Electronic Engineering Journal*, rated young people’s excitement about engineering as the best of the top five things about the World Maker Faire 2015 in Queens, New York. As learning environments, the Maker Faires created a space in which children engage hands-on with engineering in an encouraging and supportive atmosphere. Loaded with eye-catching inspirational do-it-yourself projects, Maker Faires motivated children and people of all ages to pursue every bit of information and knowledge to construct their version of whatever amazing project grasped their attention or fueled their imagination. After observing children engage in the Maker Faire, Morris came away inspired, claiming, “Some of these kids will engineer the next big paradigm shift. Others will create the next ground-breaking fusion of art and technology. These young minds will change or save the world” (para. 13). Maker Faires have become a globe-sweeping trend with the potential to give rise to ecological innovation.

The Bright Spots: Ecological Innovators

Pascale et al. (2010) coined the term “positive deviants” to describe “outliers who succeed against all odds” (p. 3). Positive deviants, rebranded as “bright spots” by Heath and Heath (2010), are people who exhibit the best practices for a given issue within a population when that population at large is in dire need of those best practices. Positive deviance, as a concept, suggests that the solution to a problem already exists within the context but has yet to be implemented on a broad scale because the innovator has yet to connect to the social or political forces that would enable widespread implementation. Looking for outlier eco-innovators who can succeed against all odds so we can learn from their experiences how to cultivate more eco-innovators, is a strategy for increasing the probability of raising young people who are equipped to innovate ecological solutions to the world's environmental problems.

Three Accounts of Young Ecological Innovators in the Mainstream Media

The following three accounts of ecological innovators stood out as notable because they were covered by the news and their work inspired continuing work in the fields of their individual innovations. The first exemplar is Boyan Slat, a Dutch man, who in his 20s developed a method to clean plastic from the ocean by iterating a prototype of a science project he had created in his teens (Venema, 2014). The second exemplar is Chaitanya Karamchedu, an Oregon teenager who determined how to turn salt water into potable water cheaply and easily by taking a perspective no known scientist had taken before (Bolduc, 2017). Finally, the third exemplar is Aidan Dwyer (2011), who created solar panels inspired by an oak tree's natural leaf arrangement which follows the Fibonacci sequence.

Boyan Slat

Boyan Slat grew up in the Netherlands. According to Venema (2014), when Boyan was 16 years old and snorkeling on vacation in Greece, he was disturbed that he saw more plastic bags than ocean life; from that moment, he became obsessed with ridding the ocean of plastic. He also had a formative life experience at 13, in which he corralled people to help him break the Guinness Book of World Records for the greatest number of rockets shot off at once. Slat credited that experience with giving him the confidence and skills to gather people and sponsors to help him achieve big, unusual goals. Slat was so committed to creating his ocean cleaning device that he dropped out of university to dedicate his time to the project. He experienced a great deal of rejection from potential sponsors and partners. Despite the discouraging lack of response, Slat stuck with it. Several months after he gave his 2012 TEDxDelft Talk entitled, “How the Oceans Can Clean Themselves,” his video went viral, and his idea gained traction.

Slat founded The Ocean Cleanup Foundation and, in June 2016, launched the first prototype ocean cleaner in the North Sea (Chow, 2016). Slat spoke of the launch as a test and, on October 15, 2016, reported on his Twitter feed that he was adjusting the boom design based on his first prototype’s performance. By May 2017, Slat (2017a) announced that he and his team of engineers had iterated the design to the point that they would launch their ocean plastic cleaning devices into the gyre of the Pacific Ocean within a year’s time. During that announcement, Slat described the parallel processes of researching the ocean plastic problem and iterating his innovation. At this grand event, Slat unveiled his ocean cleaning innovation, a series of passively floating catchment systems that, by virtue of their anchor design and structure, drift into the areas of greatest plastic concentration and allow the ocean current to push the plastic into the cleanup devices.

In commenting on the state of the world for *The Economist*, Slat (2017b) explained his logic for applying modern technological advances to solve environmental problems:

> Thanks to technology, we have made remarkable progress in the past few decades in many areas, including health, education, and material prosperity. Ironically, it is the side-effects of these advances that are now creating the largest challenges of our time, specifically when it comes to the degradation of the environment. So why not also use the power of technology to take on these challenges and restore the natural balance? (para. 2)

Chaitanya Karamchedu

When Chaitanya Karamchedu (Chai) was a high school senior, the statistic that one in eight people on the planet did not have access to clean water troubled him. Chai thought about the vast quantity of water potentially available in the earth's oceans (Bolduc, 2017). According to Bolduc (2017), who reported on Chai's project, previous scientific study and efforts in desalination focused on how water was unavailable, which led them to focus all desalination solutions on breaking the chemical bond between water and salt. Chai looked at the water availability problem differently, noting that 90% of ocean water was not bonded with salt (Bolduc, 2017; Karamchedu, 2016). By choosing to ignore the 10% of salt-bonded water, Chai focused on how to separate the 90% unbonded water from the rest of the matter in the ocean water. Using "superabsorbent hydrophilic polymers," Chai was able to separate unbonded water from the saline water, and it did not need an external energy source (Karamchedu, 2016). This process held promise for being both cost effective and available to the common person, thus yielding real hope, especially in coastal regions, for increased water accessibility. This young innovator piqued the interest of several scientific institutions because his simple solution had potential to transform water delivery for millions of underhydrated people. Chai's tinkering in the chemistry lab may lead to not only saving lives, but also to easing international political tensions that persist over access to clean water (Bolduc, 2017; Karamchedu, 2016).

Aidan Dwyer

Aidan Dwyer observed the pattern of leaves as solar collectors while on a walk in the Catskills with his parents (Washor & Mojkowski, 2013, pp. 198–199, 204). By arranging solar panels in a Fibonacci sequence, he discovered what he believed to be a 20% efficiency improvement of solar energy collection (Dwyer, 2011; Washor & Mojkowski, p. 198). The larger scientific community determined Dwyer's published measurements were not accurate, which rendered his research invalid. Nonetheless, because Dwyer was self-directed in his inquiry, and because he achieved notoriety, that experience drove him to study the problem even more deeply, to continue to tinker with and improve upon his design, and to commit to improving his solar panel design (Dwyer, 2014). Following his initial innovation debut, Dwyer made numerous presentations and met President Obama when he participated in the presidential science fair. Dwyer's father and grandfather encouraged and mentored him along the way. His grandfather coached him through the building process, suggesting materials and spending time with him throughout the process. As a young innovator, Dwyer (2014, min. 4:05) stated, "When I'm older, I definitely want to do something in innovation and science. I definitely think kids should be more involved in science, because what we do now is really going to affect what we do in the future, and we have the power to change the world." In one of his many speeches, Dwyer advised people to "be curious," to "look at problems from a different angle," and to "not be judgmental" of innovations or innovators, especially if they come from someone young (min. 14:00–15:38).

Notable and Common Factors Among These Innovators

Boyan Slat and Aidan Dwyer each spoke publicly in an effort to broadcast their ideas to a wider public, which opened doors of opportunity for them. In Dwyer's account, the support he received from his parents and his grandfather was evidently significant, although Slat's account never mentioned his parents. Slat was schooled in the Netherlands; both Karamchedu and Dwyer were educated in the United States. All three descriptions mentioned a place and materials to physically work out their project, either in a workshop or science lab. As the information on each of these young innovators is limited by what has been made available online, without further interviewing these exemplars, there is still much to be revealed about the precursory factors that may have contributed to them becoming ecological innovators. By parsing the available information, it was clear that all these young eco-innovators had a drive to contribute something novel to the world. In each of these accounts, the eco-innovators attributed their drive to a seminal moment of motivation that deepened or kindled the innovator's concern for humanity and other life on this earth. In Slat's account, his moment of experiencing more plastic than fish on his vacation in Greece launched an obsession that led to him to found an organization to clean all the world's oceans. For Karamchedu, concern about the dearth of fresh drinking water for the poor led him to think about how to desalinate ocean water cheaply and easily for drinking (Bolduc, 2017). For Dwyer, a walk in the woods with his father, where he noticed how an oak tree's leaves spread in a Fibonacci sequence, led to his experimentation with his solar capture array design. In considering the factors that contributed to these young people making a difference, they all seemed to have a seminal moment of motivation and the curiosity and support to move forward with investigating their ideas.

Wagner (2012), in *Creating Innovators,* argued that potential young innovators need to have a context that nurtures innovation and the acquisition of expertise. In relation to the exemplars connecting to expertise in their ecological fields, Slat, Karamchedu, and Dwyer did not necessarily start with expertise but were able to access it and develop it along the way. In Dwyer's account, his grandfather had the skill and materials to help Aidan construct his first prototype. Karamchedu had a science teacher, an assigned science project, and access to materials through his high school lab. Slat leveraged the power of publicity to gain access to expertise. Through his TED talk, he connected with several professors and industry experts who, over the course of several months, helped him produce "a list of 50 questions that should be answered in order to confirm feasibility" (Singh, 2014, para. 2).

Each of these innovators was nurtured along the way—they each had access to expertise, workshop space, tools, and materials to work with as part of their process. This validated Wagner's (2012) claim that students need access to expertise as well as an innovation-nurturing environment—with usable tools and materials being part of that nurturing context.

Given the value of these *bright spot* young innovators' contributions, what can we learn from their experiences that may contribute to the prevalence of ecological innovation? Table 1 organizes the common factors among the ecological innovators, then uses those common threads to direct the research topics for the subsequent literature review.

Table 1. *Common Factors Among the "Bright Spot" Ecological Innovators*

Exemplar	Access to expertise/excellence nurtured/mentor	Iterated or prototyped innovation?	Seminal moment or drive	Ecological concern/interest
Boyan Slat	TED Talk connections—several professorial and professional mentors	Yes	Snorkeling in Greece, saw more plastic than fish	Plastic in the oceans/cleaning the oceans
Aidan Dwyer	Father and very strong invested support from grandfather	Yes	Walking in woods, thought of Fibonacci sequence of oak tree leaves	Solar energy—interest in trees and Fibonacci sequence
Chaitanya Karamchedu	Science teacher	Likely—article states "he experimented"	Seeing/knowing people needed clean water	Clean water for people to drink/desalination
Topics yielded for this literature review	Nurturing excellence Mentoring	Maker movement Creativity	Ecological education Motivation	Ecological education

The fact that each exemplar achieved moderate to high recognition and honor with his work suggested a commitment to excellence, so this chapter will look to the literature on nurturing excellence. Table 1 shows that seminal moments were key motivating experiences for these exemplar eco-innovators; hence, it suggests that providing opportunities for seminal moments matters. For both Slat and Dwyer, spending time in nature catalyzed the seminal moment that launched the motivation for the ecological innovation. That concept led me to research the literature on motivation. Exposure to and understanding of the natural world seemed to be a key element for each of these young people, which pointed to the body of literature on ecological education. It was clear that access to expertise, materials, support, and time to iterate also played a part in each of their innovative lives. To further research that aspect, this chapter delves into literature on creativity and into reports of the maker movement and its corresponding makerspaces because they aimed to provide a culture and context for nurturing young innovators. As these young exemplars' lives demonstrated, mentors who invested in the young innovator's future can be a family member, friend, teacher, club leader, or even a TED talk listener—anyone who invested in the innovator's understanding and development. To understand mentoring further, this chapter also explores literature on the topic of mentoring. The following sections review literature on the topics culled from the exemplars' stories: nurturing excellence, motivation, ecological education, creativity, the maker movement, and mentoring. As this study has an overarching aim to influence education and contribute to the literature within educational leadership, this literature review culminates with a section that explores relevant literature from the domain of educational leadership.

Nurturing Excellence

This examination of nurturing excellence was based upon scholarship contributed by the notable educational psychologist Benjamin Bloom (1985), who studied the development of talent in young people. This section also contains analysis and reporting on that study by his teammates, Sloane (1985) and Sosniak (1985).

Bloom (1985) studied people who achieved the top of their field, such as competing in the Olympics or attaining a comparable demonstration of excellence. For these "luminaries," his study yielded evidence that "no matter what the initial characteristics (or gifts) of the individuals, unless there is a long and intensive process of encouragement, nurturance, education, and training, the individuals will not attain extreme levels of capability in [their] particular fields" (p. 3). In studying the developmental process of extreme talent, Bloom limited the study to Americans and investigated the role of parents, teachers, coaches, and mentors who invested in the talented person's development. Bloom and his colleagues initiated this project with the belief that developing talent early not only gives the person a sense of fulfillment, but also a means to contribute greatly to society. Through pilot studies, Bloom found that the only way to find out what formative experiences contributed to luminaries was to interview them after they had achieved greatness in their field.

Bloom (1985) studied each individual's special area of prowess in their early developmental years and the role of parental guidance and talent support throughout the talented person's coming of age. Bloom investigated (a) the type and quality of instruction the luminary received throughout their developmental stages, (b) the origins and forms of motivation and reinforcing benefits that encouraged the individual throughout their childhood and young adulthood, (c) the number of hours invested in talent progression over the course of maturation, (d) how the talented participants formed habits that cyclically reinforced further enrichment of the habit, and (e) any unpredicted factors the individuals mentioned as contributing to their expertise. Through their research, Bloom and his colleagues found that the more a person understood the time required to learn something to the point of mastery, the greater the chance that person would hone his or her ability to create the conditions to master that subject (Sosniak, 1985).

In Bloom's talent development study, the team found that among the exemplars of extreme talent within a given field (e.g., piano, neurology, mathematics), luminaries showed a similar pathway towards expertise (Sosniak, 1985). Initially, they engaged with their field freely and playfully, often with encouragement and "immediate rewards" (p. 437). This period of exploration was followed by a stage of marked seriousness in which the talented individuals focused on improvement and deeper understanding of their craft. After considerable commitment to improvement, the luminaries experienced a sense of deeper meaning in their striving, which ultimately led to imbuing their study with their own individuality, which led to their pinnacle achievement within their field.

Bloom's (1985) study investigated exemplary individuals' parental supports and home life. Running themes were found among all the parents, such as providing "resources, encouragement, and support, models, and instructional opportunities" for their children (Sloane, 1985, p. 467). For different realms of expertise, parents provided domain-specific supports. For instance, renowned sculptors' parents converted areas of the home to serve as studio space, whereas Olympic swimmers' and tennis players' parents revolved their entire family lives, including vacations, around the sports schedule and competitions. Overall, the parents allowed their family life to revolve around the children and their interests, rearranging their own lives and interests to invest in their child's development as they emphasized their child's achievement in the field. Parents in Bloom's study reported they made those sacrifices because of "the pleasure and enjoyment they derived from watching the child develop in the talent field," or felt "a sense of responsibility to develop the child's talent," or "listened to teachers, relatives, or friends who were impressed with the child's abilities and . . . urged the parents to provide even more opportunities for the child" (p. 467). A small number of the parents in the study were also well versed in the field of expertise, so they knew first-hand the rigor required for their children to excel. The parents in Bloom's study spent a great deal of time with their children, cultivating close relationships through the field of extreme talent. They also made sure to involve their children in supplemental activities, such as clubs, lessons, or teams, but they did not put as much emphasis on those as on the field of major talent. Those parents, as well as the researchers, concluded that the parents' involvement in the luminaries' learning played a crucial role and "contributed significantly to his or her achievement in the field" (p. 476). This involvement, characterized as "support and encouragement took many forms" (p. 468), including supplying materials, creating space for the children to do their crafts, managing the activity's scheduling requirements, making sure the children had good teachers or coaches, and sacrificing other priorities for the sake of the pursued field of talent.

Bloom (1985) noted that each field of talent required different specific qualities or skills to be learned at an early age. For instance, to become a great swimmer or tennis player, learning the physical techniques early in development helped; to become a great musician, sensitivity to sound and pitch discrimination were vital; and the level of academic aptitude and prior academic achievement were essential for excellence in mathematics and neurology because they were required for the academic pathway towards the necessary PhD. Besides the field-specific traits needed for greatness, Bloom found general qualities among the top achievers regardless of discipline. The common characteristics among these luminaries were (a) "strong interest and emotional commitment" to one's field, (b) ambition to attain the zenith of the field, and

(c) willingness to invest heavily in terms of time and labor to achieve the highest level in the field (pp. 544–547). Bloom's finding that different fields required different specific qualities for success brought to question what specific qualities would be pertinent to the field of ecological innovation.

To contribute a worthy ecological innovation, it made sense that, foundationally, the person would need a solid understanding of ecology as well as innovation; however, equally important was the person's drive to make an ecological innovation in the first place. Bloom (1985) found that people who made it to the top of their field maintained their impassioned focus to their field and their desire to reach high levels of excellence in their discipline, as they invested their time and energy to achieve the highest level in their field. To better understand the kind of drive that motivates someone to achieve the pinnacle of a field, such as by innovating a world-saving device or system, the next section explores the literature on motivation that fundamentally animates innovation. To that end, this next section explores these formative motivational drives that lead to lasting change.

Motivation

A review of the literature of positive psychology, also referred to as the psychology of human strengths, indicated that the category of motivational human strengths encompasses the concepts of self-efficacy, self-determination, intrinsic motivation, and self-realization (Fernández-Ballesteros, 2003). The following subsections explore seminal works in the field of educational research, theory, and philosophy for their foundational contributions on those topics, as well as look at the connection between motivation and creativity. The first subsection explores Albert Bandura's foundational work on self-efficacy. The second and third subsections look to the works of Edward L. Deci, Richard M. Ryan, and their colleagues to inform the summaries of self-determination and intrinsic motivation. The fourth subsection pulls from the foundational perspectives of John Dewey and Abraham Maslow to elucidate self-realization. The fifth provides a synopsis of Csikszentmihalyi's concept of *flow*, and the sixth draws the connection between motivation and creativity as researched by Nakamura and Csikszentmihalyi.

Self-Efficacy

Bandura (1977, 1982, 1997) contributed the self-efficacy theory to the field of educational psychology, with *self-efficacy* representing a person's sense of capability to perform the necessary tasks or behaviors to achieve a defined goal within a given domain. A person may have high self-efficacy within one domain, such as mathematics, but a low sense of self-efficacy in another, such as self-organization. Self-efficacy refers to people's certainty about their own ability to modulate their own effort, drive, intention, action, and social surroundings when focused on achieving a goal. These aspects of self-efficacy contribute to people's holistic life experiences in that they affect the type and intensity of the goals they target, the amount of energy they invest in attaining those goals, and the potential outcomes of their sustained efforts to achieve those goals (Bandura, 1977, 1982, 1997; Perry & Forsyth, 2018).

Bandura (1977) explained that when a task is easy, it reinforces a person's self-efficacy for that type of work; when a task is difficult, it does not harm a person's sense of self-efficacy as long as that person achieves the goal. Reflection on the task and the effort needed to achieve it can influence the sense of self-efficacy. If the task was accomplished easily, then a person's perception of their self-efficacy does not change; however, completing a challenge that required considerable effort raises his or her esteem of self-efficacy for that type of undertaking. Furthermore, a person who encountered obstacles along the way but still persevered and made progress, experiences a greater boost to self-efficacy than would a person who succeeded but experienced a plateau effect in the achievement. Along this line of facing obstacles to build a stronger sense of self-efficacy, in his later work, Bandura (1997) wrote:

> Motivation is perhaps best maintained by a strong sense of efficacy to withstand failure, coupled with some uncertainty that is ascribed to the challenge of the task rather than to fundamental doubts about one's abilities to put forth the effort needed to fulfill personal challenges. (p. 130)

In providing a thorough base of the reach of self-efficacy theory, Bandura (1977) provided guidelines to increase one's self-efficacy: set a goal, then arrange opportunities for self-directed advancement towards that goal. This builds the necessary skills and understanding to achieve the eventual goal. Bandura (1982) noted that, to keep self-motivation strong, it paid to set subgoals that build to the more distal desired future goals. The more immediate subgoals provide attainable incentives and orient a person towards action that prepares that person's self-efficacy. In facing global-scale environmental problems, one can grow weary or lose hope because the challenges can seem so dauntingly insurmountable. A strong sense of self-efficacy is essential to maintain steadfastness towards the goal. Bandura (1977) addressed this type of challenge as he referred to learned helplessness in relationship to his self-efficacy theory. When people lack the sense of self-efficacy to change a behavior or attain a goal, they can lose the motivation to keep trying.

Bandura (1997) suggested that to counter this type of efficacy-based futility requires competency development and “raised expectations of personal effectiveness” (p. 204). A second type of futility leads to giving up when people expect their efforts to have no impact or experience continual punishment for their attempts. Bandura suggested that remediating this type of perceived ineffectuality requires changing the environmental opportunities, so that the opportunities esteem the competencies people already have.

In his 1982 work, Bandura addressed dealing with one’s environment and suggested it is no easy task. It demands preparation and flexibility because working competently in ever-changing circumstances “requires orchestration and continuous improvisation of multiple subskills” (p. 122).

Self-Determination

Self-determination is the intentional choice to act, engage in, or perform a behavior purely out of one’s free will as opposed to doing something in response to someone else’s control or coercion, which could range from cheerful compliance to utter defiance (Deci, Vallerand, Pelletier, & Ryan, 1991). The key distinction between acting in a self-determined manner versus a controlled manner is the point of causation; in self-determination, the locus of causality comes from inside the self, but in the controlled situation, it comes from outside the self. For people to embrace self-determination, they must experience fulfillment in their need for autonomy.

Deci et al. (1991) suggested supports for self-determination for students and those in similar contexts: First, make it a habit to give students choice; second, try to eliminate (or at least minimize) controlling structures, controlling language, and rituals of control; third, practice acknowledging feelings; fourth, provide all necessary information for making decisions and for engaging in the task at hand. These four steps will support autonomy, a sense of competency, and relatedness in the classroom community. By impressing upon students that their autonomy is valued and worth cultivating, “we stand the greatest chance of bringing about the types of educational contexts that facilitate conceptual understanding, flexible problem solving, personal adjustment, and social responsibility” (p. 342).

Intrinsic Motivation

Deci and Ryan (1985) introduced self-determination theory to organize their findings from their study of motivation. Self-determination theory suggests that humans have innate psychological needs: a drive for competence, a need for autonomy, and a desire for relatedness (Deci & Ryan, 2000). Meeting these needs gives rise to intrinsic motivation and, reciprocally, intrinsic motivation is the expression of self-determination.

Ryan and Deci (2000) credited intrinsic motivation as an inherent evolutionary trait of humans because it is readily abundant in young children. Intrinsic motivation is comprised of the natural tendencies to learn, explore, find novelty, pursue challenges, and cultivate capacities. This innate active approach to life with curiosity and playfulness at the core leads to “assimilation, mastery, spontaneous interest, and exploration” (p. 70). People who are intrinsically motivated for a particular interest pursue it for the joy and gratification of engaging in the activity and do it with considerable intention and without any need for external reward (Deci et al., 1991).

Although intrinsic motivation comes naturally to humans, Ryan and Deci (2000) reported that it requires support and nurturance or it will languish. Through their research, Ryan and Deci found that supporting a person's autonomy and competence nurtured that person's intrinsic motivation; conversely, controlling a person's behavior weakened intrinsic motivation because it thwarted any sense of efficacy (p. 76). Similarly, praise given to students who were able to autonomously direct their own project increases intrinsic motivation and sense of competency, but praise given to students who were just doing what they were told to do could possibly result in hindered intrinsic motivation for that task (Deci et al., 1991).

Self-Realization

Foundational educational philosopher John Dewey (1902) argued that the aim of educational experience is self-realization more than mastering subject matter. He presented this argument in a pamphlet entitled "The Child and the Curriculum," which he published to advocate for the primacy of child development over the previously prioritized subject matter, as it was a topic of debate for him in his local schools. In this treatise, Dewey warned that when subject matter is taught without being experienced by the learner, "three typical evils result": (a) the material "is dead and barren" because it lacks any natural connection to the child; (b) "a lack of motivation" befalls the learner because there is no felt need for the content; and (c) the content gets watered down, thus losing the vital meaning of the content matter (pp. 13–34). Dewey (1893) had previously expounded philosophically upon the concept of realization in his work, "Self-Realization as the Moral Ideal." In that article, Dewey conveyed that self-realization is the act of realizing that one has a given capacity—for instance, artistic ability—and becoming conscious of that ability is part of who one is and what one can do. Dewey further postulated that engaging in an activity fully with all consciousness on the present moment is part of self-realization, as opposed to learning something for the sake of some future life or future purpose, which Dewey lamented had become much of the way of education. In response, Dewey admonished, “Cease conceiving of education as mere preparation for later life, and make of it the full meaning of the present life” (p. 660).

Self-realization is the precursor to self-actualization. Self-realization, as Dewey (1893) conveyed, means becoming aware of one’s capacities, which lays the foundation for self-actualization, or what Dewey referred to as the “ideal or infinite self” (p. 661). Maslow (1943) placed self-actualization at the apex of needs after more foundational needs are met. Maslow described his use of the term *self-actualization* as “the desire for self-fulfillment. . . . This tendency might be phrased as the desire to become more and more what one is, to become everything that one is capable of becoming” (p. 382). The need for self-actualization becomes pressing when all prior needs are satiated: the physiological needs, such as hunger and thirst, followed by the needs of safety, love, and self-esteem. These motivations, commonly known as Maslow’s hierarchy of needs, have been diagramed and adapted into myriad domains as a framework for understanding human motivation.

Logically, self-realization and self-actualization can indeed overlap, but it is more accurate to conceive of self-realization as the necessary foundation of understanding upon which to lay brick after brick of work to build up to self-actualization. To use a bright spot eco-innovator from present-day media as an example, Boyan Slat showed signs of self-realization when he designed his first ocean plastics-catchment system for a school project. That required him to conceive of himself as a person with the capacities to address the plight. Since then, with his serial speeches in public media forums, founding of the Ocean Cleanup Foundation, and launching of a prototype of his invention in the middle of the Pacific Gyre, he has persevered towards self-actualization—living up to the vision he cast of himself as a man who acts to clean the world's oceans of plastic. In 2014, the United Nations validated Slat's self-actualization, which Maslow (1962) estimated less than 1% of the adult populations achieves (p. 190). Slat became the youngest-ever person to be given the U.N.'s Champion of the Earth Award for his innovative ecological work (Pieters, 2014).

Flow

Csikszentmihalyi, Abuhamdeh, & Nakamura (2005) coined the term *flow* to describe what they observed in a series of studies they "initially called *autotelic activities;* that is, things people seem to do for the activity's own sake" (p. 600). In researching this over the decades, Csikszentmihalyi et al. found that the concept of flow emerged from the data collected from numerous study participants who employed the "metaphor of a current that carried them along effortlessly" to describe their subjective experiences of flow: enjoyment, "the merging of action and awareness, a sense of control, and an altered sense of time" (p. 600). The potent enjoyment that draws people back to flow overcomes the "psychic entropy" of life's worries because their focus on the activity at hand is fully encompassing. This immersive focus merges action and awareness, silencing self-consciousness and giving people the sense of being their actions and fully in the moment, fully in control, and so involved that awareness of time slips away.

Flow is positively associated with skill development and has positive implications for both personal growth and the evolution of human consciousness (Csikszentmihalyi, Abuhamdeh, & Nakamura, 2005). For a person to experience flow, certain conditions must be in place. First, the activity must have a “clear set of goals” not necessarily for the purposes of attainment, but to provide purpose and structure to the activity (p. 601). Second, the challenge must exist within the window of perceived ability to accomplish the challenge. If the challenge seems too easy, then the person becomes bored; if the challenge feels too daunting, then the person becomes anxious; but if the challenge appropriately matches the person’s sense of ability, then this prerequisite to experiencing flow is met. Third, inherent in the experience must be “clear and immediate feedback” that guides the person what to do next in the moment (p. 602). In concert, these three conditions allow a person to experience the intrinsically motivating state of flow. Csikszentmihalyi and his colleagues found that the “phenomenological experience of flow is a powerful motivating force” as well as “enjoyable and intrinsically rewarding” (pp. 601–602).

Motivation and Creativity

Nakamura and Csikszentmihalyi (2003) proposed the systems model of motivation for creativity. Within this model, the strengths-based perspective acknowledges both meaningful purpose and passion for the work as prime motivations for creativity. In describing the strength-based perspective, Nakamura and Csikszentmihalyi alluded to seminal experiences as motivating factors that drive the sense of meaningful purpose in one’s work: “A pressing existential problem encountered early in life (e.g., poverty, marginality, social injustice) inspires first a process of meaning construction, and then the channeling of energy into a sphere that is construed as addressing the problem" (p. 262). The strengths-based perspective allows people to credit their motivation to the act of overcoming—for instance, a person may experience a specific incident in in youth, such as a family member's infirmity, then from that circumstance become dedicated to solving that problem. Through this process, the person might discover that the work is enjoyable for its own sake.

Obviously, for eco-innovators, this touchstone experience is rooted in a profound understanding of the gap between humans' use of the world and the earth's natural state. Because ecological education is a fairly recent phenomenon, it is worth exploring its roots, philosophies, and pedagogical makeup to understand how it influenced this upcoming generation of ecological innovators. The next section seeks to do just that.

Ecological Education

Environmental education originated in the 1970s as a part of the emerging "global concern about environmental degradation" (Krasny & Monroe, 2016, p. 5). In a world where chicken nuggets come in the shape of happy face emojis; fruits and vegetables come in pre-processed, plastic sealed containers; the concept of play means engaging with a screen; and recess is 15 minutes of supervised outdoor play on asphalt with a metal and plastic climbing structure above shredded, partially synthetic rubber tires, many of our nation's children are growing up woefully disconnected from the living ecosystems of our planet. Louv (2009) surveyed our culture and named the collection of its symptoms that include childhood obesity, hyperactivity, and distractibility, "nature-deficit disorder" (p. 24). Spending time in nature provides exposure and helps students better understand and grow more curious about the natural ecosystem, which may lead to innovations such as Aidan Dwyer's solar tree. In addition, "researchers are assembling a growing body of evidence that strongly suggests the importance of nature to children's health and their ability to learn" (p. 25).

Although not intended as a medical term, Louv (2009) used *nature-deficit disorder* to describe "the growing gap between human beings and nature, with implications for health and well- being" (p. 26). Louv's suggestions for combatting nature deficit disorder targeted educators; he suggested they (a) educate themselves on the value of experiencing nature; (b) network with other teachers to support each other in this ecological endeavor; (c) teach each other; (d) "green the schoolyards," which involves transforming the school yard into a natural habitat for wildlife; (e) open nature preschools that place community and nature experience at the core of an environmental curriculum; (f) establish eco-clubs in schools that support students participating in ecological expeditions and service-learning; (g) "bring nature to the classroom," which could range from a seed exploration to having wildlife experts bring in sanctuary animals such as wild birds for an up-close experience; and (h) "create nature-based community classrooms," which would involve collaborating with other organizations in the community to bring "students to nature centers and parks" (pp. 27–28). Noting that educators cannot do all of this without a context of support, Louv also called on parents and communities to contribute to the effort to reintegrate our youth with nature by supporting legislation that fosters nature integration into education, becoming activists for this type of education, and initiating nature-oriented community gatherings such as outdoor clubs that focus on going on hikes as a community of parents and children (pp. 28–29).

Leading with Louv’s (2009) concept of nature-deficit disorder in their list of societal trends that contextualize environmental education, Krasny and Monroe (2016) listed five challenges to providing environmental education, including “concern about the psychological well-being of people with limited access to nature,” “urbanization,” “social stresses,” climate change stressors, and schools’ challenges in getting students interested in learning science (pp. 5–6). Even though those trends threaten environmental education, they also inspire innovation in environmental education, much of which comes from outside of schools. Community organizations already committed to ecological advocacy, such as the Audubon Society, nature preserves, museums, gardens, parks, and other nature-oriented nonprofits, actively seek to contribute positively to our youth’s reconnection with the natural world. In exploring the essentials of ecological education, the following sections review literature of ecological competence and ecological literacy, human interdependence and impact upon the Earth’s ecosystem, and systems thinking.

Ecological Competence and Ecological Literacy

Reconnecting with the natural world coincides with developing *ecological competence* and *ecological literacy*, concepts introduced by leading environmental educator and advocate David W. Orr, known for his transformative work in ecological education (Klein & Rauchwerk, 2016; Reisz, 2017).

Orr (1992) explained in his seminal work, *Ecological Literacy: Education and the Transition to a Postmodern World*, that ecological competence is necessary for contributing citizens to “build sustainable solutions from the bottom up” (p. 84), and requires learning how to live well in one’s environment. To achieve ecological competence, Orr maintained, start with ecological literacy and start early, because ecological literacy starts with tapping into the wonder that comes so easily in childhood. Ecological literacy requires learning from books, as well as using mathematics. More importantly, it must be experienced in nature to develop the essential loving kinship with nature that leads to the ability to interpret the signs of nature, such as the relative health of a stream, the songs of birds, and the patterns of leaves.

Orr (1992) advocated that an "environmental education ought to change the way people live, not just how they talk" (p. 91). An ecological education opens one's eyes to see the connectedness in all living things—to understand that the question "paper or plastic" at the grocery store leads either to turtles choking on plastic bags or mass deforestation, which leads to more habitat loss, soil depletion, and increased carbon in the atmosphere (Acaroglu, 2013). This aspect of ecological literacy—seeing all living things connected and part of a whole—"is radicalizing in that it forces us to reckon with the roots of our ailments, not just with their symptoms." This leads to "a revitalization and broadening of the concept of citizenship to include membership in a planet-wide community of humans and living things" (Orr, 1992, p. 88).

In an interview, David Orr contextualized our global environmental situation in terms of politics and power:

> Assuming that we can summon the wit to cap off the worst that could happen, the changes required in the conduct of our national and international politics are massive. It is time to rethink the role of the nation-state and global corporations in relation to the management of the global commons, peace, economic justice, sustainability, and the rights of future generations. (Orr, reported by Reisz, 2017)

Given the changes of human behavior required to mitigate our current trajectory towards disproportionately threatening the rights of future generations, the poor, women, and children, all of whom are most likely to suffer and die due to effects of our rapidly changing climate (Orr, 2011), education is an influential place to start for changing people's minds and habits. Through education, teachers can raise children to love and understand planet Earth, its cycles, and the complex geological, meteorological, and ecological systems that support the diversity of life on this precious planet we call home. To do this provides the foundation of an ethically and environmentally just ecological education, which includes learning about human interdependence and human impact upon the earth's ecosystem.

Human Interdependence and Impact upon the Earth's Ecosystem

In Daloz's (2004) chapter, "Transformative Learning for Bioregional Citizenship," Daloz philosophized on humanity's interdependence with all other living things on Earth and acknowledged our relatively recent detachment from this awareness. This "conceit that we are separate from the rest of the living planet" has led humans to pillage the earth, unconcerned about the consequences to other life, leading to systemic suffering to the Earth's ecology as a whole—consequences so dire that "it has nearly brought the planet and us to our knees" (p. 31). One step to ameliorate this destructive ignorance, Daloz suggested, is to develop the capacity for systemic thought, which depends upon the prerequisite ability to think critically. Both cognitive capacities require development beyond fraternal thinking, as that leads to making choices based on what is *good for me and those just like me* and fails to consider the context or the systems at play. Although consanguineous thinking may have once served evolutionary purposes, in present day geo-ecological circumstances, our awareness of our interdependence with other living organisms supports the coterminous survival of life as we know it on Earth.

Daloz (2004) argued that in these precarious times, developing a sense of our natural place, a sense of mystery and wonder regarding our natural place, and an understanding of our position in the ecology of our habitat will draw us to protect and preserve the flora and fauna of our natural home. Daloz proposed that we reconsider the boundaries of our sense of self to include the environment upon which we depend for survival because we are incapable of surviving detached from the biome that provides the conditions and sustenance for life.

As a part of this ecological education, in addition to ecological competence, ecological literacy, and a sense of species' interdependence with the rest of life on Earth, young people can be raised to grasp the myriad ways humans affect global ecology. Lieberman (2013) grouped human-caused planetary impact into seven major categories, including "(a) air pollution, (b) energy production and consumption, (c) global climate change, (d) loss of . . . biodiversity, (e) water quality and supply, (f) ocean degradation, and (g) overconsumption of natural resources" (p. 16). Although destruction in any one of these areas can be grim and, in conjunction, completely overwhelming, these categories of impact each have levers for innovation and improvement. In the potential for innovation and adaptation, hope can be found. Each exemplar addressed at least one of Lieberman's categories. Dwyer's solar tree addressed energy production and consumption; Slat's ocean cleanup system addressed water quality and supply, as well as ocean degradation; and Karamchedu's desalination system addressed water quality and supply.

Learning in any one of Lieberman's (2013) listed categories supports ecological understanding, but learning any of these in a context of systems thinking is essential for providing a truer understanding of how these categories are connected because changes in any one category often influence factors in the others. In addition to understanding human impact within any of Lieberman's categories, understanding species interdependence, attaining ecological competence, and achieving ecological literacy are all related to systems thinking.

Systems Thinking

The ability to understand the world holistically is a benefit of systems thinking. When students understand the interrelatedness of living things within systems—that a gain for Company Z could be at the expense of nature in regions B and C, which then leads those of region C to depend upon Company A, which relies upon Company Z—students are more likely to understand the ethical and often cascading ramifications of consuming at others' expense. This type of understanding, as exemplified in Figure 1, is at the heart of systems thinking.

In response to the extensive ramifications of human impact on the earth's biodiversity, Wilson (2016) proposed a solution to the earth's endangered biosphere. Wilson advocated for a radical shift in how humans engage with the planet: Demarcate half of the earth's surface to nature, so that nature can replenish itself and find its proper ecological balance apart from human interference. In depicting how species are intricately interdependently webbed, Wilson provided some clarifying examples of how species populations interact with one another in ecological systems, including the oft-cited example of the reintroduction of grey wolves to Yellowstone National Park in 1995.

Without wolves in the park for decades, the elk population boomed. Out of balance with the rest of the eco-system, elk overconsumed the aspen trees, which had consequences for species dependent upon the trees. As wolves took up their place in Yellowstone, decreasing the elk population, the trees began to grow, which beckoned the return of several other smaller species to the park, thus bringing about some restoration to the biodiversity (Reichard, 2017; Wilson, 2016).

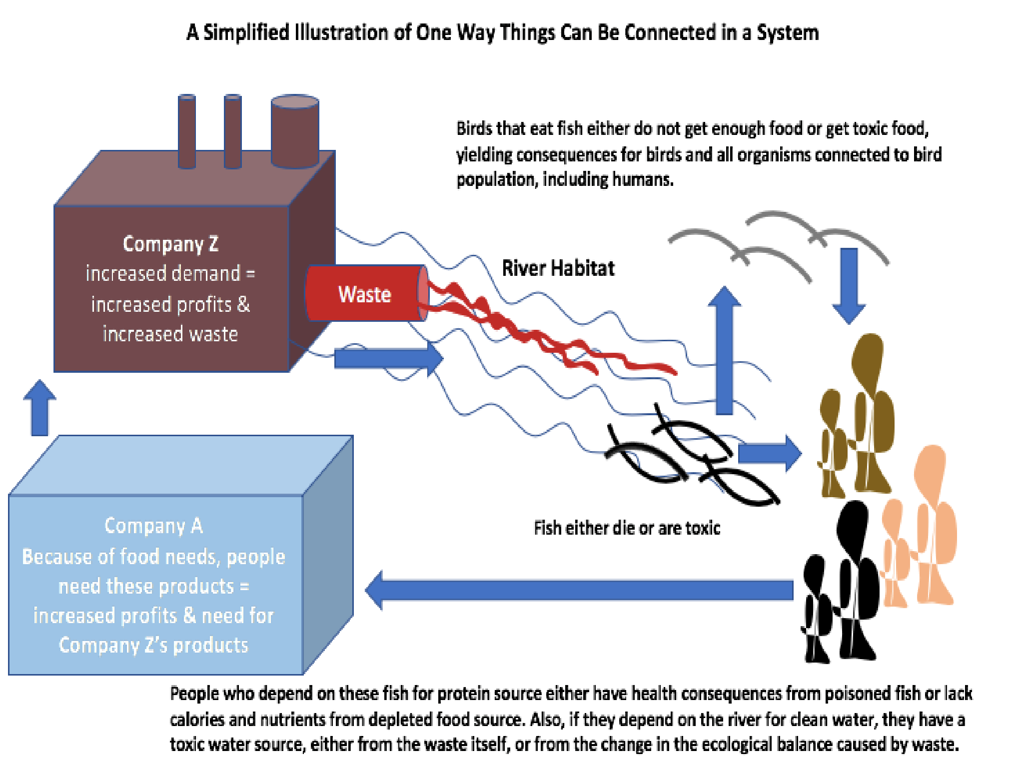

Figure 1. A simplified diagram of a human-influenced ecological system.

Systems thinking can illuminate how students come to conceptualize these complex relationships. In describing systems thinking, Senge (1990) used Earth's water cycle as an analogy to show that distant events separated by time and space were still part of an interconnected pattern. Senge noted that each component of the system influenced the other parts of the system, but that the influence was often “hidden from view” and “you can only understand the system of a rainstorm by contemplating the whole, not any individual part of the pattern” (p. 7).

Figure 2, an image created by John M. Evans and Howard Perlman of the United States Geological Survey, depicts the water cycle to which Senge was referring. The diagram (Figure 2) demonstrates how the water cycle is a closed system. The number of water molecules does not change; they just shift around from phase to phase. Figure 2 also shows how different elements influence the flow of water molecules in the system. This system can serve as a basic cognitive template to understand how a system works.

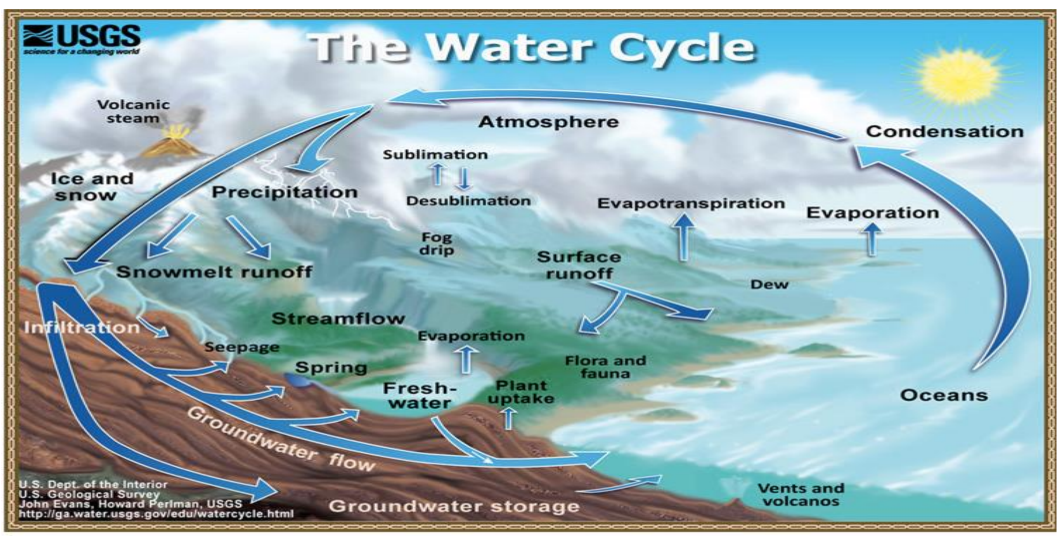

Figure 2. The water cycle. Source: Howard Perlman, USGS (public domain: https://water.usgs.gov/edu/watercyclehi.html)

In introducing “the laws of the fifth discipline,” which was Senge’s (1990) unique implementation of systems thinking for learning organizations, Senge introduced the chapter with a law: “Today’s problems come from yesterday’s ‘solutions’” (p. 57), which served as a warning for ecological innovators. Among Senge’s laws of systems thinking for learning organizations, two laws served as shorthand for understanding how humans interact and interfere with ecological systems. Senge’s fifth law, “The cure can be worse than the disease” (p. 61), referred to the myriad ways solutions can cause problems, including creating addiction or dependence upon the solution or solution provider, not to mention the cases in which the solution causes dire side effects or unintended consequences. For instance, human society has become dependent upon plastics, yet an unintended consequence of how we manage plastic is that it ends up in our oceans, killing wildlife and poisoning the food chain (Slat, 2017a).

Senge’s (1990) seventh law of systems thinking, “Cause and effect are not closely related in time and space” (p. 63), required an essential shift in thinking, as humans are most apt to link effects to things that they believe are causes because they are most proximal in space or time. However, even though cause and effect are often adjacent in space and time, that is not always the case. If we are limited in our thinking, then we will not be able to find the more distal or more complex multilayered authentic causes (p. 63).

Exposure to systems thinking as a discipline not only primes students to consider how distinct aspects of the same system are interconnected and influence others, but also broadens students’ thinking capacity to consider solutions that may require looking at the system as a whole, but through a different lens. McDonough and Braungart (2002) introduced such a shift in conceiving of our planetary system in their book, *Cradle to*

Cradle. Instead of approaching our world through a lens of eco-efficiency, they proposed a paradigm shift to viewing human impact on the planet through a lens of eco-effectiveness. Instead of trying to minimize humans' destructive impact on the earth, which presupposes that humans are inherently a consumptive species on the planet, this shift aimed to inspire people to imagine how beneficial they could be on the planet. McDonough and Braungart advocated for cessation of viewing nature as humans' victim, but instead as humans' teacher. For instance, using the cherry tree as an instructive model, the authors noted the cherry tree produces vastly more than enough fruit to repopulate itself; in addition to fruit, the tree produces beautiful flowers that symbiotically engage with pollinators, providing the protein source for honeybees (Carroll et al., 2017). McDonough and Braungart (2002) described continuing beneficence as the petals contribute nutrients to the soil and living organisms when they float to the ground in spring, and the tree's structure provides shade and habitat for creatures. The green leaves contribute oxygen to the air via photosynthesis and then, after a season of beneficially processing the air, the leaves add nutrients to the soil and microorganisms when they fall in autumn. Even further, the cherry tree increases its beneficial contribution to life as it grows each year. Eventually, when the tree comes to the end of its natural lifespan, it contributes once again with its wood, either as a functional material or as a source of nutrients through decomposition. With the cherry tree as inspiration, McDonough and Braungart proposed:

> Instead of fine-tuning the existing destructive framework, why don't people and industries set out to create the following: (a) buildings that, like trees, produce more energy than they consume and purify their waste

> water, (b) factories that produce effluents that are drinking water, (c) products that, when their useful life is over, do not become useless waste but can be tossed onto the ground to decompose and become food for plants and animals and nutrients for soil; or, alternatively, that can return to industrial cycles to supply high-quality raw materials for new products, (d) billions, even trillions of dollars' worth of materials accrued for human and natural purposes each year, (e) transportation that improves the quality of life while delivering goods and services, (f) a world of abundance, not one of limits, pollution and waste. (pp. 90–91)

In addition to these paradigm shifts, McDonough and Braungart (2002) issued a call to action to start designing all manufactured products with a *Cradle to Cradle* mindset. This concept flips the cliché of something lasting from the cradle to the grave to envision how the components of the product will affect the next generation and, more specifically, benefit the next generation in a virtuous cycle of creating good.

As a follow-up to their *Cradle to Cradle* manifesto, McDonough and Braungart (2013) furthered their vision for sustainability with *The Upcycle*, in which they aimed to inspire humanity to shift from a stance of reducing our badness on the environment to a stance of improving our goodness to a point of generating eco-flourishing abundance. As part of this transformation, McDonough and Braungart introduced the concept of technical nutrients. Essentially, technical nutrients are all the chemical and physical components that make up all objects, materials, and functioning appliances in a home, place of business, construct, or vehicle on the planet. If humanity can switch to view all components of our products as valuable and as reclaimable as gold, then we will conceive of these objects differently—and, instead of designing them to be disposed, we will design them to be upcycled—decoupled and reconfigured for other beneficial future use. This concept holds optimism at its core and requires a dexterous facility with systems thinking.

Synthesis of Ecological Education

Louv (2009), Krasny and Monroe (2016), Orr (1992), Daloz (2004), and Lieberman (2013) all advocated the importance of stewarding our planet and illuminated different aspects of what comprises an ecological education. Louv (2009) and Krasny and Monroe (2016) emphasized children being out in nature to learn how to love our natural home, and both provided several practical suggestions for adults to foster this connection for youth. Orr (1992) emphasized the importance of ecological literacy and ecological competence in guiding people towards ecologically responsible and sustaining behaviors. Daloz (2004) focused on the importance of developing people's sense of interdependence with all life on earth. Lieberman (2013) categorized the essential topics of human planetary impact to provide educators a comprehensive topic list to be sure to address all aspects of anthropogenic ecological impact for their students. In considering the interdependence of living things (Daloz, 2004), and the context of the global systems within which all things interact and abide, the ability to think systemically supports understanding ecological and global issues. Senge (1990) described systems thinking as an integrating force that pulls together other disciplines helpful to having an effective learning organization.

Instilling the capacity for systems thinking in students gives them a practical intellectual tool to facilitate understanding our natural ecology holistically, thus enabling them to view the complex system as a whole. Systems thinking, as a frame, might help people see how a change to a species population in one region affects a different species in a distal region. The ability to think systemically is consistent with Heifetz's (1994, pp. 252–263) concept of getting up on the balcony to view the dance, to see the Earth's ecological patterns at play. This literature review refers to the balcony metaphor again in the educational leadership section, as it also directly relates to equipping leaders with helpful cognitive tools to bring about the changes this dissertation suggests. Systems thinking, as part of an ecological education, also equips students to cognitively embrace different ways of looking at the system of which we are all a part, such as McDonough and Braungart's (2002, 2013) progressive take on engaging in innovation—to view, utilize, and conceptualize all objects as a temporary conglomeration of components that we can steward without harming or degrading, so that the components can continuously be upcycled to future purposes and future generations. If students can see and understand the complex interactive global system of living and nonliving things, will that provide a strong ecological foundation for potential ecological innovation? This question inspires further research.

In considering the inherent creativity necessary to hasten ecological innovation, the next section explores relevant literature on creativity.

Creativity

This section explores literature on creativity relevant to this study. Goerner's (2007) work contextualized creativity within the span of history and societal evolution. Goerner laid out the pattern of societies rising and collapsing over the centuries and posited that our current Western civilization is in a state of "learn or die" flux, which leads to either demise or reinvention. Lubart and Guignard (2004) posited that creativity can be subdivided into three categorical abilities: generalized, domain specific, and task specific. Acknowledging that creativity exists within the context of society, a culture, and a domain, Csikszentmihalyi (1999) introduced a model to convey the systems view of creativity to explore drivers of creativity. In his piece, Csikszentmihalyi referred to his previous work on the complex psychology of creativity; therefore, following the exploration of the drivers of creativity, a review of Csikszentmihalyi's (1996/2013) "Ten Dimensions of Complexity" is presented. Then, Runco's (2004) assertion that creative potential exists in everyone leads into a review of Richard's (2007) work on cultivating creativity. Eisler (2007) connected a child's experience of feeling loved to the development of creativity.

Learn or Die

Goerner (2007) built conceptual understanding for this learn or die choice by chronicling how society has repeatedly made "gestalt switches" to evolve to greater and more complex understanding when the old mode did not function anymore:

> In the year 1500, all the best minds "knew" that the earth was at the center of the universe because great thinkers like Aristotle had said so and because even ordinary observers could see the sun circling overhead during the day and the stars do the same at night. (p. 222)

Goerner pointed out how this earth-centric paradigm served as the foundation for all human thought at the time, so much so that the framework for feudalism was built upon it. Copernicus, among others, looked out upon the stars with improved telescopes and measuring devices and introduced a new idea—that the earth revolved around the sun.

Over the course of 200 years, this idea spread, the old concept faded into the past, and society adopted the heliocentric paradigm.

Goerner (2007) paralleled humanity's current global condition to that turning point in history. However, now the declining paradigm is that of humans as "selfish, genetically predetermined beasts of neo-Darwinian theory" with the defining mental model of "civilization as an empire building project" and the overtaking concept is one of humans as an "emotionally complex, collaborative learning species whose primary survival strategy is to improve collective understanding and then change collective behavior in line with better views" (p. 222). This new model, which Goerner labeled "knowledge ecology," underpins the phenomenon of group learning that leads to collaborative construction of new mental models to "navigate reality better" (p. 223). The knowledge ecology model accounts for our networked society, made of diverse groups and subgroups all interrelated, interdependent, and marked by the sharing of knowledge and resources. To explain society's current position at the fulcrum of either perishing or embracing the gestalt-shift to a knowledge ecology, Goerner argued:

> Furthermore, groups are driven to change their mental maps under exactly the kinds of conditions we now face; that is, when their current pattern of living is not working well and the troubles caused by shortfalls become massive and pressing. In this perspective, therefore, societies facing the kind of massive interwoven crises before us now are undergoing an evolutionary learning test with a single, multiple choice question: "learn or die?" As the last scientific revolution and the Enlightenment that followed demonstrate, surviving this test by learning successfully can produce a

> new stage of development with new powers, abilities, perspectives, and understandings.
>
> We are facing the same "learn or die" challenge today. For example, as the growing literature on "sustainability" attests, an increasing number of observers now believe that Western civilization is broken. . . . If one then asks why the richest democracy on earth supported by the most sophisticated science of all-time is barreling into social, economic, political, and environmental disaster, it quickly becomes obvious that the root problem lies not in a single arena, but in an interconnected web of institutional crises and failures. From education, medicine, and toxic food to energy, media, and democracy, every field is in trouble. (p. 223)

The antidote to this gloom and doom, Goerner (2007) claimed, is creativity. In a knowledge ecology where groups can build upon each other's contributions, creativity allows for collective learning. The amalgam of many individual solutions unified into an interconnected framework gives society a choice to either "survive and prosper at a more advanced stage of development" or hang on to the sinking outmoded system (p. 224). Goerner recounted Western civilization's pattern of massive societal change, noting that in each transformation, the culture preserved vital cultural lessons but transcended the constrictions of the previous paradigm. Drawing an analogy to a caterpillar in its chrysalis stage, Goerner equated the restructuring of society to bursting forth from a cocoon with beautiful new structures and previously unfathomed capabilities. Even with this promise of beauty, Goerner warned that if the society clings to the old ways, it would be like a butterfly never fully emerging from the chrysalis, meeting its unfortunate demise. Commenting on the current state of civilization, Goerner described the "omnipresent pressure . . . driving western civilization toward a new *Integral Society*, forming around the root metaphor of an 'ecosystem'" (p. 226). This critical decision point we are currently facing in the long-term cycle of civilizations spurs on creativity, both personal and collective. Goerner explained,

> During great change, individuals in every endeavor from education and medicine to politics and science reinvent their fields in thousands of generative acts of "effective novelty." More curiously, somehow these shards of solutions fit like pieces in a larger puzzle whose picture only becomes clear over time. The collective result is a better cultural roadmap that brings the society through critical times. (p. 227)

This paradigm compels integral-thinking citizens to practice ethical stewardship, which requires a sustainability orientation towards the environment and all living things, even as one garners an income. This paradigm also calls for people to resist falling into traps of divisiveness for any number of reasons, including nationality, race, socioeconomics, religion, gender, political affiliation, or power position. Instead, people from all arenas can contribute to the collaborative learning to build upon our collective creativity, which fuels the continual collective learning.

Three Categorical Abilities of Creativity

Lubart and Guignard (2004) explored creativity through a multivariate approach and concluded that creativity can be divided into three categorical abilities: generalized, domain specific, and task specific. Their definition of creativity included *novelty*, a term prevalent in the creativity literature, but also added *constraint satisfaction*, which means the creation meets the requirements of the task at hand. The criteria of novelty and constraint satisfaction carry different weights based on domain. In some more rigid creative domains, such as bridge building, the constraint satisfaction criterion is critically more important than the novelty aspect. In an oil painting, novelty can feature more heavily than constraint satisfaction.

To meet the constraint satisfaction criteria for any creative work, domain-specific skills play a part. For instance, for scientific creativity, the creator must be adept with the necessary tools and formulas to implement the instruments of that specific discipline. In validating their three categorical abilities of creativity, Lubart and Guignard (2004) looked to Amabile’s 1996 work that closely paralleled their own. Amabile’s three aspects of creativity included “domain-relevant skills, creativity-relevant processes, and task motivation” (p. 45). A person’s overall creative performance on a task is a function of these three components. Domain-relevant skills include all specific skills and knowledge unique to that type of work, such as a woodworker knowing how to use the lathe or a painter knowing what brushes achieve different strokes on the canvas. The processes related to creativity “include a cognitive style that facilitates coping with complexity and breaking one’s mental set during problem solving, the use of heuristics for generating novel ideas and a work style characterized in part by persistence and sustained attention to task” (p. 45). *Task-motivation* addresses how creative people engage in and complete their work and considers both extrinsic and internal motivation. *Intrinsic motivation* comes from within the person and is related to the enjoyment and flow a person gains from doing a task—essential for creativity. On the other hand, *extrinsic motivation* comes from external rewards or punishments and often extinguishes creativity, especially if a person's intrinsic motivation to do the task is low. Extrinsic motivation does not necessarily kill creativity; however, it can be helpful if the person already has a high level of intrinsic motivation. In considering creativity in children, Lubart and Guignard found that both the home and school environments contribute significantly to developing creativity. Additionally, external influences, such as concerts, museums, and media, can influence a youngster's creativity development. Through examining the literature, Lubart and Guignard found evidence that people can be trained in creativity, at least in domain-specific settings.

Drivers of Creativity

Csikszentmihalyi (1999), a leading creativity researcher, addressed creativity in terms of motivation and of relationship to specific domains. Initially, he approached the study of creativity as an intrapsychic process of individuals who produced novel creations. However, after years of study and longitudinal research, he "was forced by facts to adopt a view that encompasses the environment in which the individual operates" (p. 314). Consequently, Csikszentmihalyi introduced a model to convey his systems view of creativity, noting, "Original thought does not exist in a vacuum" (p. 315).

For creativity to occur, a set of rules and practices must be transmitted from the domain to the individual. The individual must then produce a novel variation in the context of the domain. The field must then select the variation for inclusion in the domain (Csikszentmihalyi, 1999, p. 315).

In rounding out this model, Csikszentmihalyi (1999) covered several conditions of culture, society, and individual background that influence creativity. Creativity exists within a cultural context in which people share ideas, learn from one another, and imitate fellow members' behaviors and contributions. Within that context, creativity occurs when a member of that culture makes a contribution that changes the culture's ideas or shared behaviors. Csikszentmihalyi suggested that, like genetic information passed by DNA, cultures have units of informational imitation, or *memes*—a term evolutionary biologist Richard Dawkins introduced in 1976 (cited in Csikszentmihalyi, 1999, p. 316).

Memes are analogous to genes in that they transmit a unit of cultural instruction among the members of the culture and to the next generation. They can last generations—for example, recipes for a staple food, designs for a simple tool, or plans to achieve a particular aesthetic—but change when a person introduces an innovation that sweeps the culture with an evolved or entirely different version of what once was. Memes are readily visible in the study of domains such as art, music, or science. Creators contribute ideas to the culture and then, if the culture accepts it and people start imitating the work, the concept becomes a meme (Csikszentmihalyi, 1999).

Creativity births continual improvement and increased complexity within culture because "creativity is the engine that drives cultural evolution" (Csikszentmihalyi, 1999, p. 320). In addition to culture, Csikszentmihalyi (1999) analyzed society and personal background as they relate to creativity. Among societal conditions that influence creativity, Csikszentmihalyi listed the amount of surplus energy a society has to give to innovation, the value a society places on innovation, the type of economic organization (some are conducive to change but others inherently obstruct it), variances in social mobility, the social system's complexity, and the level of external threat, because "threats often mobilize society to recognize creative ideas that otherwise might not have attracted much attention" (p. 323). To illustrate, the looming threat of the Cold War fueled unlimited innovation in physics for the development of nuclear weapons, and the current threat of global warming is spurring the types of ecological innovation targeted in this dissertation.

Csikszentmihalyi (1999) expounded on these societal traits, explaining that a society encumbered by daily efforts to survive is less likely to be able to devote energy to innovation. Even thriving societies must value creativity to put energy into encouraging innovation because well-off societies devoted to traditional standards of uniformity will not encourage innovation.

Paradoxical Dimensions of Creativity

An individual exists within the context of society and culture, so the contextual factors that foster creativity clearly help or hinder one’s chances for creative innovation. Even so, the person must have the capability and motivation to innovate in order to contribute novelty to a domain. Csikszentmihalyi (1996) noted that the personal traits of creativity have been well studied. Those traits include talent, curiosity, intrinsic motivation, divergent thinking, interest in discovery, perseverance, openness to experience, and the ability to hold contradictory ideas.

Csikszentmihalyi (1996) explored those traits in great depth in his book, *Creativity: The Psychology of Discovery and Invention.* Csikszentmihalyi (1996/2013, pp. 55–76) organized the complexity of the psychology of a creative person into “The Ten Dimensions of Complexity.” Each dimension holds two traits that appear diametrically opposed but, Csikszentmihalyi observed, highly creative people tend to live at the extremes and can “move from one extreme to the other as the occasion requires” (p. 57).

The first of the traits is physical energy. Creative people tend to have unusual amounts of vigor and utilize it to focus intensely for long periods of time. They also frequently are found in a state of quiet repose and may sleep more than a typical person. Csikszentmihalyi (1996/2013) highlighted that the significant thing for creative people is that they are in control of their energy output and do not subject their energy investment to the clock or calendar, but to the goals of their work (pp. 58–59).

The second dimension Csikszentmihalyi (1996/2013) explored is that of intelligence. According to Csikszentmihalyi, creative people usually display intellectual competence and possess an unusual level of naïveté. This allows them to garner deep insights while maintaining a level of emotional or mental childlikeness. In terms of creative people's complex intelligence, they are usually able to leverage both convergent and divergent thinking. *Convergent thinking* is the type of thinking needed to solve and correctly answer problems. *Divergent thinking* is needed to create multiple ideas, change perspectives, and make connections between different ideas. Creative people benefit from being strong in both types of thinking because they can generate ideas and then tell among them which ideas are good. People who are strong in only one of these types of thinking are limited in that they either cannot generate a wealth of ideas due to their lack of divergent thinking or cannot distinguish which ideas to pursue because they lack convergent thinking (Csikszentmihalyi, 1996/2013).

The third dimension of complexity pairs playfulness with discipline (Csikszentmihalyi, 1996/2013). People with a great deal of creativity tend to have an exuberance that enables them to explore and generate fun ideas; however, they need the perseverance and determination to follow through on those ideas to bring their novel creation to fruition. The fourth paradoxical pairing is that of fantasy and sense of reality. Creative contributors tend to be original without being too far afield of what is acceptable in society; hence, the culture at large tends to embrace their creations. The fifth continuum covers extroversion and introversion. Creative people tend to “express both traits at the same time” (p. 65), not only needing alone time to write or create, but also needing others with whom to share ideas, engage in conversation, collaborate to stay fresh, and work out in community some aspect of the creative work.

The sixth paradox is that creative people are simultaneously proud and humble (Csikszentmihalyi, 1996/2013). Their humility often is grounded in an awareness that they are only able to do the work they do because of the long lineage of seminal contributors before them. Their pride shows through in their ambition, confidence, and self-assuredness in what they can accomplish. The seventh paradox explores creative people’s flexibility of expression along the spectrum of masculinity and femininity. Regardless of gender, this flexibility increases the creative person’s interpersonal toolset. Even as creative people land on the whole range from transgender to cisgender, their psychological traits tend towards androgyny, thus encompassing the full range of gender-associated qualities.

The eighth set of opposing qualities creative people possess includes the dueling tendencies of traditionalism and iconoclasm (Csikszentmihalyi, 1996/2013). Remaining slightly conservative allows the creative person to learn and internalize the forms of the field; to remain purely traditional would inhibit the creative person’s work from ever making a difference in the field because it would not yield anything new. The streak of rebelliousness in creative people enables the innovators to think outside of the traditional forms and to challenge the ways things have been done previously. The ninth dialectic creative people balance is passion and objectivity. Creative people need passion to dive into their work and devote so much time and energy to it. Even so, they wield a detached objectivity to discern if their work is any good. The tenth dichotomy among creative individuals is that they experience not only significant suffering, but also a great deal of enjoyment. Because many creative people are highly sensitive, they feel “slights and anxieties” (p. 73) to a greater degree than does the general population. Creative people also experience vulnerability because “eminence invites criticism and often vicious attacks. When an artist has invested years in making a sculpture, or a scientist in developing a theory, it is devastating if nobody cares” (p. 73). Another area of suffering for creative people stems from the fact that “divergent thinking is often perceived as deviant by the majority, and so the creative person may feel isolated and misunderstood” (p. 74).

Just as creative people experience suffering, so too do they experience positive emotions such as hope and bliss. Csikszentmihalyi (1996/2013) quoted the writer Mark Strand to convey the hope that comes after finishing a project and starting a new one: “And then you begin again. You hope” (p. 74).

In describing the process of working in the area of their expertise, Csikszentmihalyi (1996/2013) explained:

> Worries and cares fall away, replaced by a sense of bliss. Perhaps the most important quality, the one that is most consistently present in all creative individuals, is the ability to enjoy the process of creation for its own sake. (p. 75)

In considering all these opposing pairs of traits, Csikszentmihalyi (1996/2013) noted that it is the duality within creative contributors that is so unique. He emphasized, “What is important to keep in mind is that these conflicting traits—or any conflicting traits—are usually difficult to find the same person” (p. 76). However, by embracing both poles, creative people can contribute their work to the evolution within their domains.

Even though Csikszentmihalyi (1999) investigated the personality characteristics of creative people, he highlighted the importance of both peers and community in nurturing creativity. He emphasized that, in addition to an individual’s proclivity to create, both accessibility to the systems of creativity and a culture of acceptance of new ideas are vitally important to supporting creativity. Although Csikszentmihalyi explored creativity by studying the traits manifested by individuals who made something transformational or contributed a meme to the culture, he also provided a chapter full of tips for the common person to develop their own creativity.

Creative Potential

The perspective that creativity lies in everyone, not just exemplars of novelty, is the foundation of Runco’s (2004) article, “Everyone has Creative Potential.” Runco argued that the term *creativity* should no longer be used as a noun in the psychological literature because it is not precise enough for scientific research. Instead, it should be used only as an adjective to define more specifically what the researcher is looking at, such as “creative performance, creative potential, creative behavior, creative personality, creative products, and so on” (p. 28). These distinctions would prevent people from conflating creative potential with creative products. Runco asserted that a consequence of using creativity as a noun in the research sciences is that researchers, inherently committed to maintaining objectivity, get pigeonholed into looking only at people who *already* produced something notably creative. This narrow definition completely ignores most of the population, which is brimming with creative potential. Runco proposed that all people have some degree of creative potential and suggested that the amount of creative potential one may possess could be charted on a standard bell curve. Most people would have an average amount of creative potential; fewer would have an extreme amount. Runco further differentiated that, even though everyone has at least some creative potential, motivation is the key ingredient for that creative potential to turn into creative performance. Given the importance of creative performance in our society as the foundation of our continual adaptation to our changing world, Runco posited that efforts to enhance people's creativity are "potentially very effective" (p. 29) and a person's modest amount of creative potential can be cultivated into a high level of creative performance.

Cultivating Creativity

Cultivating creativity requires a hospitable environment for creation. Richards (2007) identified both internal and external obstacles to innovation. She listed the following internal obstacles: writer's block, which is often caused by one's inner critic; keeping the thought buried in one's psyche for reasons such as fear; and pathologizing creativity, which makes it too daunting to approach. Richards contextualized outer obstacles as situations that educators, parents, and anyone in charge of an environment can rectify. She explained that creative people are often agents of change; consequently, their innovative activities can come across as threatening, even if they are well intentioned. Richards portrayed two ways adults in charge can squelch children's creativity: (a) a child has a good idea, but the adult does not have time to listen, despite the child's repeated attempts to be heard and (b) teachers often respond negatively to creative contributions because creative students are more likely to be "'emotional' and 'non-conforming'" (Westby & Dawson, cited in Richards, 2007, p. 34). These are both instances of adults unintentionally creating a harsh environment for creativity. With some reflection and commitment to nurturing creativity rather than unintentionally extinguishing it, adults can take the time to listen, support, and encourage children's creativity.

Love as a Factor in the Development of Creativity

Citing Solomon and Siegel's 2003 finding that children raised in a "loving and stimulating environment" fare much better in cognitive and emotional development than do their peers who do not grow up with such nurturance, Eisler (2007) presented love as an essential factor for children's development. She also cast love as a distinguishing evolutionary trait—the prerequisite for human's "capacity for intelligence, symbolic thinking, learning, communication, consciousness, caring, planning, choice, and creativity" (p. 268). Eisler further listed love as a vital component for people to develop to their fullest potentials. Giving present-day purpose to her claim that love is crucial to the formation of creativity, Eisler pressed, "Our most urgent creative challenge is building a sustainable future" (p. 261). Eisler continued to describe humans as a species with the capacity for "innovative, creative thought and action," noting that the "cultures we create will largely determine whether we continue to kill one another and destroy nature's life-support systems or build a humane and sustainable world" (p. 262). Returning to the importance of love in a person's development, Eisler cited both Miller, Galanter, and Pribam's 1986 neurological research and Solomon and Siegel's 2003 psychological work to point out that people who endured abusive childhoods or abusive early adulthoods were impaired similarly to lobotomized individuals in their capacity for self-regulation, long-range planning, learning, empathy, and caring. Essentially, a lack of love dramatically hamstrings a person's potential for development across a variety of spectra and ultimately limits that person's capacity for creativity. Stated in the positive, the influencing human factor of love must be considered when holistically conceptualizing the evolution of humanity. Similarly, love is an essential component in factoring "how we can fully develop our unique human potentials" (p. 269).

Summary of Creativity

Goerner (2007) concluded that creativity was the antidote to the gloom and doom of society's potential ecological peril. Lubart and Guignard (2004) found that people could be trained in creativity and that both home and school environments contribute to the development of creativity. Csikszentmihalyi (1996, 1996/2013, 1999) introduced both the systems view of creativity and the paradoxical traits possessed by creative people, whereas Runco (2004) argued that all people have creative potential. Richards (2007) pointed out how adults can squelch children's creativity, but concluded that adults can listen, support, and encourage children's creativity. This loving stance paralleled Eisler's (2007) work, which noted that a lack of love can drastically harm children's development, but credited love as a major force for creativity. Eisler's claim that love is an essential component for humans to develop to their fullest potential echoed Maslow's (1943) hierarchy of needs, because without the safety-inducing and esteem-enhancing condition of love, people could not reach the highest human need of self-actualization.

Self-actualization, which means maximally developing our unique human potentials, resonates with the maker movement's unabashed striving to unleash creativity. The maker movement, through makerspaces, Maker Faires, and maker communities, aims to nurture and celebrate creativity and innovation. The next section explores the available literature and relevant content on the maker movement as a vehicle for cultivating innovation.

The Maker Movement

Seymour Papert, the late co-founder of the MIT Media Lab, is credited as the father of the maker movement (Martinez & Stager, 2013). Papert developed a teaching theory he named *constructionism* to convey the most effective means of enabling constructivist learning. Constructivism has its roots in progressive, child-centered, open-ended, and inquiry-based pedagogical models. Papert composed the tenets of constructionism as a list of "eight big ideas behind the constructionist learning lab" (Papert, cited in Martinez & Stager, p. 73). A summary of those ideas includes (a) we learn by doing, (b) technology is a building material, (c) have "hard fun"—do challenging things, (d) learn to learn, (e) take time, the appropriate amount of time, for the job, (f) "you can't get it right without getting it wrong," (g) "do unto ourselves as we do unto our students," and (h) "we are entering a digital world where knowing about digital technology is as important as reading and writing" (Papert, cited in Martinez & Stager, pp. 73–74). Dale Dougherty and Tim O'Reilly, creators of *Make Magazine*, "the DIY manifesto, urging readers to unleash their creativity with little more than a screwdriver and a soldering iron" (Corcoran, 2008) catalyzed Papert's foundational work of creating the first maker*space* into the maker *movement*. *Make Magazine* interweaves “the profusion of powerful, cheap electronics; a deft software hacking community; crafting as popularized by Martha Stewart; and the growing green–or recycling–rage” (para. 11). From this magazine’s propagation of ideas, an inspired community of makers arose, creating physical workshops called *makerspaces* and convening at expos called *Maker Faires*. In describing Maker Faires, Dougherty (2012) contended:

> A lot of institutions, such as schools . . . think they understand what drives innovation and that they can manage it in a controlled environment. At Maker Faire, we see innovation “in the wild.” It hasn’t been “domesticated” or controlled, you have to look for it, and to turn a corner at any of our Faires is to see something you haven’t seen before. (p. 12)

After witnessing millions of participants in his Maker Faires, Dougherty (2012) came to a deep understanding of the potential of unbridled innovation. This understanding fueled his passion, which showed in his call to schools, businesses, and government to become more like the maker movement: “The institutions around us should look to the maker movement for tips on how to create an ecosystem of talent, connections, and learning that will lead to a truly innovative economy and society” (p. 12). Clearly, Dougherty enacted Wagner’s (2012) alliterative “play, passion, and purpose,” as he has lived out his purpose passionately calling for leaders to become more like the maker movement, essentially to engage more in creative and collaborative play.

Resnick and Rosenbaum (2013) situated the maker movement in the frameworks of Dewey’s progressivism, as well as Papert’s constructionism, both of which advance “a project-based, experiential approach to learning.” They noted, “The enthusiasm surrounding the Maker Movement provides a new opportunity for reinvigorating and revalidating the progressive-constructionist tradition in education" (p. 163). In acknowledging the rapid pace and unpredictability of our world, Resnick and Rosenbaum admitted that much of what people learn becomes obsolete. They argued that "the ability to think and act creatively" and the "ability to come up with innovative solutions to unexpected situations and unanticipated problems" (p. 166) are vital attributes for thriving in the future. Facilitating a fascination with tinkering, a primary element of the maker movement, "is a particularly valuable strategy" (p. 166) towards developing the skills of thinking creatively and producing innovative solutions to unexpected situations. Resnick and Rosenbaum suggested that the very process of tinkering grows the capacity for tinkerers to "understand how to improvise, adapt, and iterate, so they are never stuck on old plans as new situations arises" (p. 166).

In recognizing that makerspaces align with their fundamental mission to serve learners and promote learning, schools and libraries have joined the maker movement by creating makerspaces for their students and communities. Often by repurposing existing spaces, schools have created makerspaces with "a working area for creating and building models, machines, architectural plans, clothing, tools, and whatever else might emerge from a student's imagination" (Jacobs & Alcock, 2017, p. 100). They have employed learning strategies from the maker movement to mentor students in new ways (Dougherty, 2012; Peppler & Bender, 2013). Two school librarians, Smay and Walker (2015), successfully created a makerspace in their school library, then turned to advocating for other school librarians to do the same, sharing the playbook for how they involved the teachers and administration in getting it off the ground. Through their experience, they found that makerspaces "provide a place for students to explore questions, bounce ideas off one another, build something together, and fail and try again, all in a safe, creative environment" (p. 39).

Peppler and Bender (2013) reported that the maker movement's potential to fundamentally shift how STEM and art disciplines are learned is becoming nationally recognized. With the maker movement expanding nationally and internationally, "it's clear that the maker movement is an innovative way to reimagine education" (p. 4). Many students across the country "are disengaged and bored in school, and as a result see themselves as poor learners" (Dougherty, 2012, p. 12). By giving children an opportunity to create and explain their product, they demonstrate their learning. Dougherty (2012) claimed that giving students the chance to talk about their creations supports their learning as they simultaneously teach others.

Makerspaces

Makerspaces are community gathering places, often in schools, libraries, museums, community centers, or stand-alone establishments within warehouses or office buildings that are designed to provide workspace, equipment, tools, and materials for fabricating ideas into existence (Burke, 2014; Fleming, 2015; Holman, 2015; Roslund & Rogers, 2014; Smay & Walker, 2015). According to Roslund and Rogers (2014), the equipment provided in individual makerspaces reflect the interests, resources, and strengths of the community and might include tools such as robotics components, computers equipped with programming and fabrication software, glue guns, craft-tools and supplies, "a laser engraver, 3D printer, sewing machines, soldering irons, woodworking tools, and metalworking tools" (p. 10). If following best practices, makerspaces have properly trained and certified educators following proper safety protocols and enforcing safety-training courses prior to allowing members to use the machinery (Love & Roy, 2017). The proliferation of makerspaces has been called “the learning revolution sweeping the globe” (Martinez & Stager, 2013, back cover), and this claim is validated by a surge of how-to instructions on creating a makerspace through various media including books, articles, videos, and online instruction guides.

Makerspaces are rapidly multiplying due to the maker movement (Burke, 2014; Holman, 2015). The spaces themselves are often multipurpose workshops where people gather to make things, often combining web or computer technologies with real-world tactile fabrication. Examples of this process include an artisan who brings in a local street map and then, using a scanner, design-program, and laser cutter, creates laser-cut maps of copper sheeting to produce art representative of place; or a child who uses a computer program to design a unique LEGO®-compatible piece, then prints it on the 3D printer, and then uses it as part of his or her LEGO® construction project. Each makerspace reflects the creativity and interests of the specific educators, tinkerers, and community members who helped build it, but it is the creativity and collaboration of the makers using the space that bring the zeal of the maker culture to the space (Martinez & Stager, 2013; Roslund & Rodgers, 2014; Sheridan et al., 2014).

In response to the push for schools to teach 21st Century skills, educators are striving to establish makerspaces in their schools (Pearlman, 2014). In support of librarians hosting makerspaces in their school libraries, Smay and Walker (2015) shared from their experience running a makerspace in their school library. Smay and Walker professed that makerspaces are a prime resource for students interested in the concepts of design, they are great for providing children unstructured time to create in an open studio model format, and the resources can be extended and enhanced by leveraging the makerspace as an after-school program. Makerspaces can support classroom project-based learning, in that makerspaces provide “different ways for students to demonstrate their knowledge through different formats [and] media,” including constructing “3D designs or conceptual models” (p. 40). In the spirit of the maker movement, Smay and Walker developed a prototype of how to introduce and run a makerspace at a school and shared it publicly so others could follow their design, improve it, and hopefully continue to share the evolutions publicly so that all can benefit from the information.

Like Smay and Walker (2015), Fleming (2015) also operated a library makerspace and shared her practical tips in her book, *Worlds of Making: Best Practices for Establishing a Makerspace for your School.* Fleming couched her advice in John Dewey’s philosophy, referencing his acknowledgement of tools as both a human expression and the means for humans to express themselves. Fleming recounted Dewey’s assertion that children should “participate actively in their own learning, with the teacher taking the role of a partner, a guiding influence, in that process” (Dewey, cited in Fleming, 2015, p. 3). In describing how the maker movement promotes “learning-through-doing in an open social, and peer-led environment,” Fleming asserted that the maker movement enables a “culture of fun, self-fulfillment, and a sharing of ideas” (p. 3). She explained that the maker mindset “puts the learner firmly at the center of the learning” (p. 3) and encourages student participation. She suggested that Dewey would have approved of the maker movement because the movement practices align with Dewey’s progressive ideals for education, such as providing continuity of experience through the highly generative learning.

The *maker mindset*, a term coined by Dale Dougherty (2013), exemplifies progressive ideals in that it is predicated upon students constructing their own knowledge, as well as their own projects. Dougherty explained:

> The maker mindset . . . is a can-do attitude that can be summarized as "what can you do with what you know?" It is an invitation to take ideas and turn them into various kinds of reality. It is the process of iterating over a project to improve it. (p. 9)

Mentoring in Makerspaces

Historically, practical skills were learned in apprenticeships from a mentor. When a person became a professional within a trade, he or she would join a guild that trained new artisans. The new professional would collaborate with fellow guild members, and participate in the mutual challenging of one another to new standards of great work (Roslund & Rogers, 2014). Makerspaces, within the context of a collaborative community, provide the modern interdisciplinary equivalent, as members of the makerspace come with their different areas of interest and expertise. Learning how to woodwork, sew, use a lathe, operate the laser cutter, or master the other technologies and tools of a makerspace often comes not through traditional instructive teaching, but via relational mentoring. As Zachary (2005, p. 2) explained, "The practice of mentoring has evolved" and expanded to include a wide variety of mentoring styles that contribute to a culture of mentoring.

Dougherty (2016), an advocate for makerspaces in communities and in schools all over the world, expressed that makerspaces are designed to not only promote innovation, but also nurture a culture of mentoring. Defining *maker* as one who makes things and often with enthusiasm and dedication but not necessarily expertise, Dougherty explained that, as amateurs, makers need “access to mentors or to people who just know more” (p. 28). Describing the culture of the maker movement, Dougherty outlined the people who comprise it. He described makers as people who generously help others because they know they have been helped generously, too. As an advocate of the maker movement, Dougherty visited makerspaces throughout the United States to see how different places created their version of a makerspace and encouraged them along. One makerspace in Watsonville, California was dedicated to the environmental sciences. At the Watsonville, California Environmental Science Workshop, the informal learning educators referred to themselves as “practitioners,” which reflected how they were “guiding children through a learning practice” (p. 177).

Calling for mentors to be part of the makerspace regardless of expertise supports both lifelong and cross-generational learning, where knowledge and skills flow in both directions across the generations (Sharples et al., cited in Fleming, 2015). Children learn from real experts in various fields; thus, makerspaces serve as a conduit to transmit multiple disciplines of expertise. For instance, in any given session at the makerspace, a student maker could consult a host of mentors, such as an expert quilter, an electrical engineer, and a master woodworker. This access to (often volunteer) expert mentors streamlines the transmission of knowledge from one generation to the next. It amalgamates the rich technical understanding and techniques from numerous fields; thus, participants can construct a broader and deeper well of experiential knowledge through one project than any one person previously could have attained in one lifetime. The Watsonville Environmental Science Workshop welcomed participants to their environment by noting “kids are exposed to adult mentors, models, and friends” (Watsonville Public Works & Utilities, 2017). This high value on mentoring runs consistent among makerspaces.

In Boston, Massachusetts, the Flagship Computer Clubhouse—founded in 1993 as the original makerspace Seymour Papert designed for youth in collaboration with the MIT Media Lab and Boston’s Museum of Science—specifically recruited mentors to be a part of the makerspace community. In their call for mentors, the Clubhouse described that mentors support youth in using the technology to express themselves and develop trusting relationships based on respect (Okeyo, 2017). In accordance with Clubhouse and maker movement founder Seymour Papert’s philosophy, Clubhouse mentors were expected to not only lead, but also learn alongside their students. Papert depicted this adult and student co-learning philosophy in his vision for the future of education:

> It is a place where teachers do not provide information. The teacher helps the student find information and learn skills—including some that neither knew before. They are always learning together. The teacher brings wisdom, perspective, and maturity to the learning. The student brings freshness and enthusiasm. All the time they are all meeting new ideas and building new skills that they need for their projects. Some of what they learn belongs to the disciplines school has always recognized: reading, writing, mathematics, science, and history. Some belongs to new disciplines or cut across disciplines. Most importantly, students and teachers are learning the art and skill and discipline of pursuing a vision

> through the frustrating and hard times of struggle and the rewarding times of getting closer to the goal. (Papert & Caperton, 1999, II Visons line 23)

The Maker Movement as a Potential Vehicle for Eco-Innovators

Chris Anderson (2012), author of *Makers: The New Industrial Revolution*, deemed the maker movement, “The New Industrial Revolution.” Anderson summarized the recent history of innovation to contextualize the maker movement. He noted that our recent human history has forged a new knowledge domain based upon the use of the Internet for collaboration, creation, and invention, and our present and near future are about transferring that knowledge to real life. Anderson connoted this difference another way, explaining that bits are the units of the Web, and atoms are the corresponding units of the real world. The maker movement fundamentally integrates bits and atoms, which transforms how entire social and economic systems can function, thus, validating the claim that we are in the new industrial revolution—the age of the maker movement. Today, in a manner unprecedented in history, people all over the globe can collaborate on the same project, virtually simultaneously—leveraging tools, skills, and the craft of making for the benefit of all. This could come into play for ecological innovation. For instance, if Chai Karamchedu were to make a how-to video of his water desalination device, people in regions affected by a low freshwater supply but ample saltwater supply could watch his directions and work to recreate his desalination system. Another way this could support ecological innovation is in the design process—a team could work asynchronously on an ecological project and produce a collaboratively built prototype without ever being in the same room.

With the maker movement promoting Maker Faires and makerspaces and spreading the maker mindset, more people are gaining access to creating things and developing their constructive capacities. As youth adopt the maker mindset, either from a mentor in the makerspace or from peers in the maker movement, the *can-do attitude* might help them persevere when the chances look grim or the prototype fails. This maker mindset concept is worth researching further because a contagious can-do attitude would help a myriad of learners, not just the ecological innovators who are the focus of this inquiry. For Aidan Dwyer with his solar-catching Fibonacci tree, Boyan Slat with his ocean plastic cleaner, and Chaitanya Karamchedu with his hydrophilic polymer desalination kit, applying a maker mindset with serial prototyping and iterative improvements is how they created and continue to improve their world saving innovations. Table 2 compares what the literature has shown about what makerspaces offer to each exemplar's experiences. In assessing Table 2, makerspaces provide all the factors listed in the table, barring seminal experiences, ecological understanding, and systems thinking.

The collection of factors in Table 2 suggest that makerspaces could potentially serve as a vehicle for several supportive factors towards eco-innovation. This influenced the nature of this study in that it highlighted makerspace experience as an area of inquiry in the study's interview protocol (Appendix A). The supportive factors listed in Table 2 informed the protocol's construction. The presence of several of these factors across all these exemplar cases highlighted the potential significance of these factors in eco-innovators' lives.

Table 2. *Supportive Factors Found in Makerspaces and in the Exemplar Eco-Innovators*

Supportive factor	Offered in makerspace	Evidenced in Aidan Dwyer	Evidenced in Boyan Slat	Evidenced in Chaitanya Karamchedu
Mentoring	X	X	X	X
Prototyping	X	X	X	X
Innovation	X	X	X	X
Materials and tools	X	X	X	X
Workshop space	X	X	X	X
Creativity	X	X	X	X
Community of learners	X		X	
Play	X			
Collaboration	X		X	
Seminal experiences		X	X	X
Ecological understanding		X	X	X
Systems thinking			X	

Mentoring

Mentoring, a relationship in which a more experienced person helps a learner grow in the knowledge and practice of their shared interest, "is associated with positive and personal and career outcomes" (W. B. Johnson & Ridley, 2004, p. xv). Both Aidan Dwyer and Chaitanya Karamchedu credited mentors for supporting their project development, and Boyan Slat stated that once he got publicity, he gathered support and input from numerous scientists and professors to help him improve his design. Dwyer credited both his father and grandfather with mentoring him, and Karamchedu mentioned his science teacher as a support. The following section delves into what mentors do, how mentoring supports positive youth development, and what mentoring innovators involves.

What Mentors Do

W. B. Johnson and Ridley (2004) listed 19 things that excellent mentors do. Slat, Karamchedu, and Dwyer's accounts display many of these actions. Dwyer's grandfather intentionally mentored him through the process of building his model, stating, "They're the problem-solvers of tomorrow. That's why you have to spend time with them, you have to work with them and encourage them" (Dwyer, 2014, min. 3:58). In this simple statement and through their relationship, Dwyer's grandfather modeled several of W. B. Johnson and Ridley's (2004) characteristics of an excellent mentor: (a) he knows his protégé well and spends time with him, (b) he expects excellence because he esteems him as a problem-solver of tomorrow, (c) he affirms him, (d) he is a teacher and a coach, and (e) he encourages and supports him. Dwyer's father demonstrated other traits on this list: he sponsored, encouraged, and gave Dwyer exposure—as evidenced by his encouragement for Dwyer to enter the American Museum of Natural History's Young Naturalist competition (Dwyer, 2014; W. B. Johnson & Ridley, 2004).

In Ensher and Murphy's (2005), *Power Mentoring,* the authors defined power mentoring and contrasted it to traditional mentoring. Traditional mentoring facilitated short-term succession planning for key positions, but power mentoring expanded to include long-term succession planning. Dwyer's grandfather demonstrated his intentional long-term succession planning when he said of his grandson's generation, "These are the problem-solvers of tomorrow" (Dwyer, 2014, min. 3:58). The generative nature of power mentoring related directly to environmental innovation with its focus on investing in the next generation throughout the mentor’s career (Ensher & Murphy, 2005). Boyan Slat leveraged power mentoring in his protégé role as he initiated and drove the mentor relationships he gained from his initial TED talk. Slat also demonstrated another of Ensher and Murphy’s power mentoring concepts, as he has not maintained exclusivity with one mentor but has communicated with several mentors from diverse fields.

Ensher and Murphy (2005) asserted that developing trust was essential to the mentor–protégé relationship; the mentor should be able to trust the “protégé enough to allow them to take risks and maybe even fail” (p. 149). The trust must be mutual, so if the protégé indeed experiences failure, then no doubt the mentor will guide the student to learn from the mistakes and improve. For innovators, prototyping allows for design failure and contextualizes it in learning from mistakes and making a new iteration based on that feedback. Dweck (2015), in her response to the broad influence of her “growth mindset” concept, emphasized the importance of the educator or mentor being honest about the student’s achievement and coming alongside the student to help the student gain understanding. She even offered a model for a mentor’s language in such a situation: “Let’s talk about what you’ve tried, and what you can try next” (para. 6).

In addition to fostering an authentic growth mindset for their protégés, mentors can provide much needed attention, encouragement, interest, and affirmation for their protégés, which gives their learners confidence to experiment. According to W. B. Johnson and Ridley (2004), this generous emotional investment of a mentor can have a “nearly miraculous effect on a protégé’s self-confidence” (p. 10). Additionally, mentors can forge connections for their mentees and help them gain access to opportunities they would not otherwise have (p. 12).

Mentoring and Positive Youth Development

Lerner et al. (2014) connected positive youth development with mentoring, noting that effective mentoring requires “sustained, high-quality relationships with youth” (p. 24) and can provide a vital asset for developing youth. Mentors who offer youth opportunities to attain life skills and lead esteemed activities in the community are facilitating the growth of important indicators of positive youth development, conveniently organized by the letter C: “competence, confidence, connection, character, caring, and . . . contribution to self and society” (pp. 23–24). Lerner et al. provided a checklist for practitioners suggesting actions mentors can take to guide the development of these key traits. To nurture competence, Lerner et al. coached mentors to discover what their mentees enjoy. They suggested supporting engagement in those things “*without* taking over” (p. 23), to discover the children’s talents and bolster pursuit of endeavors that emphasize those abilities, to show the mentees that their skills are transferable to other areas, to engage youth in decision making that influences the completion of communal tasks, and to use mistakes as essential learning opportunities. To foster confidence, Lerner et al. urged mentors to make sure that there are others in the mentees’ lives who are also supportive so they feel loved and valuable in a multitude of contexts; to share authentically about the mentors’ own moments of low confidence; to ask the mentees for assistance when appropriate; to be cognizant of challenges that can harm confidence, noting that adolescent girls are particularly vulnerable to losing confidence; and to actively build the mentees’ social capital by facilitating valuable connections to institutions, resources, and people they would not have access to outside of the mentoring relationship. To build connection, Lerner et al. advised mentors to respect the mentees' privacy and to orchestrate situations in the community where the mentees can share their voice because this tends to meet the adolescents' need to feel significant. To develop character in mentees, Lerner et al. proposed mentors speak honestly with their mentees about their own values and let them know if a particular situation, person, or behavior is a concern. The authors also compelled mentors to model good character by aligning words with deeds, maintaining perspective and humor if the mentees have a minor slip of integrity, and allowing their mentees to make their own decisions and deal with the natural consequences of those decisions. To promote caring in mentees, Lerner et al. warned mentors that sometimes when mentees push away, they are covering deep vulnerability. Thus, the researchers advised mentors to exercise patience and a willingness to listen for such a situation. Additionally, to allow for caring to blossom as a trait in mentees, Lerner et al. reminded mentors that "caring is contagious" (p. 24) and advocated for mentors to model caring, provide opportunities to demonstrate caring in the community together, and urge mentees to promote caring in their worlds. Finally, to support mentees in contributing to society, Lerner et al. encouraged mentors to embolden mentees to get involved in causes that ignite their passion, to persuade local organizations and "institutions to welcome youth participation" (p. 24), to guide youth in assembling the resources they need to help them succeed with their contributing efforts, and to allow mentees to fail because learning from failure is worthwhile and builds capacity for future contributions.

Mentors of Innovators

Wagner (2012), in his search to find what experiential and developmental factors go into the making of innovators, interviewed several innovators from multiple fields and found that:

> All of the young innovators whom I interviewed while researching this book—including many whose stories I could not include—described a teacher or mentor who had made a significant difference in their lives. And when I then interviewed these teachers and mentors, I discovered that each of them in as outlier—an innovator—in his or her university, school, or work setting. Every one of them teaches and mentors in ways that are very similar to one another, but different from their peers. (p. 99)

These mentors not only took mentoring very seriously, but also often let the mentees lead the direction of the relationship in terms of areas of interest (Wagner, 2012). Even in sharing their technical skill and teaching their know-how, the mentors let the students take initiative on the area of inquiry. They asked life-purpose questions, such as, "What difference do you want to make in the world?" and "What will be your legacy?" (p. 124). They advocated for their students; one even "brokered the best scholarship for his student" (p. 99). They took the heat for their mentees to try something new or a bit risky. They pushed them, invested in them with their money and with their time, gave them opportunities to test their mettle, and even followed up with their protégés after the official mentoring relationship ended. For example, one mentor called his alumni interns every 6 months to check on them. These mentors, who played significant formative roles in innovators' lives, either created or were part of a culture for their students that promoted “(a) collaboration, (b) multidisciplinary learning, (c) thoughtful risk-taking and trial and error, (d) creating, (e) intrinsic motivation, and (f) play, passion, and purpose” (p. 200).

Passion and purpose are main drivers for innovation. Wagner (2012) determined that mentors served a vital role in fostering passion and nurturing purpose (p. 139). In considering all that the mentors provided his case innovators, Wagner encouraged potential mentors: “You don’t have to be a parent or a teacher to make a huge difference in a young person’s life. But what you must do is listen carefully for—and then nurture—that vital spark of passion” (p. 139). Through this advice, Wagner suggested that if mentors attune themselves to their mentees’ passions and nurture them, then their students will be more able to create the very innovations that our world needs.

As mentorship creates value on a personal level, we must next ask ourselves, how do we create this value at a system level through influencing contemporary educational systems? The next section explores literature oriented towards educational leaders to facilitate change and towards educators who aim to bring practices that support ecological innovation into schools.

Educational Leadership in Relationship to this Overall Inquiry

Considering the vast, varied landscape of domains and fields relevant to the study of the factors and conditions that go into the lives of young people who become ecological innovators, this work should produce suggestions or implications for school leaders, as education is the primary target arena for this inquiry’s contribution. The literature gathered for this section presented foundational frameworks, constructs, and research that support the relevance of this inquiry to school settings. The following portion of the literature review is organized into three sections: Literature that directly informs educators about how to nurture the emergence of eco-innovators; literature that presents ways in which schools can inadvertently obstruct or intentionally promote an environment conducive to innovation; and literature that, when viewed through a dual lens, supports the eco-innovation processes and the ongoing efforts for school and instructional improvement. These *dual lens* literature selections provide congruent patterns at different levels of scale, following a fractal pattern, a “form created from repeating patterns evident at many levels of scale” (Wheatley, 1999, p. 123).

Literature that Informs Educators How to Support Eco-Innovation

The following literature, which informs educators about supporting eco-innovation in education, includes Scheffler’s (1985) conceptual framework for understanding human potential, 21st Century skills, civic engagement in a democratic society; supporting creativity in schools; and supporting motivation in schools.

Scheffler’s Conceptual Framework for Understanding Human Potential

Education is foundationally in the business of nurturing human potential; therefore, this section starts with a review of Scheffler’s (1985) conceptual framework for understanding human potential. Scheffler’s framework is relevant to this inquiry because it orients educators to appreciate students’ capacity, facilitate students’ motivational tendencies, and enable students’ capabilities to flourish. This subsection explores Scheffler’s framework, which focuses on human potential from three perspectives.

From a broader stance encompassing the guiding questions for this dissertation, Scheffler (1985) inquired, “What courses of study and training, what forms of practice or life experience would help given students to realize their evident potentials?” (p. 11).

Scheffler posited that his question was based upon the notion that the activities people engage in influence the outcome of their potential. Asserting that education should effectuate children to achieve their potentials and that potentials are inherently dynamic, Scheffler noted that students, as well as their parents, teachers, and all of society, bear the responsibility of educating students to reach their potential because both personal and social intention directly influence what people can become. This combination of internal and external intentions for one's actualization is "bounded only by available resources and the limits of ingenuity" (p. 11). In line with Runco's (2004) assertion that everyone has creative potential, Scheffler (1985) warned educators not to contribute to the withering of children's potentials. In this warning, Scheffler suggested that educators should "instill as many useful habits as early as possible"; nurture a child's inquisitiveness because squelched curiosity "may eventually die" (pp. 12–13); and be aware of critical ephemeral windows of time that best support learning specific activities, such as a second language or how to swim, which are both supported by starting when the child is young. Scheffler suggested that educators must approach students' future potentials with a "hopeful imagination" while maintaining "a realistic appreciation" that those potentials may be fleeting (p. 13). In his concern that students' potentials languish due to any number of reasons, Scheffler connected nurturing children's potentials to the trajectory of society:

> Have valuable potentials remained hidden through lack of general knowledge or lack of social interest? Have apathy, or poverty, or bias, or misguided policy thwarted the appraisal of children's potentials and cruelly closed off their life prospects? Such worries, natural to parents and

> teachers, are central also to the concerns of society at large, for what open and closes the life prospects of children determines the direction and quality of society itself. (pp. 13–14)

Scheffler (1985) introduced a conceptual framework that addressed human potential from three precursory interpretations: “capacity to become” (p. 46), “propensity to become” (p. 52), and “capability to become” (p. 58). According to Scheffler’s framework, the capacity to become means that nothing is blocking the person from becoming that potential version of self, although it does not mean that the person will orient towards that outcome. The framework described propensity to become as a person’s motivational tendencies to do something if given the opportunity. Scheffler explained that the capability to become a certain version of self (e.g., a swimmer, doctor, or eco-innovator) relied on the person’s capacity to do so, the environment allowing it to occur, and the person being empowered to achieve that end. *Capability*, Scheffler clarified, means that if the person “makes the effort, he will [achieve that goal]” (p. 60). Scheffler detailed the formative aspects of nurturing capability as “removing impediments,” “empowering,” and “promot[ing] a positive attitude toward” that activity (p. 60). He added:

> Now to increase or enhance potential, under the present interpretation, is to empower the person to acquire the feature in question or, more briefly, to empower the relevant learning. It puts the means of learning within the person’s decision range, thus putting the learning itself within his effective grasp. Increasing a person’s potential, in this sense, heightens the effectiveness of his learning efforts, increasing his powers of self-

> determination by putting his future dispositions within range of his own choice. (p. 61)

Scheffler (1985) determined that potential precedes but does not guarantee capability, and the outcome may land anywhere on the spectrum ranging from good to evil. Therefore, nurturing the tendency towards good outcomes requires an education that includes “initiation into some scheme of values” (p. 62).

Through this framework, Scheffler (1985) provided a tool for educators to understand more deeply how they contribute to realization of human potential by anticipating, identifying, and nurturing whatever potentials should arise and to imagine how they might organize schools for such purposes. Additionally, Scheffler advocated for the transmission and development of ethical standards as a necessity, so that students could leverage their potential for indisputably good purposes.

21st Century Skills

This subsection briefly touches on a framework designed to help educators and policy makers provide a relevant, impactful, comprehensive, and empowering education for today’s youth. It is relevant to this inquiry because this framework is foundational to many efforts being made in education in the United States, and key themes and skills from the framework directly support the concept of nurturing eco-innovation in schools.

The Partnership for 21st Century Skills developed the Framework for 21st Century Learning in 2009 as a guide to support the transformation of education in the United States to “better prepare students for the demands of citizenship, college, and careers in this millennium” (Kay, 2010, p. xiii). The proposed model responds to the evolving needs of our student population because the world is rapidly changing, and our young people will soon be responsible for leading and stewarding the planet and everything in it. The 21st Century skills aimed to prepare students to “think, learn, work, solve problems, communicate, collaborate, and contribute effectively throughout their lives” (p. xx). The skills proposed, considered groundbreaking for the education domain, included “creativity and innovation, flexibility and adaptability, and leadership and cross-cultural skills” (p. xxiii). These skills are the building blocks of success in that they fuel inventiveness, adroitness, tenacity for iteration, capacity for innovation, and ability to stand up for worthy ventures. The push for 21st Century skills development completely aligns with and supports inclusion of programming to support ecological innovation in schools.

Civic Engagement in a Democratic Society

Eco-innovators are examples of people who actively engage in civic society with a focus on what can be improved and who intend to contribute something beneficial in response. Thus, the next section explores literature in a closely related field—educational practices that promote civic engagement in a democratic society. Westheimer and Kahne (2004) introduced a framework for understanding different approaches to civic education that supports educators in guiding students to effectively take part in a democratic society. Their framework organized positively engaging citizens into three categories: “the personally responsible citizen,” “the participatory citizen,” and “the justice-oriented citizen” (pp. 3–5). As Westheimer and Kahne described these three groups, the personally responsible citizen focuses on contributing to society through volunteering, helping, being responsible for themselves, and focusing on personal character development; the participatory citizen “actively participate[s] in the civic affairs and the social life of the community at local, state, and national levels" and takes part in "collective, community-based efforts"; and the justice-oriented citizen critically analyzes society to "address root causes" of social justice issues and repair injustices (pp. 3–5). Westheimer and Kahne illustrated how these three groups engage differently in society: "If participatory citizens are organizing the food drive and personally responsible citizens are donating food, justice oriented citizens are asking why people are hungry and acting on what they discover" (p. 4).

Westheimer and Kahne (2004) studied different citizen education programs and found that the educational experiences yielded different effects based on the type of citizenship upon which the program was founded. Students of the participatory action program had increased "personal responsibility to help others," knowledge of their "social capital for community development," and "leadership efficacy" (p. 19). Students in the program that emphasized social justice had increased "interest in politics," deeper awareness of the structural factors related to poverty, and greater ability to think critically about root causes of societal ills (p. 19).

Westheimer and Kahne (2004) cautioned that if citizen education programs only emphasize personal responsibility, then those programs risk conveying only a conservative and self-centered concept of citizenship to the students. Explaining that many programs focus merely on personal responsibility, the authors challenged that effective democratic citizenship "requires collective participation and critical analysis of social structures" (p. 22) and, therefore, a more comprehensive view of citizenship education that includes participatory and justice-oriented approaches to citizenship is needed.

Westheimer (2015) built upon this previous work with his colleague Kahne in his book, *What Kind of Citizen? Educating our Children for the Common Good,* in which Westheimer revisited the three types of citizens and explored how schools could become places that support students maturing into effective democratic citizens. He criticized how the culture of standardized testing has obfuscated “the goal of making schools meaningful, engaging, and thoughtful” (p. 97) and lamented, “In too many classrooms, students are told what to think rather than how to think” (p. 100).

Westheimer (2015) urged educators to shift the focus from knowledge as something to be acquired for the sake of passing a test to knowledge in the service of achieving larger goals, such as civic goals, because children “growing up in democratic societies . . . will be asked to participate in decisions that affect all of us” (p. 97). Given this future responsibility, Westheimer asserted, “Programs and activities that teach students how to think deserve far more attention in our classrooms” (p. 97).

Supporting Creativity in Schools

This subsection supports the overall inquiry in that it explores literature from educators who proposed practical implementations for cultivating creativity, an essential building block for eco-innovation, in schools. G. W. Johnson (2014) advocated for nurturing creativity in schools and identified how teachers can nurture students’ creativity. Piirto (2014) catalogued several ways to increase creativity in the classroom. Lynch (2018) introduced key elements for an educator to host an innovative classroom. This survey ends with pulling in other related literature that validated the importance of reflection in nurturing creativity.

The 21st Century skills framework emphasized creativity as a vital element of an education that will properly prepare a child to thrive in our ever-evolving world. Even with this call for creativity, “creativity is not nurtured in the current educational system” (G. W. Johnson, 2014, p. 223). G. W. Johnson (2014) identified standardized education as the “antithesis of creativity,” claiming, “Standardized education and its tests are killing creativity” (p. 224). G. W. Johnson noted that creativity in a context of standardization is often punished, so astute teachers of creative-minded students are left teaching students to game the system, an unintended consequence of educational standardization that circumvents the purpose of standardization.

Proposing that educators support creativity in the classroom, particularly for advanced students, G. W. Johnson (2014) identified the importance of the teacher’s ability to foster creativity and composed a list of traits teachers should bring to the practice of nurturing creativity:

> Teachers must be able to appreciate and admire ideas and answers that are not standard, should not be overly judgmental, should be receptive to new ideas, should be holistic in their approach to education, and need to be willing to take a risk. They should be playful, sharing appropriate humor. Teachers of the creative should be well-educated, perhaps generalists. They must have some basic knowledge of the domain in which the child seeks to be creative. They must be willing to help students find outside opportunities, tutors, and mentors. Teachers must enjoy gifted and talented children and have an extended repertoire of instructional methods or

> techniques in order to meet the learning styles of a diverse group of students. (pp. 225–226).

In providing guidance for educators to establish a safe space for creativity to thrive, G. W. Johnson (2014) addressed the importance of establishing an environment conducive for creativity and enabling “flow,” as introduced by Csikszentmihalyi et al. (2005). Such an environment, G. W. Johnson (2014) suggested, must have quiet, which can be achieved in a variety of ways with several different management strategies. This environment, G. W. Johnson continued, must also provide freedom for the students to find their own comfortable space to work, a space unfettered from the traditional concept of a desk. It should include nooks, rugs, comfortable mats, the floor, and a table in addition to traditional tables or desks, which students may work at, under, or on as long as they are producing. The teacher, according to G. W. Johnson, must also pay attention to grouping, making sure to alternate pairings and to keep groups small (two or three students), while monitoring the groupings to make sure collaboration is taking place and supporting the development of creativity. G. W. Johnson addressed that the tone for the psychological environment should be one of wonder, encouragement of ideas, curiosity, risk-taking, and an expectation of productivity.

Piirto (2014) introduced an alliterative series of “I” words to cover the essential curricular elements to bolster creativity—“incubation, improvisation, inspiration, imagery, imagination, intuition, and insight” (p. xxi)—and then invited a cadre of educational leaders to expound upon those curricular elements. *Incubation* is the necessary time for an idea to percolate in the creative person’s mind. G. W. Johnson (2014) pointed out that the modern classroom is not hospitable to incubation time because it flies in the face of direct and dynamic teaching but is still vital to the creative process. Kettler and Sanguras (2014) conveyed the significance of *improvisation* across a spectrum of domains ranging from children's play to professional innovation. Kettler and Sanguras acknowledged that it takes committed preparation to be able to improvise in teaching, but the improvisational teacher can create "open-ended inquiry and an environment of exploration" which, by way of flexibility, leads to students learning "to value the process of learning and the power of creativity" (p. 8). In addressing improvisation, G. W. Johnson (2014) suggested that teachers sometimes need to throw in an obstacle for students to necessitate improvisation along their path of learning (p. 230). Providing *inspiration* can be as simple as loading the learning environment with the exemplary work of peers or of model contributors to the domain, or as adventurous as taking a fieldtrip to experience some sort of hands-on experience in the domain. In addition to exposure to excellence and a variety of exemplars, the educator should also provide a variety of materials for the students to play with to gain inspiration.

G. W. Johnson provided some practical suggestions for teachers to develop students' capacity for imagery and imagination, all of which are designed to stimulate the senses. Two of G. W. Johnson's suggestions included reading aloud to students from descriptive literature while they listen with their eyes shut and having students listen to old-time radio shows, then instruct them to map out the story in pictures. *Intuition* and *insight,* Piirto's (2014) final two I-words to imbue into the curriculum to bolster creativity, take time to develop. *Insight* is the "grasping the gestalt or wholeness of a thing or idea" or the ability to "synthesize the details into a big picture" (p. 233). In contrast to insight's outward orientation, *intuition* requires an inward orientation. It is the "ability to listen to the quiet voice inside, to trust one's feelings, and to be willing to act on a hunch." Intuition can be developed by giving students the solitude to focus on their own deepest thoughts, then give them the chance to write them down in the form of a journal or "thought log" (G. W. Johnson, 2014, p. 233).

Inspiration in the classroom involves students seeing and experiencing the form and models from the domain in which they are expected to create (G. W. Johnson, 2014). As the overarching aim of this work is to establish an environment that cultivates innovators, it makes sense to educate the students in an innovation-rich environment. Lynch (2018) proposed some traits of an innovative classroom including reflection, creativity, connection, problem finding, collaboration, goal setting, and opportunities for revision. These characteristics reiterate much of what has been explored in the preceding pages of this literature review. However, one vital trait, *reflection*, is worth filling out a bit more here. Reflection supports students in constructing a purposeful understanding of their experiences (Dewey, 1938/1997), the development of intuition (G. W. Johnson, 2014), and the promotion of transfer (Perkins & Salomon, 1988), which is the capability to apply something learned in one situation productively in a different situation (Gillespie, Thompson, Lowenstein, & Gentner, 1999). Reflection is a key aspect of bringing metacognitive practices into the classroom, and metacognition, the thinking on one's thinking, increases understanding and performance for the learner (Griffiths, 2013; Grotzer, 2013).

Supporting Motivation in Schools

Because students must be motivated to create eco-innovations, and teachers and adults are in positions well suited to motivate students or create setting where students' motivation can thrive, this subsection reviews Daniel Pink's (2009) theory of human drive and his practical strategies for promoting motivation among youth.

Pink (2009) built his work upon Deci and Ryan's (1985) self-determination theory, which emphasized that competence, autonomy, and relatedness motivate people. In modifying self-determination theory's components, Pink (2009) kept autonomy the same but upped the emphasis on competence to mastery and tweaked relatedness to purpose. According to Pink, humans have three motivating drives: the drive for autonomy, mastery, and purpose— "the yearning to do what we do in the service of something larger than ourselves" (p. 219). With this theory at the foundation of Pink's work, he suggested 10 strategies for schools and parents to help students.

Pink's (2009) first tip challenged teachers to give homework only if it meets all three of these criteria: it allows students autonomy over how and when to do the work, it "[promotes] mastery by offering a novel engaging task" as opposed to a review or rehash, and the students "understand the purpose of the assignment" (p. 186). Pink's second tip was to give students a "Fed Ex Day" (p. 187), which emulates the Fed Ex company's ritual of having an entire day set aside for people to work on whatever project they wish, any way they want, and with the colleagues of their choosing. After students engage in this exercise in autonomy, Pink suggested, they should make presentations to their peers about their interesting projects. Pink's third suggestion was for schools to implement do-it-yourself report cards, an exercise that promotes mastery as well as autonomy, as it gives the students the chance to set goals and self-assess. Pink's fourth proposition guided parents to give their children both an allowance and chores, but to make sure that these two aspects of family life are uncoupled. The allowance provides autonomy; the chores provide a sense of responsibility to the family. However, to couple the two turns chores into a for-profit endeavor only, which nullifies the purposeful contribution to the family. Pink's fifth encouragement was to "offer praise . . . the right way" (p. 189), meaning to praise effort instead of intelligence and to make praise specific, private, and purposeful. Pink advocated for educators to help children see the big picture by helping them understand the purpose and relevance of each lesson and making as many real-world, hands-on field-trip-type connections as possible. Touching on education policy, Pink admonished us as a culture to "pay teachers more intelligently" (p. 191), meaning in-tune with human motivation. The model Pink proposed involved raising all teachers' base pay and making it easier to fire terrible teachers. Pink's eighth tip assigned readers to investigate five unique forward-thinking schools that implemented practices congruent to Pink's triune of mastery, autonomy, and purpose to see what happened in real-life when schools purposefully aim to cultivate students' motivation. Building on his suggestion to get out of the book and into the real world, Pink recommended another field-trip-type adventure with his suggestion to connect with and learn from un-schoolers, as their philosophy promotes autonomy and mastery. Pink's final charge called educators to "turn students into teachers" (p. 196) by giving students the opportunity to research and teach class as well as serve as experts on a subject. This type of exercise promotes all three motivational drives because it raises students' responsibility for their personal and community learning.

Literature that Informs Educators how to Support Eco-Innovation by Addressing Structural Educational Issues that Obstruct or Promote Innovation

This following literature informs educators about how schools can unwittingly obstruct innovation with their current structures and systems or promote a culture conductive to innovation. Westheimer (2015) and Levinson (2012) addressed how educational systems have fared in the context of standards, assessment and accountability (SAAs) in relationship to education for democracy and ways in which SAAs have obstructed meaningful learning. Isaksen and Akkermans (2011) and Jacobs and Alcock (2017) contributed literature oriented towards promoting innovation in schools.

SAAs in Relationship to Education for Democracy

Westheimer (2015) emphasized that the type of citizenship education matters because differently founded programs yield different results. From his previous research, Westheimer learned that civic education programs designed to forward students' participation "do not necessarily develop students' abilities to analyze and critique root causes of social problems," and programs oriented around social justice do not necessarily improve students' public participation (p. 97). Westheimer suggested that if educators aim to foster students' civic participation and students' critical thinking about the root causes of societal problems, then they must explicitly address both aims. He further emphasized that there are specific requirements for the education of a citizen in a democratic society, including that citizens learn "how to think critically, ask questions, evaluate policy, and work with others towards change that moves democracy forward" (p. 99). Westheimer listed priorities for schools to prepare students to become contributing citizen of a democratic society, including "teach students how to ask questions," "expose students to multiple perspectives and viewpoints on important issues that affect everyone's lives," "provide opportunities to analyze and discuss different viewpoints," "show that 'facts' are less stable than is often thought," and engage controversial issues (p. 99).

Westheimer (2015) noted a groundswell of dissatisfaction with standardized testing and a desire for more meaningful education has started:

> Across North America and elsewhere in the world, parents, teachers, administrators, and students are increasingly convinced that we need curriculum worth focusing on and schools that make that possible. They are increasingly impatient with calls for educational standards, accountability measures, and assessment tools that consistently fail to capture a broad variety of classroom goals, including civic engagement, participation, and the kinds of thinking skills that effective democratic citizenship requires. (p. 100)

According to Westheimer (2015), schools across the United States have made it clear that they no longer want teaching to be solely about preparing students for standardized tests. He optimistically interpreted these schools bucking against the system of standardized tests as evidence that "the kinds of schools we need and want are possible" (p. 101).

Much of what Westheimer and Kahne (2004) and Westheimer (2015) suggested for civic education within a democratic society applies to supporting students to actively engage in society for the purposes of nurturing students to have the capacity and capability for eco-innovation.

Similar to Westheimer (2015), Levinson (2012) examined "how schools can help prepare all students to be empowered democratic citizens" (p. 259). Levinson argued that high-stakes testing has produced counterproductive results by forcing educators to constrain their teaching to focus on preparing their students for standardized tests at the expense of critically engaging their students in content and educational experiences that empower them to put their learning into practice as involved citizens. For instance, Levinson listed "bilingualism, biculturalism, moral reciprocity, or deep understanding of the natural environment" as domains unacknowledged by SAAs (p. 273).

Levinson (2012) also explored the potential for public good, the democratic virtues, and the failures of administrating SAA measures on schools. Through her examination, Levinson concluded that SAAs should be limited for the sake of democracy, and their reach over schools should be reduced so that teachers and students can have liberty of judgement and control over their own pedagogy and learning. She explained:

> [Teachers] can't model empowerment if they feel totally disempowered. Similarly, students can't practice democracy, or experience empowerment, if they have no voice and no power in determining what they learn, why, how, or when. In this respect, the imposition of SAA measures upon teachers and students, no matter how carefully considered they are, intrinsically undermines good civic education. (p. 281)

Levinson (2012) shared from her personal experience. She had taught a semester of civics without state-level accountability measures dictating her curriculum and she was able to "provide quite an effective civic education"; even so, that year of teaching was cut in half by the time allocated to "high-stakes, heavily tested math and reading instruction"

(p. 282). In explaining her pedagogical choices during that experience, she noted that it was a semester particularly open “to creativity and innovation.” It “represented the height of democratic legitimacy” because she co-constructed the civics curriculum “with [her] students rather than merely complying with the demands of elite adults” (pp. 282–283). With complete freedom for the direction of her class, Levinson collaborated with her students, interns, and local community organizations to “devote serious time to Hurricane Katrina . . . a cause that [her] students enthusiastically embraced.” Then, the remainder of the course was guided by her “students’ interests and concerns” through a series of investigations that were personally and contextually relevant to them (p. 283). Levinson’s semester of civics without top-down imposed SAAs led to the students gaining “knowledge and skills that helped them become more empowered citizens (p. 283).

Levinson (2012) argued that “education *for* democracy” yields civics standards that “strive to transform society in order to achieve a revitalized democracy in which citizens are fully engaged and empowered” (p. 285). This stance also considers how today’s students grow into tomorrow’s adults; thus, it aims to equip them to become “democratically minded and empowered adult citizens” (p. 285). Levinson concluded that “visible demonstrations of civically engaged and empowering teaching practices would replace other modes of assessment” and that this shift towards vibrant civic engagement could “build capacity, motivation, and public support for high quality civic education practices” (p. 288). Her critical thought towards civic education in schools directly connects to students critically engaging with ecological problems that face our world, as they are inherently civic issues that require empowered civic action.

Supporting Innovation in Schools

Some of the previous literature selections in this section supported the concept of innovation in schools, some more and others less directly. The following two reviews cover researchers who increased the focus on promoting innovation specifically. Isaksen and Akkermans (2011) focused on the role of leadership in promoting innovation, and Jacobs and Alcock (2017) targeted policy makers as they proposed tenets to support innovation and hold schools accountable for bolstering innovation.

Isaksen and Akkermans (2011) studied how organizational leaders influence the level of innovation within the organization, as well as the organizational cultural climate for creativity and innovation. Their study "confirmed that leadership does, in fact, play a very important role in creating an organizational climate that supports innovation" (p. 181). As an encouragement to school leaders who take steps to create a working climate that supports innovation, the study also revealed that people who reported "higher degrees of innovative productivity" (p. 176) viewed their working climates more positively. Similarly, people who reported better climates for innovation also viewed their leaders as more effective. Isaksen and Akkermans provided an implication of this study for leaders interested in promoting innovation. They suggested that leaders "should include a focus on deliberately creating a climate for innovation" (p. 181). More specifically targeting how education can support innovation, the following work by Jacobs and Alcock (2017) proposed a specific shift for education.

Jacobs and Alcock (2017) proposed a bold shift for education: Change policy to hold schools accountable for innovation (p. 176). In proposing this shift, Jacobs and Alcock composed five tenets to support this transformation. They first encouraged student products to be authentically rooted in an experience, such as conducting a real fieldwork, producing a case study, or composing a video documentary of real-world events relevant to the student. The second tenet required that the audience for the presentation of the product be authentically related to the context of the project. For example, projects such as Slat's ocean cleanup or Karamchedu's desalination kit would present well to a society of water engineers. The third tenet called for students to engage in investigations that take extended time and require students to "compile findings, create the narrative, revise the text, and employ a range of sources to reflect depth of insight and rigor" (p. 177). An example of this would be giving students the opportunity to follow the moon's phases over the course of the school term and keep a journal on this activity (Duckworth, 1987). The fourth tenet challenged teachers to collaborate with students "as innovative designers and describe what innovation might look like in an assessment project" (Jacobs & Alcock, 2017, p. 178). This collaborative enterprise stretches both students and teachers to ruminate on, identify, and create the pathways towards innovation. The fifth required students to embrace their identities as self-navigators and professional learners, as well as become literate in the communication modalities of the ever-evolving technological world. This tenet set the standard for students to self-monitor their development on their individualized education plan daily, "year to year in a digital-media format" (p. 178). These tenets, combined with educational leaders and policy makers embracing the charge to herald innovation with enthusiasm and commitment, can help facilitate increased innovation in schools by making it a priority.

Literature, When Interpreted Through a Dual Interpretation, Supports Eco-Innovation in Schools

This subsection reviews literature that touches upon ways in which the processes of ecological innovation complement and strengthen educational leaders' ongoing efforts towards school improvement. The literature examples cited for their dual interpretation potentially can equip educational leaders to support ecological innovation not only by supporting their innovative school improvement leadership, but also by giving them a solid understanding of useful cognitive constructs that support ecological innovation.

This subsection starts with the suggested learning cycle Bryk et al. (2015) proposed because it parallels the iterative learning cycle present in the practice of engineering design and innovation. Given the necessity for educators to practice what they encourage for their students, the following learning cycle would be not only helpful for schools for the sake of improving anything in their practices, but also valuable as a practice that strengthens educators' ability to coach the type of iteration necessary for eco-innovation. Similar to Heifetz and Linsky's (2002) concept of *getting up on the balcony* and discerning between technical and adaptive challenges, those concepts not only serve school leaders for most leadership situations, but also are directly analogous to skills potentially needed for ecological innovators creating solutions to today's environmental problems. Given the metalevel nature of these leadership practices, they are valuable for their own sake—valuable for leaders adapting their schools to support eco-innovation, and valuable for leaders to internalize so that they can pass them on to their teachers and students so that future generations of students can have them readily available as conceptual tools.

Bryk et al. (2015) leveraged principles from improvement science to hasten school progress by connecting progress to the practice of *improving learning*. In *Learning to Improve: How America's Schools Can Get Better at Getting Better*, Bryk et al. proposed six interconnected principles that each have the potential to drive improvement within America's schools: "make the work problem-specific and user-centered," "focus on variation in performance," "see the system that produces the current outcomes," "we cannot improve at scale what we cannot measure," "use disciplined inquiry to drive improvement," and "accelerate learning through networked communities" (pp. 12–17). Although all these principles were means of systematically engaging in improvement research, "starting small and aiming to learn fast" (p. 179) serves the overall purpose of precipitating school improvement. The concept of seeing the system that produces the current outcomes is both an encouragement and a warning to consider any given part or problem in a school as part of a dynamic system. Even the best suggestions implemented by the best educators can falter if they are not able to integrate into the complex systems already in place. Heifetz (1994) and Heifetz and Linsky (2002) provided an analogical tool for educational leaders (and leaders of all domains) to see the systems at play: "getting up on the balcony."

Getting on the balcony is a framework to support leaders in "making interventions, observing their impact in real time, and then returning to the action" (Heifetz & Linsky, 2002, p. 53). To briefly recapitulate the metaphor, a person on a dance floor can be aware only of his or her own body's movements in relationship to the music. Perhaps the dancer is also aware of his or her partner's movements, but much of what is going on is outside of his or her frame of vision. If that dancer were to take a moment to get off the dance floor and go up to the balcony, then the dancer would now have a more holistic perspective on all the movements happening in concert on the dance floor. The dancer could see the patterns of movement created by all the dancers as a whole in relationship to the music and in relationship to one another.

Heifetz and Linksy (2002) suggested toggling between those two perspectives—to "practice switching roles, watching what is happening while it is happening, even as you are a part of what's happening" (p. 54). This concept applies to school leaders who wish to further the supports in their schools to promote ecological innovation in a multitude of ways. First, it gives educational leaders an apt metaphor to communicate the importance of educating youth to step outside of their limited perspectives and to regard themselves and their impact on the earth as an influencing component within a larger dynamic ecological system. Second, it serves as a framework to help the leaders themselves lead change in their educational systems. The framework encourages leaders to shift their perspective to "move from participant to observer and back again" to promote an objective stance on one's own actions and to view one's influence as part of a larger system replete with patterns (p. 54). Third, Heifetz and Linsky used the balcony metaphor to provide specific suggestions to eliminate one's blind spots when leading change. They suggested leaders ask themselves, "What is going on here?" Following this grounding question, Heifetz and Linksy proposed four preventative steps for leaders to avoid common leadership pitfalls: (a) "distinguish technical from adaptive challenges, (b) find out where people are at, (c) listen to the song beneath the words, and (d) read the behavior of authority figures for clues" (p. 55).

To distinguish technical from adaptive challenges, Heifetz and Linsky (2002) charted that technical challenges can be solved with current knowledge and that the people in authority can do the work. In contrast, adaptive challenges require that the people with the problem must learn new ways to solve the problem because known solutions will not work. Distinguishing whether the problem is a technical or adaptive challenge is an essential diagnosis, because, as Heifetz and Linksy identified, “The single most common source of leadership failure results from leaders addressing adaptive challenges as if they were technical problems (p. 14).

In “find[ing] out where people are at,” Heifetz and Linsky (2002) suggested that listening with curiosity and empathy matter greatly in getting constituents to work together with the leader. If leaders do not take the time to listen to their constituents’ perspective and use that perspective as the starting point, then those leaders are “liable to be dismissed as irrelevant, insensitive, or presumptuous” (p. 63). This suggestion paralleled other leadership maxims, such as the fifth habit from *The 7 Habits of Highly Effective People*: “Seek first to understand then to be understood” (Covey, 2004, p. 235), and a “golden rule” Bryk et al. (2015, p. 26) referenced: “Observe and consult the people on the ground who know the most about the problem.”

After listening to understand where people are at, Heifetz and Linsky’s (2002) next step, to “listen to the song beneath the words,” is advice to pay attention to the deeper meaning of what people are saying—and to interpret people’s input within the context of the entire situation. The work of Stone, Patton, and Heen (2010), who advised leaders through the process of navigating difficult conversations, supports this practice of listening for a deeper story. First, a leader must identify the type of difficult conversation they are having: a “what happened?” conversation, a feelings conversation, or an identity conversation. Each of these conversations comes with their own unique challenges, and all involve dropping assumptions and listening deeply to the other (the song beneath the words) to transform the situation from an adversarial argument into a learning conversation.

Heifetz and Linsky’s (2002) last step, to “read the behavior of authority figures for clues,” reminded leaders that since authority figures are responsible for large swaths of an organization and serve as a hub of information as they are connected to multiple facets of the organization, they are often aware of the rumblings of change to come, and therefore will behave accordingly. The balcony metaphor is one of many valuable frameworks Heifetz and Linsky posited. The creation of the holding environment, controlling the temperature, and sacred heart are also profoundly helpful concepts for strengthening leaders who intend to lead transformation, including changing schools to be places that nurture and promote ecological innovation.

Bryk et al.’s (2015) “using disciplined inquiry to drive improvement” (p. 124) principle favored starting with small changes to iteratively cycle towards greater improvement. This principle described the cyclical process of asking questions to gain better insight into a given practice, be it pedagogical or systematically functional, and using the results from each observation to formulate the next guiding inquiry question. As a fractal of the type of iteration necessary to cultivate in students who will become innovators, this practice builds upon itself, leading to continuous improvement. This process fuses two typically disparate roles of educator and researcher into one unified role: educator as researcher.

Because educators often balance many obligations, including keeping a class of students running, starting small with an inquiry-guided improvement idea is not only a preventative measure to avoid the all-too-common erosion of trust and culture of cynicism that accompanies the tired cycle of new program employment (Bryk et al., 2015), but it also enables educators to "[learn] quickly and cheaply" (p. 16). Keeping change small allows for the education show to go on while educators iteratively improve their practice. Starting with a small inquiry-based change also serves as a strategy for rapid learning. Rapid learning increases the educators' capacity and know-how within a system, which propels effective system-wide improvement implementations towards success.

Bryk et al. (2015) introduced the PDSA cycle as a means for applying the principle of using disciplined inquiry to drive improvement. The PDSA cycle was designed to be an iterative process of improvement that focuses on testing one thing at a time. The model places inquiry at the center of the process because each change is implemented as an observed trial, which is evaluated as objectively as possible with an eye towards improvement. As part of the inquiry, sense must be made of what has been observed in order to understand how to make small adjustments in the endeavor of continuous improvement. In the "study" phase of the PDSA cycle, educators can play the role of observational researchers of their own trial interventions. Once the constructive adjustments are made, the new iteration goes into effect and the cycle begins anew, creating a "developmental continuum for reliable change" (p. 133). Essentially, the PDSA cycle united the formerly separated silos of educators and researchers into one empowered group of educators who use disciplined inquiry to state the problem, apply a small test of a change to address the problem, study the implementation, make tweaks, and repeat with the adjusted prototype of an intervention. Then, with a posture of unyielding inquiry, they start to plan again based on the new baseline, and then launch into the experimental cycle again. This cycle can be implemented to try out interventions to increase ecological innovation in schools, as well as serve as a contextual fractal for how young innovators can internalize and apply a methodology for iteration and design improvement.

This subsection reviewed literature that addressed aspects of school organizations that would provide an authentic and appreciative milieu for the emergence of eco-innovators. School organizations that are determined to develop habits of inquiry and systemic thinking and are steeped in curiosity about innovative practices and instructional improvement, are likely to provide a beneficial context for nascent eco-innovation.

Synthesis of the Literature Review

This literature review employed Pascale et al.'s (2010) concept of *positive deviance*, or *bright spots*, as Heath and Heath (2010) called them, to highlight cases of young people who actively served as exemplars of environmental innovation as they publicly promoted their solutions towards a healthier ecology. By gleaning details from published stories about what may have contributed to their actuation as ecological innovators and then researching those topics, this review explored research on nurturing excellence, motivation, environmental education, creativity, the maker movement, mentoring, and educational leadership—all through the lens of ecological innovation.

In considering how this chapter answered the driving motivation undergirding this literature review—*How do we develop leaders who possess the virtue of seeing their* *personal success as interdependently linked to the well-being of other living beings on the planet*—this literature review explored how nurturing excellence, motivation, and creativity, combined with ecological education, the maker movement, mentoring, and educational leadership, contribute in part and in concert to the development of such innovative people.

Orr (1992) introduced ecological competence and ecological literacy for all people as necessary means for the earth's population to achieve global sustainability. Orr noted, "The study of environmental problems is an exercise in despair unless it is regarded as only a preface to the study, design, and implementation of solutions" (p. 94), for which ecological competence and ecological literacy are prerequisites. Senge (1990) explained how systems thinking, as an integrating discipline, incorporates multiple bodies of knowledge to contextualize all the phenomena at play in a system, which creates effective conditions for learning. Dougherty (2013) introduced the concept of the maker mindset, which is essentially an attitude of capability and ingenuity empowered by familiarity with iteration. Wagner (2012) found that innovators' mentors encouraged "collaboration, multidisciplinary learning, thoughtful risk-taking, trial and error, creating, and intrinsic motivation" by promoting "play, passion, and purpose" (p. 200).

In concurrently considering Orr's (1992) concepts of ecological competence and ecological literacy, Senge's (1990) laws of systems thinking, Dougherty's (2013) description of the maker mindset, and Wagner's (2012) description of mentoring innovators, the nexus of these works led to my further inquiry. In reviewing their work as a synthesized whole and through a lens of developing ecological innovators, the following synthesizing questions emerged: How do we develop ecologically minded systems thinkers who can address the challenges of this world with ecological innovation? What would result from mentoring children to care for their environment, understanding the world from a systems-thinking lens, and guiding them in the ways of the maker mindset—to be quick to learn from mistakes, iterate, and try again? What would happen if, in the dual context of an outdoor ecological education program combined with a makerspace, students received high quality mentoring? What would happen if these same students were guided into adaptive ways of thinking, including nonlinear systems thinking, which addresses causality, iterative prototypical thinking, and creative constructive thinking? What would happen if, within the maker movement, a strong ecological education component was introduced?

Louv (2009), Krasny and Monroe (2016), Orr (1992), and Daloz (2004) showed that children raised in nature not only grow to love and understand nature, the cycles of our planet, and how all living things connect in one system, but also reap holistic benefits such as health and wellbeing. As in benefitting from nature, the following literature also points to ways children benefit from ample time and nurturance in makerspaces. In synthesizing Martinez and Stager (2013), Corcoran (2008), Dougherty (2012, 2016), Peppler and Bender (2013), and Smay and Walker (2015), children benefit from the opportunities such as creating, learning how to work with tools, and solving problems—all experiences that playing and producing in makerspaces afford.

The literature review on mentoring framed what mentors do, mentoring and positive youth development, and mentors of innovators. Mentoring has been "associated with positive and personal career outcomes" (W. B. Johnson & Ridley, 2004, p. xv). Ensher and Murphy (2005) encouraged mentors to focus on long-term succession planning and investing in the next generation, as well as building relationships with multiple mentors from a variety of fields (pp. 31–32). Ensher and Murphy explained that developing mutual trust is a hard requirement that allows mentors to trust their protégés enough to release the protégé to take risks knowing that the mentors will help guide them back to recovery from failure by helping them learn from the mistakes (p. 149). Because mentors foster a growth mindset for their mentees, they nurture the protégés' self-confidence (Dweck, 2015; W. B. Johnson & Ridley, 2004). Lerner et al. (2014) linked mentoring to six indicators of positive youth development: "competence, confidence, connection, character, caring, and . . . contribution to self and society" and guided mentors to nurture their mentees towards these outcomes (pp. 23–24). The multifaceted influence of mentoring as described in the preceding review, builds a comprehensive picture of how mentoring can positively influence protégés. All the exemplar eco-innovators had mentors and received the benefits of mentoring, which were described within the literature; hence, mentoring became a line of inquiry for this study's interview protocol.

The review explored literature from the domain of educational leadership that connects the relevance of this study to school settings. This included two frameworks: Scheffler's (1985) framework for understanding human potential, and a framework for 21st Century learning (Kay, 2010). The 21st Century learning framework provided a structure for educators to equip students to "think, learn, work, solve problems, communicate, collaborate, and contribute effectively throughout their lives" (pp. xx, xxiii). Additionally, this framework aimed to support students' "creativity and innovation, flexibility and adaptability, and leadership and cross-cultural skills" (Kay, 2010, pp. xx, xxiii). Westheimer and Kahne (2004) organized a framework around three onramps for engaging in democratic civic action. Dweck (2015), W. B. Johnson and Ridley (2004), and Lerner et al. (2014) provided examples of executing the mentoring theory in practice. G. W. Johnson (2014) provided guidance for educators to support their students' creativity, including connecting students with mentors and creating an environment conducive to entering flow. Piirto (2014, p. xxi) introduced several concepts to bolster creativity, including incubation, improvisation, inspiration, imagery, imagination, intuition, and insight. Kettler and Sanguras (2014) encouraged teachers to practice and provide opportunities for their students to improvise because it leads to "open-ended inquiry and an environment of exploration" (p. 8). Regarding supporting motivation in schools, this literature review explored Pink's (2009) suggestions for schools to maximize motivation by leveraging the three motivating drives: the drives for autonomy, mastery, and purpose, which connects to Dougherty's (2012) description of innovation "in the wild" (p. 12), Papert's philosophy of constructionism (Papert, cited in Martinez & Stager, 2013, pp. 73–74), and Wagner's (2012) concept of intrinsic motivation relying upon play, passion, and purpose (p. 200).

The reviewed literature that addressed how schools can either obstruct or promote meaningful learning such as innovation included Westheimer's (2015) work, which urged educators to provide an effective civic education that would foster students' future democratic engagement. This connected to Orr's (1992) argument supporting ecological literacy, that ecological sustainability requires a renewed and active "civic competence" (p. 84). Further, Westheimer (2015) and Levinson (2012) called out how standardized testing takes away from more fruitful types of learning.

Both Isaksen and Akkermans (2011) and Jacobs and Alcock (2017) addressed leadership to promote innovation. Isaksen and Akkermans (2011) asserted that leadership must promote a climate that supports innovation in order for innovation to thrive (p. 181). Jacobs and Alcock (2017) proposed a change in policy to hold educational leaders accountable for supporting innovation in their schools and backed this proposal with five tenets.

Both Bryk et al.'s (2015) PDSA cycle for educators to improve their schools and Heifetz and Linsky's (2002) cognitive tools to understand dynamic processes in leadership provided models that can be purposefully implemented to support innovation within the realm of ecological innovation, as well as in school improvement leadership.

Given this extensive exploration of topics to understand the domains relevant to eco-innovation more completely, this inquiry is not only grounded more securely in the literature, but also undergirded with more targeted questions. What would happen if we raise motivated and creative youth to collaborate, innovate, and integrate digital with hand-wielded tools? What if we also raise youth to be mindful of how their innovations might have unexpected consequences for other inhabitants of our planet? What if we raise youth to employ foresight and technical skill to tweak their prototypes before any harm is done?

A few aspects of ecological innovation stood out in this review. Iterative prototyping was an essential aspect of innovation, and the maker movement specialized in this practice. The ecological education literature suggested that a sound ecological education that included ecological competence, ecological literacy, knowledge of the categories of human impact on our planet, and systems thinking would ground learners in the essential scientific understanding to responsibly steward the environment. The mentoring literature indicated that mentoring has the potential to provide students with the nurturing, guidance, and training to apply their skills and curiosity with passion, purpose, and perseverance. Motivation and creativity are fuel for the journey.

Leveraging the nexus of the bodies of literature covered in this chapter to design a qualitative research study to inform educational leadership, I conducted qualitative research case studies on exemplars similar to those chronicled in this review (Boyan Slat, Chai Karamchedu, and Aidan Dwyer). After gleaning initial information from reading about their lives and watching their videos, it compelled me as a researcher to interview other bright spot innovators like them to see if any running themes among their lives might suggest a tweak or addition to education.

CHAPTER 3

Method

Introduction

The purpose of this study was to answer the guiding research questions:

1. What do people who have produced ecological innovations, and others associated with them, report as the critical experiences, factors, and conditions in their development as ecological innovators?
2. What factors and conditions do ecological innovators suggest can inspire ecological innovation among their peers and young people?
3. What pathways towards ecological innovation and common experiences, factors, or conditions emerge from the stories of ecological innovators?

This chapter outlines the research design and methodology used for this study, describing researcher bias, background, and role; delimitations; ethics; and participant recruitment and selection in detail. It presents instrumentation, data collection, limitations and field issues, and data analysis procedures. This chapter also addresses data validity, verification, and security.

Overview of Research Design: Multiple Case Study Approach

The multiple case study method fits the purpose and goals of this research. It allows each of the study's three unique cases to be investigated and analyzed as discrete complete cases, as well as analyzed as a whole body to get at the quintain, the area of target interest, which was the phenomenon of becoming an eco-innovator. Stake (2006) defined *quintain* as "an object or phenomenon or condition to be studied—a target, but not a bull's eye. In multiple case study, it is the target collection" (p. 6). For this study, the quintain was the phenomenon of being an eco-innovator. This study is comprised of one quintain of three cases of eco-innovators.

The foundation for this research design was a multiple case study, which could be described as a repeated application of an *instrumental* (also called *single*) case study (Creswell, 2013, p. 99). Creswell (2013) explained that a case is a bounded set, such as the story of one person, one community, or one relationship or project. For this study, each case was bounded by the parameters the research design placed on the study. That is, each case was first bounded by the criteria established by the study's delimitations—if potential participants did not meet the delimitation criteria, then they were not considered for selection. Second, the cases were bounded in that, for auxiliary participants to be considered for the study, a primary participant or primary participant's parent (in the case of a minor) must have suggested them as potentially helpful informers about the primary participant's development as an eco-innovator.

Stake (1995) described an *instrumental* case study as one used to help gain insight into a research question by investigating that particular case (p. 3). He suggested that an instrumental case accomplishes more than understanding the specific person who is the subject of the case; it also sheds light on the area of inquiry, for which there is "a need for general understanding" (p. 3). Moreover, he asserted that in a multiple case study, also called a *collective* case study, the researcher chooses multiple individual cases to investigate the research question. Stake introduced the idea that each individual case must be considered as its own whole, even as simultaneously considered part of the collection of cases. Stake (2006) named this tension the "case–quintain dilemma" (p. 1). He explained that the researcher gains a deeper understanding of the quintain through the dual processes of comprehending the individual cases as unique stories and comparing and contrasting specific aspects of the individual cases that collectively are considered a whole body.

This process gives the researcher an understanding of the phenomenon of interest that would not be possible without delving into the individual stories. By using the multiple case method, this study sheds light on the specific, described through individual cases, and yields generalizable findings by paying attention to the quintain and viewing the data as a whole.

Researcher

Researcher Bias and Background

Qualitative research, according to Stake (1995, p. 95), "champions the interaction of researcher and phenomena." Stake asserted that responsible research requires accurate recording and description of the data that arose from the study. Even so, he warned, "interpretation of those phenomena will be shaped by the mood, the experience, the intention of the researcher. Some of these wrappings can be shucked, but some cannot" (p. 95). He addressed this issue of *bias* by advocating for transparency and encouraging researchers to "give the reader a good look at the researcher" (p. 95). This section responds to Stake's call for researcher transparency.

I am an educator with experience in teaching science, leadership, community service, and communications. I have taught nursery, elementary, middle, and high school; adults, undergraduate, and graduate students. I have worked on contributing positively to the field of education for more than two decades in a variety of settings, including public and private schools, after-school settings, summer camps, educational television, nonprofit settings, local government service, and higher education.

I have a Master’s in Television Production, through which I learned the art of interviewing people to get a good story. This background in documentary arts influences my interviewing style—I use an interview protocol but allow the interview content to flow like a natural conversation, putting everyone at ease. I reflect back to the people with whom I am talking to check for understanding, which also validates, for them, that they have been heard. The opportunity to tell their stories anew to a fully attentive listener often leads people to draw new connections in their thinking and gain new insights about themselves. As such, I often do not interrupt when something has been shared but for which I do not have context. Instead, I will look it up later to understand more deeply what they had shared. For instance, as you will read in the next chapter, Primary Participant Elisha shared that the Six Day War and the Yom Kippur War were influential to his becoming an ecological innovator. I did not understand the reference at the time. Researching them after the interview, I understood more deeply how those conflicts were key factors in his development as an eco-innovator.

A summer appointment teaching biology in Hawaii sparked my interest in ecological innovation. Two events together made a significant impression upon me. The first occurred during a service fieldtrip. While my students and I weeded an invasive seaweed species that had been choking the native sea grass species into decline over a period of years, a peculiar fish swam around my feet. One of the ocean educators pointed to it and called to the other participants. With great enthusiasm, the educator said the fish is a great sign of hope that the work they had been doing was making a difference. That fish, a keystone species for the habitat, had not been seen in that area for a long time. Its appearance indicated that the native sea grass was making a comeback. This moment cemented in my mind the importance of taking ecological action.

The second key moment that inspired my interest in ecological innovation occurred while I participated in a beach cleanup—and witnessed ecological innovation firsthand. The ocean educators used an innovation they had created to remove debris, such as plastic, from the sand. The device looked like a large window screen framed with sturdy wood and attached with bungee cords to a larger wooden frame that surrounded the screen. The larger screen was built with legs like a table. People would pour buckets of sand onto the screen. Someone would shake the framed screen, causing the sand to pour through the bottom, clean and free of plastic and debris that could not fit through the mesh. After a couple of hours of many people pouring their buckets of sand through this innovation, barrels full of plastic were removed from the sand. This experience filled me with both great sadness and purposeful hope. Years later, when considering dissertation ideas to study, I felt inspired to study something related to ecological innovation.

Creswell (2013) explained *bracketing* as a means of providing transparency of bias by "discussing [my] personal experience with the phenomenon" (p. 78). Given this explanation, I must bracket out myself as a parent with definite beliefs about nurturing my sons towards excellence in their present and future lives. As a parent who puts a great deal of intentionality into my children's educational and enriching life experiences, I entered this research with bias in my belief that parents can influence the outcome of their children's lives. One of my sons is a maker, and I arrange life experiences to enrich and inspire his making proclivities. I do this because it seems to bring him joy, but upon reflection, I realize I also believe that this support will somehow improve his chances to succeed and to contribute something positively influential to society someday. My other son is oriented towards social-justice issues. I put the same energy into finding and creating experiences for him to exercise and grow in his areas of interest. I do this because of my belief that it will strengthen his character and increase his capacity for doing good work now and in the future. It is this bias for viewing parental influence as a likely cause for young people to pursue creating eco-innovations that I must bracket for this study.

Researcher as Biographer and Interpreter

Stake (1995) introduced the idea that a case researcher often plays different roles throughout the course of the research: “teacher, participant observer, interviewer, reader, storyteller, advocate, artist counselor, evaluator, consultant, and others” (p. 91). He further explained, “Each researcher consciously or unconsciously makes continuous decisions about how much emphasis to give each role” (p. 91). In describing the researcher as *interpreter*, he stated, “Finding new connections, the researcher finds ways to make them comprehensible to others” (p. 97). As an interviewing *biographer*, I elicited the primary participants’ life stories via interviews and supplemental forms of data then composed vignettes to encapsulate those stories. The vignettes were narrative representations of individual interviews that held only the content of that one interview from that person’s perspective. I took the role of interpreter during the interviews. In the spirit of checking for understanding, I repeated to the participants my interpretation of what they had said, sometimes offering a connection I had made in their story. The participants often agreed with that interpretation, but if I had not fully understood their meaning, they further expounded on their points. I was also a *teacher*, as evidenced by the instance when my checking for understanding led a participant to have a new insight about their own life story, forging a new connection between an experience in their past to their present.

Delimitations

The participant selection criteria delimited this research. A second tier of delimitation occurred when I stopped pursuing one of the original case participants due to lack of available auxiliary case participants and supplemental information about the participant.

This study did not aim to prove or disprove that certain factors and conditions cause people to become eco-innovators or, due to sample size, to gain statistically significant information about ecological innovators. Instead, it was designed to build comprehensive case studies to gain a qualitatively rich sense of eco-innovators and their circumstances.

Adhering to Ethical Standards

I maintained a concerted effort to adhere to ethical standards throughout the dissertation process. I completed the National Institute of Health's "Protecting Human Research Participants" course (Appendix F) and attained Lesley University's Institutional Review Board approval (Appendix G) prior to working with human participants.

Informed Consent

All primary and auxiliary participants signed informed consent forms (Appendix C). For the participant under 18 years old, a parent also gave expressed and written consent (Appendix D). Before each interview, I reviewed the participant's rights with them and reminded them that they could withdraw, ask questions, or stop the interview at any time for a break or permanently. I then asked participants to provide verbal assent before the formal interview process commenced. Thus, I attained expressed and written consent (Creswell, 2013) for each primary and auxiliary participant.

Participant Confidentiality and Anonymity

To maintain confidentiality and anonymity for the primary and auxiliary participants, I changed names, specific locations, and other identifying information. This introduced a small but addressable issue, in that some participants preferred I write about them using their real names because they could benefit from the recognition or publicity for their work. However, I was clear from the initial communication that, even if they wished otherwise, I would protect all identities and identifying details or locations for the purposes of this doctoral research. The participants understood and agreed to these terms. To honor that anonymity, some details about themselves or their innovations are described only vaguely in this dissertation.

Data Security

I kept the data anonymous and secure by assigning codes and pseudonyms to each participant. First, participants were assigned alphanumerical codes, such as PP1 for Primary Participant 1 and PP1-Mom, for the mother of Primary Participant 1. Later, when writing the cases, pseudonyms replaced those codes. All data were maintained on a password-protected computer using FileVault for Mac, and transcripts in password-protected accounts on Rev.com, Trint.com, and NVivo, a data analysis software program developed by QSR International and supplied by Lesley University. Signed participation forms were kept in a locked safe, and all personally identifiable data will be kept locked and secure for 5 years.

Participant Diversity

This was a criterion-based multiple case study with three cases, two of individual eco-innovators and one of a paired team. I honored diversity within the small sample set to the extent possible. The four primary participants were: for Case 1, an Asian-Caucasian American female in her teens who implemented biomimicry to design a solar-powered condominium in the shape of a pinecone, covered with flexible solar panels arranged in the Fibonacci sequence; for Case 2, an Israeli male in his mid-50s whose innovation focuses on bringing solar power to developing communities; and, for Case 3, a Palestinian male and an Israeli female in their mid-20s whose innovation focused on improving water quality and safety for people without consistent access to water or water infrastructure.

Participants

Selection Criteria

This study aimed to find the factors and conditions in young people's lives that might influence them to become ecological innovators. As summarized in Table 3, the following criteria guided participant selection (Creswell, 2013, p. 158). The person must have

- Started to develop their first ecological innovation before the age of 30 years. (This age cutoff did not restrict people older than 30 who started eco-innovating before the age of 30 from participating in the study. However, the criterion was based upon the assumption that the factors and conditions that motivated a person who started eco-innovating after the age of 30 may not be as relevant to influencing schools and parents of young children as the factors and conditions that motivated younger people.)

- Spoken English fluently. (I cannot speak any other language as fluently as English and did not want to miss important information or nuances that would have been lost if I conducted the interview in another language or with the help of an interpreter.)
- Made a novel ecological solution consistent with the definition of ecological innovation as presented in the definition of terms section of the Introduction: *A process or product created by an eco-innovator. This object or process must in some way aim to mitigate or ameliorate detrimental environmental conditions or promote the survival of living creatures in context of their natural environment.*
- Created an eco-innovation for personal motivation or academic interest, and not for an employer. (The employment element could confound my inquiry of the person's drive and motivation.)
- Individuals in their lives who are familiar with the ecological innovator's development, available, and willing to serve as an auxiliary participant.
- Given consent and, if the participant is a minor (under the age of 18), also have the written consent of a parent or legal guardian to participate in the study. (In the case of a minor participant, the parent or legal guardian will be the responsible participant for reading and approving the vignettes and subsequent cases as part of the participant checking process.)

Table 3. *Selection Criteria to Serve as a Primary Participant for a Case*

Factor	Inclusion criterion	Exclusion criterion
Age	Started making first eco-innovation before the age of 30 years	Did not start making ecological innovation until after the age of 30 years
Language	Spoke English fluently (does not have to be first language)	Did not speak English fluently
Process	Engineered a novel process or product (e.g., science-fair project or at-home innovation) to ameliorate or mitigate anthropogenic affects to the earth or the life it sustains or to help make life more sustainable for the people and creatures living on earth	Used a kit or predesigned project for a science-fair entry
Biomimicry goal	Used *biomimicry* (the practice of emulating biological structures and processes to inform innovation and design) to make an innovation that directly aims to ameliorate or mitigate anthropogenic affects to the earth or the life it sustains or to help make life more sustainable for the people and creatures living on earth	Used biomimicry to make a product that is “cool” but not directed towards ameliorating or mediating anthropogenic affects to the earth or the life it sustains
Motivation	Made eco-innovation from personal motivation or during time of academia	Made eco-innovation for their employer; Came up with innovative way to support environmental causes either fiscally or practically; Social entrepreneurs, environmental activists, environmental educators who had not engineered, developed, or constructed some object or process to ameliorate or mitigate anthropogenic affects to the earth or the life it sustains or to help make life more sustainable for the people and creatures living on earth
Consent for minors	Youth eco-innovators under the age of 18 years who had parental/guardian consent to participate in the case study and who provide personal consent for themselves (both affirmations required to include a minor in this study)	Youth eco-innovators under the age of 18 years whose parent/guardian did not give consent to participate, and youth eco-innovators under the age of 18 years who do not give consent to participate, even if their parent/guardian gave consent

Sampling Method

In addition to the selection criteria (Table 3), two methods were used to identify participants—snowball (or chain) sampling to connect to “cases of interest from people who know people who know what cases are information-rich” (Creswell, 2013, p. 158) and opportunistic sampling to “follow new leads; taking advantage of the unexpected” (p. 158).

Recruitment

Primary participants. Participant recruitment aimed for diversity in gender, race, and ethnicity, using both the selection criteria and the “snowball or chain” sampling method. Being an ecological innovator was the essential criterion required for participation eligibility. The chain sampling method involved asking each participating ecological innovator for leads to other ecological innovators, which proved helpful in finding other criteria-meeting participants (Creswell, 2013, p. 158). This sampling method led to primary participants from the United States, Israel, and Palestine.

Recruitment began by reaching out to two eco-innovator exemplars: Boyan Slat through his organization’s website and Chaitanya Karamchedu through his school principal via email. Both inquiries were declined. I then developed a recruitment website to explain the research. It included a dynamic initial contact form that sent potential participants’ information to me. To attract potential candidates to the website, I created a recruitment flyer that explained the research and included a QR code that linked to the recruitment website (Appendix H). I posted the flyer near the ecological studies classrooms at a California university with a specialized ecological innovation program. Targeted recruitment emails (Appendix I) that included the flyer were sent to professors I had met at a conference on sustainability and innovation and at an ecology-oriented community event, and to an environmental engineering professor in my network.

These higher-education contacts worked in settings that, according to their program websites, support ecological innovation. Because the intent was to keep the case study size between two and six participants, outreach targeted only three university professors from three parts of the United States. However, despite the professors' enthusiasm and encouragement, the website, flyers, and outreach to professors yielded no participants.

The next recruitment step leveraged local networking with nature-education-oriented nonprofit organizations; I met with two organizations' leaders. A phone discussion with the leader of a Massachusetts nonprofit that promoted science for youth, combined with word of mouth recruitment, led to the primary participant for Case 1, Chaeli, who designed her eco-innovation at the nonprofit's summer camp. Although I did not use this phone call in the case, it helped me understand Chaeli's educational summer experience when she spoke of it in her interview. Soon after this phone call, Chaeli's mother submitted the form on the recruitment website in accordance with the criterion for minor participants (summarized in Table 3).

Local networking continued as the outreach expanded to include Facebook and Twitter. The second participant was identified through a social connection via a doctoral cohort colleague who knew of an ecological innovator making a presentation. My attendance at that presentation led to recruiting the primary participant for Case 2, Elisha, and to meeting the team of Jaffer and Leah, who became the primary participants for Case 3.

Auxiliary participants. The design for this study included ascertaining the perspectives of influential people, such as parents, mentors, or teachers, to provide perspective on the primary participants' lives. Each primary participant generated a list of people to interview on their behalf to provide informed perspectives on the primary participant's life as an eco-innovator. The following people (by pseudonym) participated as auxiliary participants: Chaeli's mother, Lily; Chaeli's gardening mentor, Seth; Chaeli's science teacher, Mrs. Wu; and Chaeli's grandfather, Grandpa; Elisha's mother, Hannah, and Elisha's middle-school science teacher, Dr. Sterne; and Jaffer's host-mother and mentor, Malia. Jaffer and Leah also provided auxiliary perspectives on each other.

Compensation. All participants and auxiliary interviewees received a thank-you email, with an option to choose either a $25 gift card or a $25 donation in their name to a charity of their choosing. Additionally, each participant received an entry into a random drawing for a $100 gift card that was conducted and delivered at the conclusion of the data collection.

Description of Primary Participants

The recruitment process yielded the primary participants for the three cases: Chaeli, Elisha, and the pair of Jaffer and Leah. It also yielded another potential participant who was dropped later from the study due to a lack of auxiliary perspectives and supplemental data.

The primary participants in each case designed something to ameliorate or mitigate an environmental problem. Like the range of exemplar innovators explored in the literature review (Chapter 2), the study participants' innovations were at different levels of ideation or implementation—ranging from science project to international implementation. The three cases covered in this study were Chaeli, innovator of Pine-Condos; Elisha, solar innovator; and Jaffer and Leah, team innovators of a water-monitoring app.

Primary participant for Case 1: Chaeli. Chaeli, a middle-school aged Asian-Caucasian American female living in New England, created *Pine-Condos*. Her innovation used biomimicry to design a model of a condominium complex in the shape of a pinecone. Solar panels shaped like pinecone scales surrounded the building with mathematical adherence to the Fibonacci Sequence. For Chaeli's case, her mother, science teacher, grandfather who mentored her in science, and camp counselor participated in interviews to share their perspectives on Chaeli.

Primary participant for Case 2: Elisha. Elisha, an Israeli American man in his 50s living in Israel, had developed a patentable solar cell as a teenager. He has since become a solar-power systems innovator aiming to provide solar power to communities in the developing world. For Elisha's case, his middle-school science teacher and mother gave interviews about his development as a young innovator. His wife also gave permission to use her published memoir, which included relevant experiences and characterization of his development.

Primary participants for Case 3: Jaffer and Leah. Jaffer and Leah are an innovation team who created a water-monitoring app for people in areas where water is in short supply and therefore stored in rooftop tanks. Jaffer, a Palestinian man in his 20s, innovated more than one water solution to help people access and monitor clean water in developing or ostracized communities in the Middle East and Guatemala. Leah, an Israeli woman in her 20s, is an award-winning eco-designer who has collaborated with several groups to help design earth-friendly products using McDonough and Braungart's (2002) *Cradle to Cradle* approach. For Jaffer and Leah's case, both also served as auxiliary participants because they spoke descriptively about one another. Jaffer's house mother, who mentored him during his time living in the United States, participated in the study as an auxiliary participant to their case. Table 4 presents interview participants by case.

Table 4. *Interview Participants by Case*

	Case		
Interview participant	1. Chaeli Biomimicry design for solar-powered condominiums	2. Elisha Solar power to the people	3. Jaffer and Leah Water-monitoring app
Primary	1	1	2
Auxiliary: primary participant's			
Mother	1	1	
Science teacher	1	1	
Mentor	2		1
Total interview participants	5	3	3

Setting

I interviewed primary and auxiliary participants individually (except for Chaeli and her mother, who were interviewed together) in safe, comfortable settings agreed upon by the participant and me. Because these interviews were audio recorded, I suggested to the participants that the settings be quiet so the audio would be free of background noise. This turned out to be variable among the participants; some settings had more background noise than others. The settings included a hospital room, a café, the outdoor seating area at the primary participant's innovation lab, two public libraries, a quiet indoor seating area in the vestibule of a university museum, and home living rooms.

Instrumentation

Through the literature review (Chapter 2), it was possible to anticipate factors and conditions that could be in the eco-innovators' lives. These findings shaped, but did not restrict, the design of interview instruments.

Data Collection Tools and Procedures

The researcher-developed interview protocol can be found in Appendix A. Each case study began with an interview using this protocol with the primary participant. During the first meeting, recommendations and contact information for potential auxiliary participants were gathered using the researcher-developed questionnaire (Appendix B). Transcripts from these primary participant interviews served as the foundation for each case. Individuals who the primary participants mentioned as influential were interviewed using a form of the original interview protocol tailored to the auxiliary participants and focused on gathering information about the primary participant. Drawing materials were available during each interview, and interviewees were invited, but not required, to use them.

Additional data collection tools included observation notes taken during the interview that provided more insight into the participants, such as details about the participants' behaviors, mannerisms, symbolic clothing, jewelry, or actions during the interview; illustrations that participants generated during interviews; internet videos featuring the primary participant; online articles or published materials about the primary participant or their work; relevant correspondence; and new information about the eco-innovator gained through the participant-checking process (Creswell, 2013, 2014). Digital photos taken of drawings created during the interviews were included as data. In one case, the participant sent digital copies of his initial innovation sketches. These data collected were stored and backed up with secure password-protected technology. Each case had its own protected file for all related data, which consisted of primary and accompanying auxiliary participants' audio interviews, diagrams, illustrations, notes generated during interviews, surveys, observation notes, and any other supplemental materials (also see Appendix E).

Table 5 provides an overview of the forms of data collected, and Figure 3 visually depicts the data in relationship to the individual cases and to the quintain. Creswell (2013, pp. 161–162) "encourage[d] individuals designing qualitative projects to include new and creative data collection methods," which include, for case studies, "a wide array of procedures as the researcher builds an in-depth picture of the case." Referring to Yin's 2009 work, Creswell recommended multiple forms of data collection for case studies, such as "documents, archival records, interviews, direct observation, participant observation, and physical artifacts" (pp. 162–163). Creswell additionally recommended constructing a matrix to organize the multiple types of data collected for the cases. Each primary participant in this study had substantively different forms of data that contributed to each case (see Table 5, Figure 3, and Appendix E).

Table 5. *Forms of Data Collected for Analysis by Case*

Data source	Case: 1: Chaeli Biomimicry design for solar-powered condominiums	Case: 2: Elisha Solar power to the people	Case: 3: Jaffer and Leah Water-monitoring app
Interview			
Primary participant	1	1	2
Primary participant's mother	1	1	
Primary participant's science teacher	1	1	
Primary participant's mentor	2		1
Video, primary participant speaking on their innovation		1	1 (Jaffer)
Video, primary participant as an eco-innovator			1 (Leah)
Newspaper article about primary participant		1	
Book with content about primary participant		1	
Online artifacts, documents about primary participant	1	1	2
Supplemental research to provide context about primary participant's life		1	1
Attended event/presentation that gave deeper context about the primary participant's activities	1	1	1
Observation notes	1	1	2
Total data sources	8	10	11

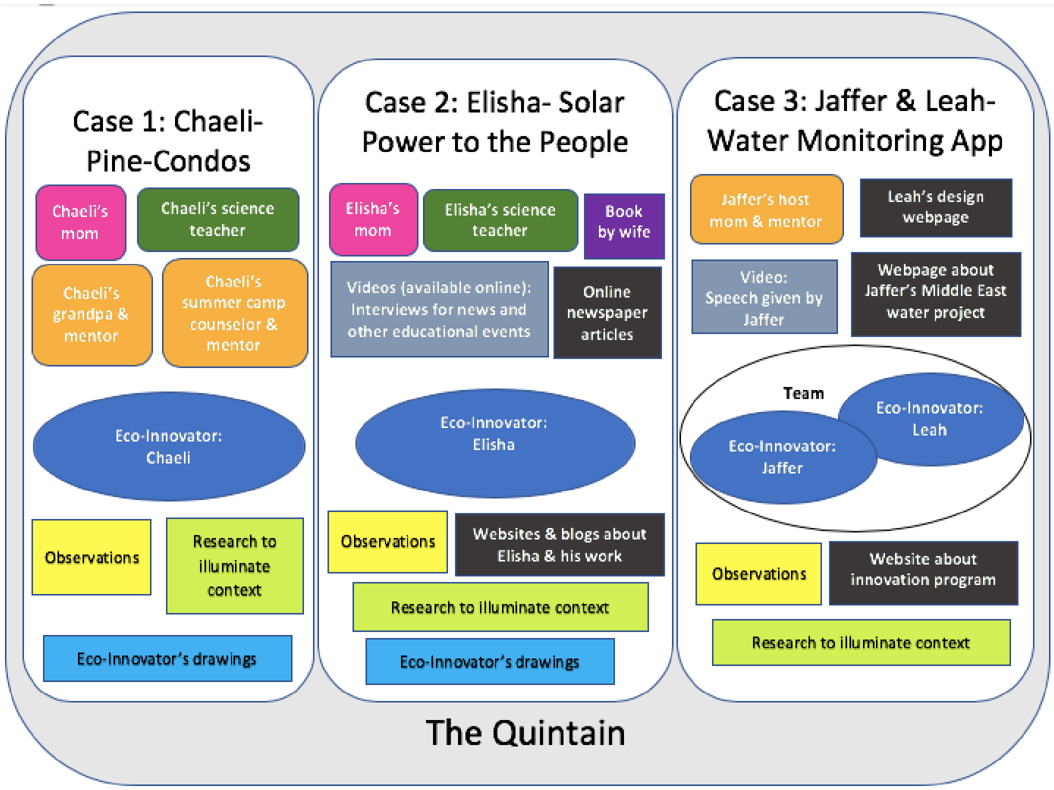

Figure 3. The case quintain structure for the multiple case study research inquiry.

Data Analysis Procedures and Data Representation

Analysis of the data gathered used both an *emic focus* and an *etic lens* (Creswell, 2013). An *emic focus* means the stories conveyed in the case section transmit the participant's, rather than the researcher's, viewpoint (Schutt, 2012). An *etic lens* shapes the cases and the method by which the data are interpreted. Because researchers are human, the viewpoint is inherently subjective and processed through the researcher's etic lens (Creswell, 2013). Further, Stake (1995) asserted that case studies are inherently empathetic. Given that empathetic stance, I aimed to maintain fidelity to the participants' perspectives by using participant's statements and expressions as literal building blocks for almost every sentence in each case.

The data analysis for this study did not occur in a linear process. Schutt (2012) described the process of interpreting data as a dance for two—the researcher and the data—“a complex and dynamic craft, with as much creative artistry as technical exactitude, and it requires an abundance of patience, plodding, fortitude, and discipline” (p. 323). Both Stake (1995) and Schutt (2012) referred to Parlett and Hamilton’s 1976 concept of *progressive focusing*, which accurately describes my process of engaging with the data interpretively from the beginning and throughout the data-gathering phase. I used that progressive understanding to hone the research inquiry with each progressive and follow-up interview to focus on investigation areas that seemed fruitful in terms of meaningful data.

In terms of the practical execution of the data analysis, two concurrent streams of analysis occurred: a case-writing process that involved theming the data (both the emergent themes and themes that directly connected to the themes from the literature review) and a coding process. In the coding process, I used NVivo to code the transcripts for the purpose of quantifying and comparing the prevalence of those themes. Because each case was analyzed as its own entity prior to analysis as part of the whole quintain, each analysis procedure was tailored specifically to that unique case. The “Gathering Themes from Cases” section summarizes the individual case analysis process. Then, the “Data Analysis Process” describes managing the balance of data gathering and analysis for the three cases and the quintain. Appendix J provides additional details of the order of events.

Gathering Themes from Cases

Content used to build each case generally included interviews and follow-up communications with the primary and auxiliary participants. I used NVivo to organize and code the raw interviews using eclectic coding, which primarily used in vivo (participant's own language) and descriptive (summarizes primary topic) coding methods (Saldaña, 2016). For the second step, I composed vignettes based on each interview, which I sent to the interviewees for participant checking and editing. I then used the participant-approved vignettes to serve as the foundation for a long-form narrative case based on the primary participant's interview and enhanced with participant-checked content from the other contributors.

After the first long-form case was composed, I organized codes from the raw data into themes that were culled for the quintain analysis. I then edited this long-form case to a short-form case based on initial emergent themes for both the case itself and the case in the quintain context. I coded the short-form again using eclectic coding (Saldaña, 2016). I iteratively organized the codes and collapsed them into the themes reported in the Results (Chapter 4). The resultant themes from each case were used for cross-analysis of all three cases in the quintain (at end of Chapter 4).

Chaeli's case procedure. Table 5 and Figure 3 (preceding) show the interviews and content sources used to build Chaeli's case. That content included a pair-interview with Chaeli and her mother Lily, a solo interview with Lily, follow-up phone conversations with Lily, and follow-up communications with Chaeli and Lily; an interview and follow-up written communication with Chaeli's science teacher Mrs. Wu; an interview and follow-up written communication with Chaeli's grandfather and mentor

“Grandpa”; and an interview and follow-up written communication with Chaeli’s gardening mentor, Seth. The participant-approved vignettes then were used to compose a long-form narrative case primarily based on Chaeli and Lily’s interview, then built upon with content from the auxiliary participants’ interviews and follow-up communication. Themes that emerged from Chaeli’s case were sorted by guiding question, recorded in NVivo, and then used to inform the quintain. These themes are reported and analyzed in the Results (Chapter 4).

Elisha’s case procedure. Content to build Elisha’s case included interviews and follow-up communications with Elisha, Elisha’s mother, and Elisha’s science teacher; videos and written content by and about Elisha available online, such as news interviews and online newspaper articles; Elisha’s sketches; and a published book written by Elisha’s wife (see Table 5 and Figure 3). The participant-approved vignettes used to compose a long-form narrative case were based primarily on Elisha’s interview, then built upon with content from his wife’s book, his science teacher’s interview, and his mother’s interview. I conducted research about relevant world events to support my understanding of the historical context and included relevant information from that research where necessary to clarify the case for the reader. Supplemental information from Elisha’s television interviews, newspaper articles, and presentations that Elisha gave were incorporated when relevant. Themes that emerged from Elisha’s case were sorted by guiding question, recorded in NVivo, and then used to inform the quintain. These themes are reported and analyzed in the Results, Chapter 4.

Jaffer and Leah’s case procedure. Content to build Jaffer and Leah’s case included interviews and follow-up communications with Jaffer, Leah, and Jaffer’s host-mother and mentor Malia; a video of a speech in which Jaffer addressed members of the U.S. House of Representatives at an event at the U.S. Capitol; a video about Leah collaborating with a group of blind artisans; online content about Leah as a grant award recipient; and information about the innovation program, the Israeli environmental institute, and the Middle East sustainability organization through which Jaffer created a water-filtration system for the Bedouin people (see Table 5 and Figure 3). The three vignettes based on the three interviews were used to compose a long-form narrative case. Supplemental information from the online materials about Jaffer, Leah, or their innovation program was used to enhance my understanding and clarity of the case. Themes that emerged from Jaffer and Leah's case were sorted by guiding question, recorded in NVivo, and then used to inform the quintain. These themes are reported and analyzed in the Results, Chapter 4.

Analysis in Eight Steps

All written interview transcripts, audio recordings, online video recordings, and other forms of textual data were typed into Microsoft Word™. The entire corpus of raw data was imported into NVivo, organized into the three cases, and then coded. The data analysis occurred in eight steps (Table 6).

Table 6. *Data Analysis Process*

Step	General analysis	Use of NVivo	Use of case writing	Purpose/result
1	Organized content from interviews and supplemental data. Initially coded data.	Entered all raw data into NVivo. Coded data using eclectic coding process: mostly used in vivo and descriptive coding.		Large number of codes emerged. Allowed researcher to see initial emergent themes.
2	Wrote individual interview vignettes. Participants checked vignettes for accuracy & anonymity.		Organized data by case. Used raw data from interviews and supplemental data to write vignettes of each specific interview.	Served as primer to convey story. Helped researcher understand themes holistically. Participants checked and validated data.
3	Compiled all data from a given case into one unified narrative case (repeat three times—once per case).		Constructed three individual long-form cases from the consolidated participant-validated vignettes & supplemental data.	Provided deeper understanding of each case. Illuminated first round of themes as content was conveyed thematically under organizing headings.
4	Winnowed cases to reveal emergent themes from cases.		Condensed the three long-form cases into three short-form cases. Wrote sections reporting the emergent themes per case. These were used as formative material for writing of quintain analysis.	Provided a second round of themes. Provided deeper understanding of each case. Made cases more palatable for readers.
5	Quintain analysis: considered emergent themes from all three cases as a whole.			Collapsed emergent themes from three cases into unifying themes across all cases.
6	Quintain/cross-case analysis	Used NVivo matrix coding to see collapsed themes (by frequency) across all three cases.	Reviewed cases for expressions of top themes calculated by NVivo. Wrote quintain themes to connect themes to case content.	Revealed final themes that emerged from this multiple case study. Connected themes to cases (Chapter 4).
7	Organized themes under guiding research question they answered.			This was first step to ascertain findings
8	Collapsed themes into findings.			Revealed the findings.

Coding Process

Both the NVivo and case-writing coding processes leveraged the holistic coding method of eclectic coding to incorporate in vivo, descriptive, pattern, and versus (binary-term) coding to preserve the participants' meanings and find connections and patterns in the data (Saldaña, 2016). Using a balance of inductive and deductive coding allowed new themes to emerge and confirmed the themes present in the exemplar cases from the literature review.

Each case was analyzed first with holistic coding, then hypothesis coding, and then with a return to analysis of the emergent codes. After each case was analyzed individually, the quintain was analyzed as a whole to see what themes existed among all three cases. To ensure qualitative validity, I engaged in Creswell's (2014) recommended strategies to help ensure validity of the data analysis process.

Case-Writing Process

The first stage of the analysis portion of this research involved listening repeatedly to the interviews through the interview-transcription process. I transcribed all interviews with the primary participants and some auxiliary interviews. The other auxiliary interviews, as well as the online video content, were transcribed initially through the transcription services Trint.com and Rev.com. I then verified, corrected, and further detailed them. Table 7 shows the complete list of participant interviews by case and how each was transcribed.

Table 7. *Interview Transcription Methods*

Case	Participant interview/data	Method: Researcher-only transcription	Not audio recorded (written content and notes in analysis)	Trint app[a] supported transcription	Rev.com transcription
1: Chaeli	Chaeli	X			
	Mother (Lily)			X	X
	Mentor (Grandpa)		X		
	Science teacher (Mrs. Wu)		X		
	Mentor (Seth)			X	
2: Elisha	Elisha			X	
	Science teacher (Dr. Sterne)				X
	Wife		X		
	Mother				X
	Supplemental television interviews and other video content				X
3: Jaffer & Leah	Jaffer			X	
	Leah			X	
	Jaffer’s mentor				X
	Jaffer’s speech (available online)				X

Note. [a]The Trint app transcriptions needed significant edits; they served only as a starting point for researcher’s transcription.

The transcripts were then turned into vignettes, which were then consolidated into cases. That process involved deleting unrelated content (e.g., chatting about the weather) from the transcripts and researching contextual information, such as the Yom Kippur War. Then, focusing on one part of the interview at a time (e.g., an interviewee’s response to one question), I converted the transcript wording to the third-person point of view and arranged it for themes, story flow, and chronology. After the primary participant checked and approved the vignette, I repeated the process for each auxiliary interviewee. I added the auxiliary vignettes and supplemental information to the primary participant's vignette to complete the long-form case narrative. Once participants checked this version, I further edited the narrative for content and clarity into the case that appears in Chapter 4. This process is described in additional detail in Appendix J.

Qualitative Validity

I employed six of the nine strategies Creswell (2014) listed to achieve qualitative validity: "spending a prolonged time in the field," "triangulation," "member checking" which is referred to as *participant checking* in this dissertation, "rich thick descriptions to convey the findings," "clarifying the bias the researcher brings to the study," and "using peer debriefing to enhance the accuracy of the account" (pp. 201–202), as well as a method of external auditing to strengthen the data analysis.

Prolonged time in the field. I spent a prolonged time in the field to develop an in-depth understanding of the phenomenon of what went into the lives of eco-innovators. This began by studying the exemplar innovators presented in Chapters 1 and 2 in August 2016. I attended conferences and fairs on environmental sustainability and eco-innovation, Maker Faires, and environmental talks by professors at various events. Outside the interview process, I engaged in educational discussions about eco-innovation with a professor of hydrology and sustainability, a professor of environmental engineering, a marine biologist, a geologist, entrepreneurs, and science educators, and engaged in an expanded look at related literature. Data acquisition and participant checking continued for 11 months after the first primary participant interview in June of 2018.

Triangulation. *Triangulation* is the use of more than one approach to research an inquiry (Heale & Forbes, 2013). Besides the understood purpose of strengthening validity, Heale and Forbes (2013, para. 4) referred to Tashakkori and Teddle's 2003 handbook on mixed-methods research, to explain that triangulation can also be used to yield "complementary results" that highlight "different aspects of the phenomenon," or to enable "divergent findings" to "lead to new and better explanations for the phenomenon under investigation."

I triangulated the data by interviewing the primary participant; conducting auxiliary interviews and gathering supplemental materials such as news articles and online content (written and video material) about the eco-innovators; and verifying the written cases through the participant-checking process.

Participant checking. I used participant checking to "determine the accuracy of the qualitative findings" (Creswell, 2014, p. 201). By sharing the written vignettes with the participants and attaining their feedback, input, and agreement about the portrayal of data that represent them, the participants validated the texts that comprised the cases (Maxwell, 2013). The case-writing process offered three distinct opportunities for participant checking. First, the three adult primary participants and Chaeli's mother were asked to read and give corrective feedback on their specific case write-ups, and I incorporated their feedback. Second, the auxiliary participants were each asked to read their vignettes, which were based on their individual interviews. These auxiliary vignettes were then modified based on their input. All participant-checked vignettes were developed into a multiple-perspective case study based on the primary participants. Third, once completed, the adult primary participants and Chaeli's mother were asked to read the draft of their long-form cases for accuracy, participant privacy, and general feedback. Corrections were made and the feedback was incorporated into the next draft.

Rich thick descriptions. I aimed to compose "rich thick descriptions" for the reader to engage more readily with the case protagonists' stories (Creswell, 2014, p. 201). I wanted to capture the setting, the tone, and the very essence of the primary participants through these cases. Additionally, when a participant mentioned an event or setting, such as their hometown, a program in which they had participated, or a world event such as a war they experienced, I read about it to understand more fully the eco-innovators' contexts and experiences.

Clarifying bias. I addressed potential bias earlier in this chapter and revealed it transparently in this dissertation's dedication and acknowledgements sections. I also disclosed my position and potential bias to participants in our opening conversations and in the informed consent paperwork.

Peer debriefing. A graduated PhD cohort member served as a peer coach and debriefing partner by reading drafts, providing feedback, asking questions, and providing qualitative research design references. This peer also performed a data analysis and coding as part of an external audit. I also had the support of a doctoral committee from ideation to completion. Creswell (2014) asserted that this strategy adds validity to the researcher's account.

External audit. After using NVivo to create a codebook of all the codes, the PhD peer coach coded the transcript from Jaffer's interview three times using in vivo, process (using gerunds only to describe actions), and values (inferring participant values and beliefs) coding (Saldaña, 2016). This alternative approach to the data analysis instigated peer discussion that prompted critical thinking about my choices for how to interpret, code, and name clusters of data. As a process, it supported deeper engagement with the data analysis and reduced threats to validity.

Limitations

A limitation of this study was the small sample size—three cases of four primary participants. Their stories were rich and informative, but the data yielded were not analyzed with the intent of showing statistical significance, nor can the data be used to state definitively any trends specific to the general population of eco-innovators. The number of cases was decreased by one. That is, one potential primary participant provided a wonderful first interview but I was unable to gather enough supporting data for that eco-innovator from auxiliary interviews or supplemental data; therefore, I dropped that case from the study.

Another limitation was the intersection of time constraints with variable access to primary and auxiliary participants. Three primary participants were available for face-to-face data collection for only a brief time before traveling back to their home countries (Israel and Palestine). Their short stays eliminated the possibility of in-person follow-up interviews. The geographical barrier also limited me from visiting their innovations in context; however, via video footage, I viewed Elisha's innovation. Seeing their innovations in context may have given me deeper understanding of the problem they were solving or stimulated me to ask questions that could have revealed informative data about their case.

Even though all primary participant eco-innovators were fluent in English, not all potential auxiliary participants were. The language barrier thereby limited the number of auxiliary participants for the case on Jaffer and Leah. I also was not able to obtain the perspectives of the participants' fathers for different and equally valid reasons. Finally, one potential auxiliary participant agreed to participate but then did not respond to further communication.

Recording and transcribing the interviews turned out to be an iterative process that evolved over the course of the study. Initially, I recorded the interviews with a Dictopro™ digital audio recorder and a video camera recorder as backup. However, for reasons explained in the Field Issues section, I stopped using the video camera as a backup device and started using a phone-app for transcription as back-up to the Dictopro™ voice recorder.

Field Issues

Creswell (2013) noted that field issues can occur during research. Although I had planned to use a video camera for a backup recording device and as a potential tool to capture important visual information, the camera and its supplemental equipment proved too cumbersome to carry and seemed inappropriate in spaces such as a hospital room or public environment, where setting it up would draw undue attention to the interview taking place. Also, if the setting did not have an electrical outlet nearby, the video camera battery did not last long enough for some interviews—and interrupted the interviews by beeping to indicate low battery. Hence, after the first two primary participant interviews (successfully recorded with the Dictopro™ voice recorder), I did not use the video camera as a backup device.

Having much success with the Dictopro™ and frustration with the video camera, I conducted one auxiliary participant's interview with only the Dictopro™ as a sole source of recording, but it failed to record the interview. After my discovery that the interview had not recorded (in the presence of the auxiliary participant), the participant graciously sent me an email with written responses to the interview questions to compensate for the failed recording. She stated that by reviewing the questions after the interview, she was able to remember quite a bit of what she had said.

Following this incident, I used the Trint™ app, a password-protected automated transcription service with a phone application that enabled my iPhone to record the interview and then automatically transcribe it. This app (and later, Rev.com) was used in parallel with the Dictopro™ for the remaining interviews. The uploaded automated transcripts saved time by pre-transcribing an approximation of the interview; however, the software-translated interviews needed much editing and led me to use the Trint™ transcriptions only as a base for my own transcription. Even when the sentences were transcribed inaccurately, the audio recording was clear, which made it easy to listen to and transcribe accurately. Discussing this imperfect process with other doctoral researchers and my dissertation advisor led me to try Rev.com, another password-protected transcription service, for the remaining transcriptions. By that point in the research, the data included supplemental materials such as a video of one candidate giving a speech (available on YouTube) and an auxiliary participant phone interview. Rev.com had very few errors.

Another field issue was that one auxiliary participant did not feel comfortable having the interview audio recorded. To honor the participant and make her feel comfortable, I asked if she would feel comfortable if I took notes on the laptop during the interview. The participant agreed. Therefore, for that interview, I did not audio record the interview but took approximated verbatim notes in MS Word on the computer during the interview. This interview happened to be part of the eliminated case, so it did not directly affect the results of this study.

Chapter Summary

This chapter outlined the research design and methodology for this multiple case study, including the rationale for this design; the researcher's background, potential biases, and role; delimitations; sampling method; participant recruitment, selection criteria, and description; interview setting; and analysis method. This chapter also reviewed the study's limitations and field issues.

As a criterion-based case study, participants were selected based on their meeting the required criteria, their willingness and consent to participate in the study, and, in the case of the minor, a parent's consent and willingness to participate as an auxiliary participant. This chapter discussed the instrumentation and the data collection and analysis procedures and provided a transparent explanation of my research process, procedures, and commitment to adhering to rigorous ethical standards. Except for the portion analyzed during the external audit, I alone collected and analyzed all data. I typed some transcripts and submitted others to a confidential, password-protected professional transcription service.

CHAPTER 4

Results: Cases, Quintain, and Findings

Introduction

This chapter presents the three cases followed by a data analysis of the quintain. I chose the case study method to research eco-innovators for two reasons. First, based on previous work in the field, including Wagner's (2012) study of what makes an innovator in general and Bloom's (1985) developmental study of what factors and conditions go into the lives of people who achieve excellence, I learned that people's developmental stories are often contained in the memories of more than one person, such as their parents, mentors, and teachers. Case study allows for interviews from different perspectives on the same topic. Thus, for that multiple-perspective intention, case study was a good fit. Second, newspapers often write articles about eco-innovators, and filmographers video their work, and I wanted to include artifacts such as those articles, videos, and documents that contain relevant information about their stories. The case study method was a good fit for that purpose, as well. This chapter closes with a presentation of the findings as they relate to the three guiding research questions:

1. What do people who have produced ecological innovations, and others associated with them, report as the critical experiences, factors, and conditions in their development as ecological innovators?
2. What factors and conditions do ecological innovators suggest can inspire ecological innovation among their peers and young people?
3. What pathways towards ecological innovation and common experiences, factors, or conditions emerge from the stories of ecological innovators?

The first case presented covers the story of Chaeli, a middle-school-aged American (U.S.) girl who designed a model for Pine-Condominiums, a solar powered building. The second case follows the story of Elisha, an Israeli man who started innovating solar designs when he was in high school and who later established an innovative solar-power solution for communities. The third case explores a team of two serial eco-innovators, Jaffer and Leah, who each had created more than one eco-innovation prior to meeting each other. Jaffer and Leah collaborated to create their water-monitoring app to serve people who store water in rooftop tanks. After the three cases, the themes that arose from the quintain analysis are presented, which leads to the findings of this investigation.

Case 1: Chaeli–Designer of Pine-Condos

Chaeli, the innovator of “Pine-Condos,” a proposed architectural innovation that employs biomimicry in the design of a completely solar-powered building, participated in this case study at the beginning of summer vacation after her sixth-grade year. The interviews were held in her mother Lily’s antepartum hospital room. Lily was not sick but on strict bed rest to prevent pre-term delivery of her third child. Sitting with her legs propped on her mother’s bed, Chaeli was searching her school yearbook she had just received. Every time she found herself in a picture, she got excited. She pointed out mistakes: a picture used twice; someone’s name spelled wrong.

Chaeli came across as thoughtful, confident, and friendly. She demonstrated unbridled affection for her mother as she cuddled up to her in the hospital bed.

Early Childhood

When asked to tell her life story leading up to her eco-innovation, Chaeli replied simply: “I was born.” She paused. Intentionally or not, that statement—her pause—in the context of her unborn sister’s high-risk situation, was loaded with sober awe.

Chaeli is the second child in a family with a mother, father, and now three children. Her older brother Ryan was born with trisomy 21, or Down syndrome. This circumstance contributed to Chaeli’s development. Ryan routinely participated in structured support activities for social and emotional development, so from the time Chaeli was an infant, she engaged in early intervention along with him. Because Ryan was late to develop speech, he learned American Sign Language (ASL)—and Chaeli learned ASL with him. She communicated with Ryan and the ASL-signing babysitter fluently. Thus, she grew up with ASL as her co-first language.

Chaeli remembered learning about science in kindergarten. She mentioned going into the school garden and explained that the gardens were supplied by “this agency that works with our schools so that they all have gardens and stuff.” She jumped to a scene from third grade:

> When we were writing poems, a turkey flew down into our garden and everyone went to the window to stare at the turkey, and then a bunch of people wrote poems about the turkey. And then I wrote this really funny poem about school that detailed it as a prison, which was really funny to all the other students, because even back then I was known as the smart kid, like a nerd or whatever you call it. So, everyone was really surprised that I wrote that poem. But you know, I was kind of bored in school.

Family Context: Dinner Games and Thematic Learning

Both of Chaeli's parents have graduate degrees in business, as well as science undergraduate degrees. Her father's undergraduate degree is in environmental science. Chaeli was born into a family that had always gone on bike rides and hikes and participated in earth cleanup days. The family belongs to the Massachusetts Audubon Society, a nature conservation organization, and participate in Audubon Society events, such as clean ups and nature-themed birthday parties. Recycling and composting are normal family routines.

Another family routine is having dinner together every night, with the rule that there will be no books or phones at the dinner table. They often play a game they made up called, "Questions of the House." At her mother's urging, Chaeli explained the game: "So, my brother will say some random thing, like 'where did spinach originate?' And then, like, we'll guess and someone will look it up. Then we'll be like 'spinach originated in so and so.'" Lily expounded upon Chaeli's initial description of the game:

> It's all these random questions, and then we try to keep a record of it in a book. . . . We talk about it, and it becomes competitive. It's whatever we're doing at that time. So, like when, right after we came back from the Space Camp, there were all these questions about space.

Lily explained that the purpose of the Questions of the House game is to field the children's curiosities, keep the conversation going, and make the children think about things. Lily noted, "Those questions do kind of move in themes, depending on what's going on in our lives. . . . We just let the conversation go wherever it needs to go." Lily also revealed her philosophy underpinning the Questions of the House game: "I think giving them that freedom and creativity to explore [their questions] ignites their curiosity." In fact, Lily reported that both children have continued to test rockets. Chaeli added that they had tested water as a rocket fuel a couple of days prior to the interview and would be testing solid rocket fuel on the upcoming Sunday. Chaeli and Ryan had gone to Space Camp 15 months prior to the interview and were still testing rockets and researching solutions for space junk.

Lily started thinking about all the ways they continued to follow the space theme as a family. She listed going to the local science museum regularly, attending the museum's special observatory nights when they open their giant telescope for the public to view the night sky, attending observatory nights at a local university, and visiting the Smithsonian Institute. As she reflected, she summed up that their family activities were physically active and science or outdoor related, and their family had been like that from its beginning.

Context: Growing up in an Eco-Conscious City

In describing her city, Chaeli remarked on its absence of nature, but after describing its typical buildings, her thoughts lit upon a nearby patch of nature:

> I'm very, very lucky because less than a block away from me, it's essentially like this huge . . . there's this field, it has a baseball diamond. But besides the baseball diamond, there's this field with lots of grass and nature, and we go there a lot and we play soccer and stuff like that. . . . Sometimes at that field, we'll see bunnies and stuff like that. Actually, I think the first video I ever took on my phone was of this bunny fleeing to the bleachers off the field.

Noting that the city hosts several scientific industry businesses, as well as research universities, Lily commented on their eco-conscious urban environment:

> Living in our city really facilitates that because there is a lot about stuff, you know, bike riding in the city and trying to make that easy for folks with bike lanes—and most families have only one car—they share cars and a lot use public transportation, and there are a lot of city parks. Right by our house, there is a beautiful street that is closed on Sundays to really encourage recreational use of the river. There is a lot of accessible recreation to the river, so there's sailing, boating, all these things outside. Then there's all the stuff like city composting and recycling.

Lily also noted that a nonprofit organization partners with the school district to provide holistic gardening education for the public schools. The program starts in pre-kindergarten and grows in complexity each year into middle school. Lily credited the local schools for contributing to a context that can facilitate interest in things such as science and the environment. They provide students opportunities such as Math Olympiad and Genius Hour, a program designed for students in the sixth grade and up to have mentored exploratory time with local science professionals.

Another benefit of their city, Lily explained, is the free summer programming for youth. Some students even are paid a stipend to participate. Lily described how the city markets the summer offerings:

> Our city runs a summer-camp fair night, and all the camps go there and. . . families are invited to come. And we took the kids around and said, "Why don't you look around and see if anything looks interesting to you?"

Chaeli chimed in, “So I looked around and grabbed all these flyers and I thought, ‘Oh, there’s this girls’ science camp this looks cool! You get to invent stuff!’” Her attendance at that girls’ science camp that summer stimulated her to create an eco-innovation there. However, that stimulus was given to Chaeli within a larger context, in which her home life, previous schooling, and the gestalt of her city and its industries promoted environmental stewardship and innovation.

Empathy for Living Things and Care for the Environment

Lily mentioned that Chaeli was compassionate towards all living things, animal or human. Chaeli added that the first time she felt compassion for other living things, she was very young, looking at a red panda in a zoo habitat. “It was all alone and sad. . . . It made me sad because it was all alone.” Her empathy for animals is part of a larger emotional sensitivity. Although she divulged feeling sadness, she demonstrated a great deal of happiness and joy as she shared her catalog of animal photos on her iPhone. She started with the video of the rabbit darting from the bleachers at her local park. Coming upon a series of photos of her holding a fish she had caught while vacationing in Pennsylvania, she preemptively defended herself: “Whenever we go fishing, I never kill it or keep any of the stuff I catch. I send it back.”

As she scrolled through her iPhone photos, she found a series of animal shots she took on vacation in Florida and noted, “There’s actually a lot of wildlife in Florida.” Showing a picture of birds, she relived the story of tiptoeing cautiously towards them to get a closer picture. As she swiped through, she narrated her shots of lizard, crows, “duckies,” a frog, and a giant leaf that amazed her with its size.

When the children were younger, the parents chose nature-oriented vacations because they personally enjoyed those types of vacations. As the children got older, Chaeli's parents gave them choices but always included nature-oriented options. For instance, Lily explained, she would offer, "'Would you like to go to a Seaquarium camp or Disney World?' and they would pick Seaquarium camp because it's more fun, you know?" She reflected that she and her husband started the habit of doing nature and environmentally oriented things on vacation but, over time, the children grew their own interests in environmental and scientific options. As a result, Chaeli has chosen camps with opportunities for her to swim with marine mammals such as dolphins, manatees, and seals while learning about scientific themes such as conservation.

Chaeli recalled learning about the Great Garbage Patch in the Pacific Ocean when she was about 8 or 9 years old. She had been playing an interactive geography app on her iPad that showed interesting animals around the world along with international landmarks. "It was like you would spin the globe and you would see all these things—places like the Taj Mahal—and I remember, one of the things was the Great Garbage Patch." She clicked on the Great Garbage Patch and the app started giving details about this phenomenon in the Pacific Ocean. Chaeli described her experience of that moment:

> I was really sad that all this plastic and garbage and junk was just floating in the ocean. And it's the size of Texas, too. And I, well, at that time, I didn't really have a good understanding of how big Texas was, but Texas was bigger than me, and Texas was bigger than Massachusetts, and Massachusetts was big, so it was a lot of garbage.

She repeated her sense of sadness and her resolute decision to not throw plastic into the ocean.

Math Olympiad

Chaeli participated in Math Olympiad from third through fifth grades. She would arrive at school early for the practice. As she recounted, Math Olympiad was open to all students who earned an A average in math. Chaeli rated the experience as “pretty fun.” Math Olympiad would send her home with homework, but Chaeli reported that she almost never did it unless her parents found out there was homework and sometimes made her do it.

When she learned about the Fibonacci sequence in Math Olympiad, Chaeli remembered feeling like, “Oh, this is cool.” A couple of years later at the science camp for girls, while looking at nature images, another camper mentioned the Fibonacci sequence. Chaeli thought, “Oh yeah! We can use The Fibonacci sequence like on a pinecone.”

During our interview, Chaeli drew a freehand sketch of the Fibonacci model (Figure 4). As she drew, she narrated. “The Fibonacci sequence can be found a lot in nature. You know, like in seashells and snail shells and things like that. . . . It can be found on a pinecone. So that’s what gave us the initial idea.” Chaeli’s urgency to draw to help her explain came across as evidence of her desire to communicate clearly as well as a technique to help ground herself in her own thinking.

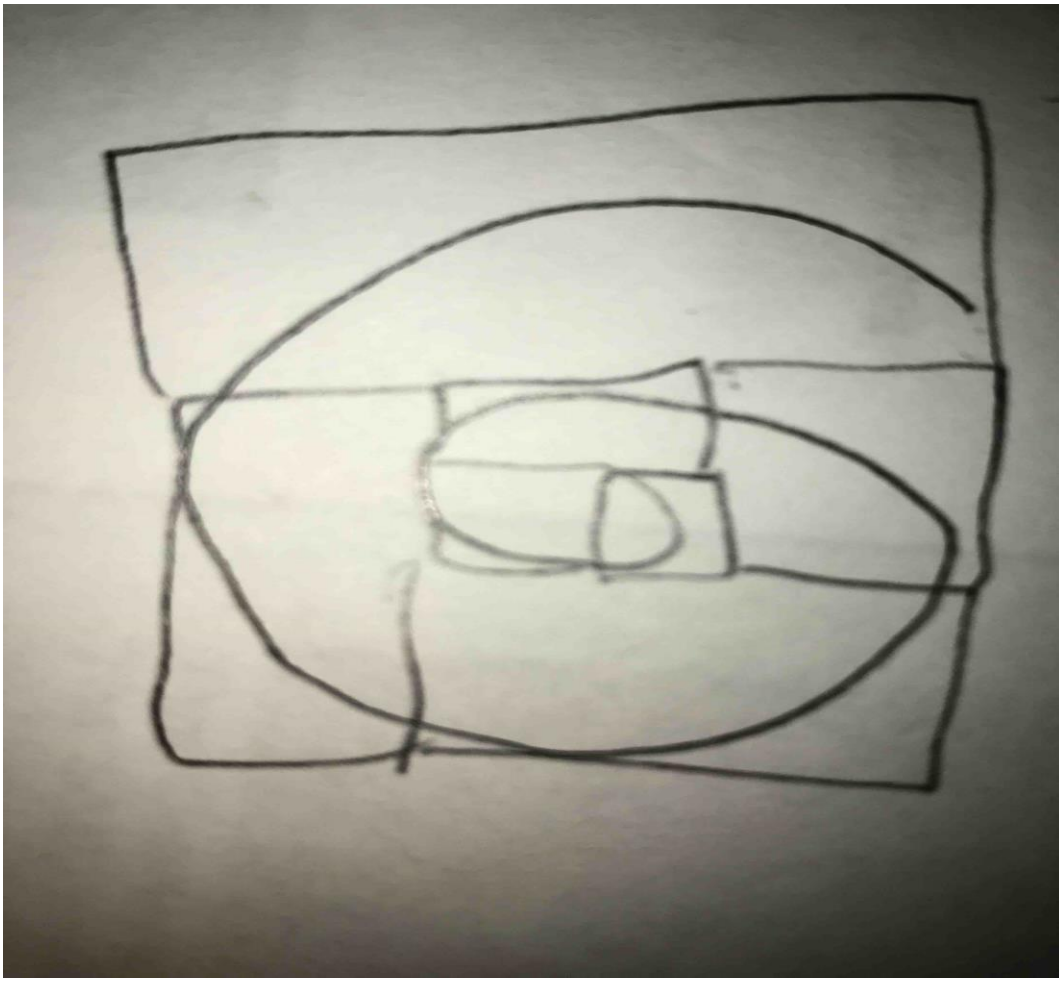

Figure 4. Chaeli's freehand drawing of the Fibonacci sequence.

Gardening

Chaeli started gardening at school while in kindergarten. Her city benefits from a nonprofit partner organization that supplies gardening and nature-based education for the school system. Chaeli engaged in a gardening curriculum that built upon itself each consecutive year of her public-school education. In kindergarten, she and her classmates went outside to find an excitingly large number of apples and were introduced to an apple press. The children took turns cranking the press and then drank the freshly pressed apple cider.

Lily described the gardening program from her vantage point of having an older child in the system. The students grow up along with the gardens as part of their elementary-school experience. In middle school, they build on their gardening knowledge in hothouses. The middle-school science classes use the garden to run experiments, gather evidence, and participate in authentic design challenges such as designing better greenhouses for the gardens at the program headquarters. Beyond the school year, Lily enthused about their summer internship program.

Chaeli piped up, “That’s what I’m doing for 6 weeks . . . this summer. . . . Paid.”

Her mother explained, “They pay the kids—these are 12- and 13-year-old kids—to basically learn how to be eco-sustainable citizens.”

Chaeli composts at the program. “The compost bins are disgusting,” she said, adding, “We have a journal prompt every day . . . then we take care of the garden for like a half hour. We water it, we weed it—we do stuff like that. Sometimes, we draw.”

Lily suggested that Chaeli’s gardening camp counselor, Seth, would provide valuable perspective on Chaeli’s development as an eco-innovator because he had mentored Chaeli a great deal to develop her environmental understanding.

Chaeli’s Gardening Camp Mentor’s (Seth) Perspective

Seth had mentored Chaeli in gardening and cooking skills for two summers in a row at the gardening camp. The gardening camp for fifth through eighth graders runs every summer in weeklong (Monday through Friday) sessions from 9:00 a.m. to 1:00 p.m. Camp starts every day with an opening circle, then the children play team-building games. Each day, the students work in the garden, prepare a meal with garden ingredients, and practice the steps in the complete food preparation cycle: planting seeds, tending growing plants, harvesting the food, preparing it for eating, incorporating it into a meal, and composting the refuse. The students participate in lessons that Seth pulls from a curriculum bank. They also learn practical kitchen skills, such as how to use a hot plate, electric skillet, knives and cutting boards, other kitchen tools, and recipes.

In describing how Chaeli engages in the camp, Seth acknowledged her for bringing a great deal to the program:

> She’s kind of more advanced than most kids there in terms of her education. So, the concepts or ideas that we try to teach, she’s able to communicate those to the kids, which helps because sometimes it’s easier to learn from their peers than from a teacher, necessarily, or an older adult. And I think that she cares a lot about it, too. So that’s another thing. And just like having the other students see her in that process, like caring so much and also being a little more advanced, I think gives them something to strive for.

Seth mentioned that he and his colleagues plan to continue nurturing Chaeli by inviting her to participate on the youth leadership team. The team meets during the school year to help improve the program “but also gives the students opportunities to learn and grow in terms of STEM learning and gardening. . . . There are opportunities for them to present their ideas and presentations to our board members and other adults.” According to Seth, immersing students in the care and maintenance of a garden trains them in environmental stewardship because it connects them with their environment and gives them a sense of what their environment can provide.

Seth has worked with Chaeli one-on-one at the camp and described her as an eager learner. He said it is clear she wants to do her best but she also seeks approval:

> She will come to you with ideas, and you can offer her feedback, and she—most times—will accept it. But she's also very headstrong and she knows what she wants to do. So, there are times where she will just continue to do what she wants and she'll make it work in the context that we give her.

He noted that she is more flexible with menial tasks, such as chopping vegetables, and will defer to adults when it comes to safety—but when it comes to design, she is headstrong, persistent, and less willing to stray from her initial vision.

Seth also has seen Chaeli deal with failure in the contexts of a recipe not turning out or accidentally burning the food on the griddle. In those instances, she needed some time to absorb the failure before she could "just take that big sigh and get over it." Seth saw disappointment in her facial expressions and body language:

> It's hard for her to fail in general. . . . I think she wants to work on something until she gets it right. It might just be hard for her to give up on it and start over again. First is fixing what she was working on before.

Mentors play a key role in setting up the relationship between the students and environment, Seth explained, so the students grow to truly care about the environment. Seth also mentioned that providing students with the materials and space to engage with gardening and nature was important. Expounding that mentors should actively "mak[e] that connection fun, enjoyable, and long lasting," Seth shared that facilitating a student's personal relationship with the environment does not always happen immediately. It often requires long-term development:

> A lot of the kids in the city are afraid of being out in nature and in the wild spaces because of the bugs or animals or they're just not used it. . . . So, I think just showing them that there's nothing to really fear about being in the garden [is important].

He further explained that as the relationship between the students and the environment is built, the students become more curious about and interested in the garden and nature, even to the point of advocacy.

During the summer program, Chaeli participated in a climate change lesson that Seth facilitated. The students learned about the mechanisms of climate change, the carbon cycle, how carbon is introduced into the environment, how plants, trees, and other organisms naturally take it out, and the impact humans are having on the cycle. The students were given tools and resources to look up a problem "within that whole terrible idea of climate change" for which they felt they could somehow affect positive change.

Seth addressed how difficult it can be to expose children to the horrible situation of climate change without overwhelming them with dread. In designing the climate change curriculum, he and his colleagues consciously thought about how to keep the students engaged with hopefulness:

> We were very focused on providing attainable solutions, or like having something like, "Here's what you can do," like, "This is a terrible

> problem, and it huge, it seems overwhelming, but here are some concrete steps that you can do to fix it." And that it is possible.

Further, the documentaries they chose to show to students (such as one about farmers going on a hunger strike for their wages) had a "light at the end of the tunnel." Chaeli was a part of watching this documentary and the debriefing session afterwards. Then, after all exposures to potentially overwhelming information about the consequences of climate change, Seth and his colleagues debriefed and discussed the issues with the students. Finally, because the students shared their work with the larger group, they provided hope to one another. Each student gave an example of an action step to make things better.

Chaeli experienced iteration at the gardening camp. Seth explained that iteration is built into the program within a larger commitment to a STEM learning process that includes the steps: (1) identify the problem, (2) think, (3) come up with a solution, (4) design that solution, (5) test it, (6) gather feedback, (7) improve, and (8) present your design or ideas to your viewers as either a final solution or an iteration to be improved. When Chaeli went through this cycle, she chose to continue to improve her design on her own time, beyond the camp's parameters. Seth shared that Chaeli went through this STEM design process to make a vertical garden project. She made her garden from plastic bottles cut open to hold dirt and connected by tubing so all three levels could be watered simultaneously. She was able to take her three-level water garden home to hang in her window and grow plants.

Seth noted that Chaeli's position as a younger sister to a boy with Down syndrome "forced her to be a little bit more humble" and to think about social dynamics.

This has helped Chaeli be [less] "I know what's best," and more like, "Let's see what the group decides," or "Let's see what's best for everyone," and not "best for me." I think that has given her an approach to "not help myself, but to help others."

Reflecting on this for a moment, Seth emphasized Chaeli's humility and then extrapolated that empathy is important for someone to be an innovator:

> I think the whole point of innovating means you're going to create something or design something that's going to help other people. . . . So, I think having a connection to the community or helping someone who needs help gives you the ability to empathize more and feel like that's something you want to do.

In considering the city context where Seth's organization provides school gardening programs, Seth connected the fact that Chaeli created an eco-innovation to her access to a camp that facilitates innovation: "I think just being able to have access to that makes a huge difference in whether or not that's something you would want to pursue." He contrasted Chaeli's access to summer programming, supplemented education, and her parents' support to that of a child living in another area whose city may not provide the same access and opportunities. He emphasized that her family has the interest and means to be able to "provide unique opportunities in this space."

Girls' Science Camp Leads to Eco-Innovation

The summer between her fifth and sixth grades, Chaeli attended her usual garden camp. The following week, in the same location, she attended the science summer camp for girls. At the science camp, she partnered with two other girls to use biomimicry to proto-design a solar-powered condominium. They modeled the design after a pinecone's structure, which follows the Fibonacci sequence. As part of the camp experience, Chaeli and her two friends “invented a company, called Pine-Condos, . . . like a pinecone . . . Pine-Condos. We made a logo.” Chaeli drew the logo on the whiteboard for me—it looked like a pinecone with the word *Pine-Condos* above it.

As part of the camp process, prior to designing their eco-innovation, the girls were led into nature, told to look around, and challenged to invent something using the practice of biomimicry. Chaeli’s group “found a pinecone, and we thought, ‘Oh, cool.’” At first, the play on words did not occur to the team. They just thought they would make a pinecone-shaped solar-powered building. Later, they realized they could combine the words and so they adopted the portmanteau, *pine-condos*.

During the camp activities that preceded their innovation process, the students walked for about 5 minutes to a (by city standards) nature-rich park. An abundance of fallen pinecones and butterflies populated the park. The children spent a lot of time just trying to catch butterflies. Chaeli and her team collected samples of natural objects, which included a pinecone, from the park. As they observed their samples, the team agreed that they would “use this pinecone.”

Using that pinecone as a template, Chaeli and her team made a first-draft model of her Pine-Condos innovation with the materials the camp supplied. Even though they envisioned actual solar panels, the camp materials used were purely representational. They formed pinecone-scale-shaped solar panels from modeling clay attached to a cylindrical tube. As Chaeli drew the model for me, she explained that the solar panels “would constantly turn to get the sun.” Chaeli’s design included a tree-root system for the multipurpose of anchoring the foundation and providing an organic-type pattern for the pipes and electrical wires to be positioned in the ground below it.

In describing the curricular process, Chaeli explained, “The camp was only 2 weeks. There was a deadline. We first came up with the concept maybe like halfway into the first week of camp. The model development started at maybe a week into camp.” As Chaeli and her team were thinking about the Fibonacci sequence, they planned for the larger pinecone-scale-shaped solar panels to be at the bottom. The panels would get smaller as they went towards the top of the building. Chaeli credited her third-grade Math Olympiad team for her understanding of the Fibonacci sequence.

Chaeli then described her experience working with the science-camp team to create their eco-innovation. The camp leaders assigned the student into teams and then delegated roles. One student took responsibility for the art, and another for facilitating the creative process and integrating their work. Chaeli described her role in the team as the math person who had generated the idea for the innovation. Chaeli said that it was fun working and collaborating with the team, although she lamented that one of her teammates went away for 3 days and the other was out sick for 2 days. Consequently, Chaeli worked alone for 2 days, during which she felt lonely; “I had nobody to pitch my ideas to, so I didn’t know if they were good or if they really sucked.” Even though her two teammates did not attend all of the days, Chaeli made a lasting best friend from that camp with a girl who was not on her team.

Chaeli’s mother added:

> I think making it fun is a big part of it. My daughter had a lot of friends at these camps and she really engaged with her peer group, so that made her

> want to go. Another element that was really fun was the competitiveness. Because kids this age like feeling that there is a prize at the end, that they're presenting at the end—so that's probably an incentive.

Chaeli reflected that the camp made her think about incorporating solar panels into her family life:

> I thought it would be cool having a solar panel running my house . . . because it's kind of like photosynthesis I guess—like artificial man-made photosynthesis. . . . It takes the sun's energy and it uses it to power your house, and that's kind of how photosynthesis works, where the plants take the sun's energy and they use it to power themselves.

Chaeli's Ideas to Support More Students Becoming Eco-Innovators

When asked to generate a recipe for making more ecological innovators, Chaeli generated the following plan:

> Step 1: Ask them [the students/participants] what they know.
>
> Step 2: Take them out to nature somewhere and point out cool stuff.
>
> Step 3: Take them to a landfill or like a cut-down forest—some place where they can see the effects of plastic and stuff—show them the effects on nature. Maybe show them a couple photos of the Great Garbage Patch and stuff like that.
>
> Step 4: Then ask them what they can do to make things better with that situation. Ask them what they can do to make, I don't know—a more eco-friendly landfill or something like that.

> Step 5: Then have them come up with some sort of invention or something like that that would be able to help some sort of problem, like coral reef bleaching, for example. Tell them to come up with an invention that will stop the spread of coral reef bleaching—something like that.
>
> Step 6: Then see what they've found. Then ask them what they've learned.
>
> And then, yeah, that's the end of your 1-day camp.

Chaeli said she had learned most of that from her science camp, even though the camp did not take them to a landfill or ask the campers what ecological problem they could solve. Rather, it guided them to look to nature for inspiration. Chaeli introduced the ideas of going to a landfill, visiting a clear-cut forest, and seeing pictures of the Garbage Patch because

> that would kind of show them what they're actually dealing with and the effects of trash and things like that can have on the environment and things like that. We actually did *not* go to something like that, but I feel like if we had, it would have had a bigger effect on the kids.

She logically explained that her reason for putting the step to ask what they can do to make it better after experiencing the deleterious consequences to the environment was because they would have just seen the problem. The next step would be to figure out how to solve it, "because everybody can make an impact."

Chaeli listed materials she would provide for her campers: journals, colored pencils, disposable cameras, rulers, acidity tests to test the land, clear plastic bags and folders, gloves, a trash picker, and body protection in case the land was toxic. She also mentioned that she would provide journal prompts to spark the campers to write about and illustrate the things they observed.

In thinking about this process, Chaeli iterated her Step 3: “Take them to a beautiful forest *and then* take them to a forest that has been cut down.” As she was honing her recipe for creating eco-innovators, Chaeli paused and shared, “You know, this park that is near my house used to be a landfill.”

She went on to plan her eco-innovator camp. “So, you could take them to the park and then to a landfill and then tell them that the park they just visited used to be a landfill and then that would be a good connection.” Chaeli indicated she believed this would ignite their interest in the relationship between garbage and the environment.

When asked to prioritize the steps of her plan, Chaeli concluded that the most important step was to expose children to the “nasty” places that human have created on the planet so they could see the negative impact on the earth. She suggested, if there were an unlimited budget, to take the group to the Pacific Garbage Patch because experiencing it would be far more impactful that just seeing photos. Paired with this exposure to “horribleness” is “asking them what they can do about the horribleness.” The next vital step was to challenge the participants to “invent something to deal with the horribleness.”

Even when prioritizing, Chaeli argued that keeping the steps of taking students to someplace beautiful and asking them what they already know are vital:

> [Exposure to the beauty of nature] shows them that nature is pretty, that nature is amazing, and that you know nature is awesome. But to contrast that, to take them someplace horrible will show them what will happen to nature if we keep doing stuff like this.

Thus, keeping the initial step of asking what the students know before entering into the lesson, Chaeli argued, is important because it is the place from which one can base research and plan lessons. As she imagined this plan for increasing eco-innovation in schools, she adopted the mindset of a teacher.

Science Teachers

In telling her life story, Chaeli mentioned her science teachers. Without prompting, she said, “In fourth grade, my science teacher was kind of great. We learned about light bulbs and we went outside and stuff.” She said her fifth-grade teacher inspired her environmental stewardship through the subject matter. “It was more about nature. You know, like we grew plants in bags and we went outside into the garden and we weeded the garden and stuff like that.”

Lily, aware of how the city’s school system works, contrasted her city’s science program with other school districts. In her district, starting in fourth grade, science teachers are specialists. Lily shared:

> The point is, the specialization starts early enough that the teachers feel like they own the subject and go farther with the kids, so I feel like they’re able to engage the kids more; that usually doesn’t happen until middle school or later.

Later, Chaeli mentioned that her sixth-grade science teacher at her new private school, Mrs. Wu, made a difference in her understanding the importance of ecological issues. Mrs. Wu assigned the students to find an ecological problem in the world and then do a project on it. Chaeli’s first choice was an investigation on coral bleaching. Because another classmate had taken that topic already, Chaeli then decided to do her project on space junk. She researched the problem of space junk, as well as two solutions, then put together a presentation and wrote a newspaper article educating her classmates about space junk.

During our interview, Chaeli clearly and comprehensively talked about space junk for 4 minutes. While explaining, she expressed optimism that we could find a novel way to solve the problem but admitted that people on Earth need to be willing to sacrifice satellite television for a couple of years. As she came to the end of sharing what she learned about space junk, she agreed that her teacher had given her a challenge—and she just ran with it.

Mrs. Wu's Perspective

When describing Chaeli, Mrs. Wu did not hold back:

> She is a stellar student in every aspect. She has a strong work ethic and came with a wealth of knowledge of the natural world. She loves to be engaged in hands-on experiments and she asks excellent questions. She likes to ask, "What if . . . ?" questions. She looks for exceptions to the rule. She dreams up unlikely scenarios. She thinks outside the box.

Mrs. Wu's account provided more detail about Chaeli's space junk project:

> After we had covered all the topics in our curriculum, we ended with environmental issues and concerns. I wanted the students to get a sense of the global crises we were facing without ending on a depressing note. I had each student pick a topic from a curated list and do research on the scope of the problem, some current initiatives, and potential solutions. Chaeli chose space debris because coral reefs were taken. There was not a

> whole lot of information out there; she struggled to find sources. But she did a fine job, found some stats, and built this little diorama.

Three years prior to Chaeli's matriculation at her private school, the headmaster had applied for a grant to build a makerspace. The school received the grant, and the administration and architects figured out how to situate the makerspace in the center of the school. Mrs. Wu reported that Chaeli "can often be found at the school makerspace."

Sharing Chaeli's enthusiasm for the makerspace and being connected to Chaeli's family through the same church, Mrs. Wu once invited Chaeli and her mother to join her at her neighborhood makerspace.

> [Chaeli] made a small house out of wood. She had several pieces of wood, but she needed to cut it. Though I was trained in power tools, I didn't feel comfortable using them around her, so I showed her how to use the saw. Though it was hard work, she persevered and ended up cutting the wood pieces she needed.

After Chaeli made the house, she sewed a pillow. Regarding her facility with the sewing machine, Mrs. Wu said, "Lily didn't know how to use a machine, so I am assuming Chaeli taught herself how to use the sewing machine."

Mrs. Wu also shared her perspective on Chaeli's relationship with her older brother. "Growing up with a sibling with special needs has given her [Chaeli] a heightened sense of compassion towards others and also a sense of wanting to right perceived injustice. She is very protective of her brother Ryan." Mrs. Wu shared an anecdote about Chaeli being the only sixth grader to speak in front of the entire student body of sixth to twelfth graders on the topic, “Welcoming.” According to Mrs. Wu, in her speech, Chaeli noted

> how welcomed she felt coming to this new school, but shared a story about her brother, sitting alone at lunch every day. She challenged the student body to be the kind of person who would leave their group of friends and sit with someone who sits alone. Everyone was moved by her story and awed by her poise and courage.

LEGOS®

Chaeli has many LEGO® sets and had used them for as long as she can remember. With the new baby coming, the family hired an architect to remodel the house—inspiring Chaeli to use her LEGOS® to construct her ideas for redesigning their house to accommodate the baby. Lily contextualized Chaeli’s fluency in the language and forms of architecture:

> So, my daughter has an interest in design. So, she was involved with some of the initial meetings with the architect. And I think that dialogue really peaked her interest and understanding in materials and understanding why we use different materials for different parts of the house and understanding different things like heating and windows and how that affects electricity and efficiency.

In thinking on her daughter’s use of LEGOS®, Lily shared her perspective. “I think LEGOS® and free play are so important for kids to unleash that creativity.” In reflecting on how most toys are given away over the course of a child’s development, Lily noted that Chaeli has kept all her LEGOS® and her dollhouse. Chaeli balked that her mother mentioned the dollhouse, but Lily pointed out that she uses the dollhouse to express her creativity of design. Hearing it framed that way, Chaeli agreed that she likes designing.

Activism

Lily reflected on Chaeli's activist nature and shared that her daughter has a precociously broad worldview for someone her age. Unlike other children who seem aware only of their immediate environment, Chaeli has a "sense of civic duty." Lily explained that Chaeli believes that she can make an impact on the world and sees the importance of affecting even "just one person." Like her mother and father, Chaeli's main arena of activism is advocating for children with Down syndrome.

Lily, an ardent advocate for children with Down syndrome, took a moment to explain, "My daughter's older brother has Down syndrome, and Down syndrome kids are targeted for abortion. So, one thing, my daughter is an activist on that position."

In support of her brother and all people with Down syndrome, Chaeli has participated in the March for Life. To raise awareness about people with trisomy 21, Chaeli sold mismatched socks, which represent the way the 21st chromosome looks in the genetic makeup of people with trisomy 21, to friends and classmates to wear on World Down Syndrome Day. She donated the proceeds from her socks sales to a Down syndrome advocacy organization.

Grandpa-Mentor Shares his Investment in Chaeli

Lily suggested that Chaeli's grandfather (Grandpa) should participate in the case study as an auxiliary participant because he directly mentored Chaeli in science. She noted that when Grandpa would come to visit, he brought hands-on science explorations and “fun experiments” for Chaeli and Ryan. Chaeli delightedly added how, with Grandpa, she learned about diffusion by putting different colored M&M candies in water and watching the color swirl off the M&Ms in streaks and then diffuse out into the water.

An intellectually sharp retired chemical engineer in his 90s, Grandpa listed a few of the scientific experiments he did with Chaeli and Ryan. He discussed each in great scientific detail, explaining that when he had planned the experiments, he mainly thought they would be fun ways to connect with his grandchildren; however, he also would explain certain physical properties and scientifically relevant phenomena as they arose. Describing Chaeli as “very curious,” Grandpa remembered that during the M&M-diffusion-in-water activity, she peppered him with questions: “Why is it doing that? You’re not moving the water at all, but the color is moving.” He explained to her that water always has currents running through it, even if she could not see it. He said, “[Chaeli] asks a lot of questions; she is nosy in a really good way.”

Prior to serving up scientific explorations for his grandchildren, Grandpa intentionally invested in others’ scientific learning. He volunteered for several years as a scientist mentor through a pen-pal program facilitated by the Boston Museum of Science until the program ended in 2000. He also volunteered as a guest science teacher for a YMCA children’s program where his daughter (Chaeli’s aunt) teaches.

Grandpa explained that he tried to bring something different for every visit. He kept a “Kids’ file,” a collection of experiments and demonstrations that came from the American Chemical Society and the American Institute of Chemical Engineers; he had been a member of both for more than 50 years.

Follow-Up Conversation with Lily

After Lily read the first draft of this case, she shared some final reflections. She reiterated how Chaeli's engagement with the early intervention services alongside her brother (even though she did not need it) and learning ASL "supercharged her brain." Lily recalled, "Chaeli was speaking really complex sentences before the age of 1 [year]."

Lily updated me on how Chaeli recently had been tending to the local homeless population, giving them bags filled with a toothbrush, toothpaste, water, and snack. She said, "Some people need a little extra help," and for Chaeli, "knowing that she can make a difference, . . . that's big for a 12-year-old."

For her final thoughts, Lily affirmed her daughter's disposition: "She is definitely really optimistic and has hope for the future. They say that love, hope, and faith are the things you need, and I feel that those three things that she's exhibited."

Case 2: Elisha–Solar Power to the People

Elisha, a dual citizen of Israel and the United States, approached this case study process with generosity and humility. He attempted to buffer any research expectations with the preemptive admission, "I don't know if I have that much to say." He admitted this lightheartedly, with a cocked head, shrugged shoulders, and one hand lifted and open. Humble in appearance, Elisha wore a rainbow Swatch watch and several cause-related bracelets: one for Bono's One Campaign, an organization committed to ending extreme poverty; another for Liberia—in support of getting the people access to power; still another for a peace program between Palestinian and Israeli youth; and one for the Rwandan youth village where he installed his first solar field. One carried the words of both Martin Luther King, Jr.—"I have a dream"—and Theodore Herzl (father of Zionism)—"If you will, it is no dream."

Elisha did not volunteer information about his numerous international awards and honors for his humanitarian work in bringing solar power to developing nations and people groups in need of a power infrastructure. Instead, he talked about his bracelets and made light of his staff's chagrin that he wears them at public appearances. Elisha singled out his last bracelet, emblazoned with the word *Hope*. He explained, "Hope is what the Jewish people represent to civilization, which is the value of hope. I think it's the most important one. I had this a decade before I put any other arm bands on."

Contexts: Anything is Possible in Israel, Oil Embargo, and Earth Day in the United States

Elisha grew up in Israel in the years following the Six Day War.[1] He described that the Israeli leadership's political narrative at the time easily fit the Biblical account of the Hebrew people as underdogs winning miraculously. He remembered Israel's winning of that war as filling his cultural context with "a sense of like anything in the world is possible." Sachar's (1996) historical account of that time in Israel confirmed Elisha's account, stating, "The Israeli people stepped from darkness into light. Even the bereaved

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[1] The Six Day War took place in June 1967 between Israel and Egypt to the south, Syria to the north, and Jordan to the east. By the conclusion of that brief war, Israel had gained control of the Gaza Strip and Sinai Peninsula to the south and southwest, the West Bank of the Jordan River to the east, and the Golan Heights in the north (Sachar, 1996).

among them were shaken by the overpowering relief of collective deliverance, by the unimaginable scope of their triumph, and by the crowning miracle of Jerusalem restored" (p. 667).

Elisha recalled the earliest catalyst for him becoming an eco-innovator was his second war experience—the Yom Kippur War.[2] When he was 8 years old, Elisha's family moved to a Boston-area town in Massachusetts so that his father could pursue his PhD. Elisha's bedroom window in their third-floor apartment overlooked a gas station. Elisha remembered

> looking out my window and seeing a long line of cars snaking its way out of sight down [my] street because of the Arab oil boycott, and thinking, "I can't believe there's like this war going on back in Israel" (where I was

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[2] The Yom Kippur War, also called the October War, was a continuation of the Arab–Israeli conflict. It erupted on October 5, 1973 (during Yom Kippur), when Egypt and Syria launched attacks on Israel. The geopolitics of that war exacerbated tensions between the United States and the Soviet Union, as each superpower backed their respective allies. Despite a perceived end to the war later that month, continued unrest and a sense of instability lingered (Sachar, 1996). The "Arab members of the Organization of Petroleum Exporting Countries (OPEC) imposed an embargo against the United States in retaliation for the U.S. decision to resupply the Israeli military and to gain leverage in the post-war peace negotiations" (Office of the Historian, U.S. State Department, n.d.).

> mentally from) . . . and like there's a continuation of war below my bedroom window.

When the Yom Kippur war broke out, Elisha engaged in discussions with his parents, in school, and within his Jewish community. When Jewish community leaders held a press conference on the steps of a local synagogue to declare their support for Israel, Elisha was there. He listened to all the speeches. "I just walked up to the podium and stood with all the leaders." He remembered feeling "a sense of unification, because I had come from Israel, and we were being attacked." Despite being with the leaders, Elisha felt powerless, which got his mind percolating. As a young Israeli boy living in America, he kept thinking, "We have to figure out something about this oil thing."

Shortly after participating in the Jewish community's show of support for Israel in the Yom Kippur War, Elisha started sketching solutions to rid the United States of its oil dependency. He first sketched a solar-powered car and then an underwater-wave machine to collect wave power. Elisha shared some sketches from that era. One (with his identifying name blocked out) is shown in Figure 5.

Elisha related that experience to conditions of climate change now:

> People don't understand, [but they] have to understand that there's a big bad problem out there. They have to understand it from home and from school. I had the blessing of being in Israel post-[19]67, where the feeling was "miracles can happen, and we can do anything." So, I had that, plus there's a big bad problem outside my window. I had both those dynamics going . . . urgency and hope, together.

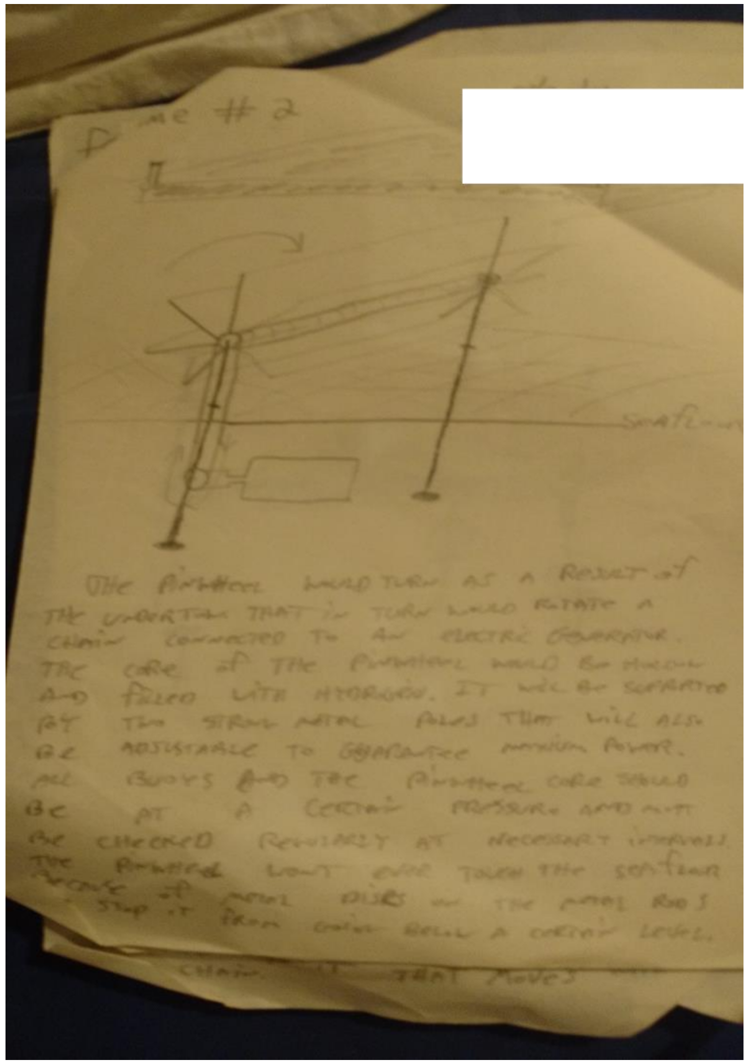

Figure 5. Elisha’s sketch of his underwater-wave machine to collect wave power.

In recalling his context, Elisha also acknowledged growing up in a “liberal town” that closed off the street outside of his window for Earth Day. It was the 1970s, and he went with his mother to celebrate at the Earth Day festival. “The fact that it was fun and countercultural made it cool. I guess for a kid’s worldview, that it was on my street was cool. So, it was accessible, and there were a lot of people.”

In Nature: Woods, Trees, Beaches

Sometime after Elisha's parents divorced, his mother, Hannah, took him to an "in the woods" festival. There, a man demonstrated that it was possible to heat water and hot dogs with solar energy. Circumstantially, Elisha's mother eventually married that solar-oven man and so Elisha became his stepson.

The woods-based celebration theme was reinforced spiritually at school, Elisha recalled. At his Jewish day school, the students celebrated Tu BiShvat, an environmental festival of trees, by planting trees and taking nature walks. Elisha referred to these environmental festivals from his early life as "a good early soup of unplanned things."

As a child in Israel, he had regularly hiked with or without grown-ups—that was the norm. He remembered knowing not to pick certain flowers and planting trees as a normal activity. When he moved to Boston, he recalled feeding the ducks with his father and going to Cape Cod for a week of science in nature. He contrasted his two contexts growing up—Israel and the United States. In Israel, engaging with nature was foundational and routine; but in Boston, time in nature was not as valued.

In remembering how nature shaped his thinking, Elisha recalled being younger than 5 years old and learning to swim at the beach. His parents instilled in him a fear of the undertow. This awareness of the ocean's power led him to design one of his first energy-harnessing designs, a mechanism to generate power from ocean waves. He named this invention, "The Undertow."

An Encouraging Science Teacher

Elisha's "phenomenal science teacher," Mrs. (now, Dr.) Sterne, nurtured his love of science. Although year after year, Elisha failed most classes at his Jewish day school, he would get As in his science and Bible courses. Each year, school administrators considered holding him back a grade but always promoted him. Mrs. Sterne "very much nurtured curiosity and gave feedback and was very encouraging. She was so encouraging."

Dr. Sterne passed out children's science magazines and asked the students to read the articles and write reports about what they read. He described her "hovering around the test tubes and saying good things. She was very important—for fifth, sixth, seventh, eighth grade."

Dr. Sterne taught Elisha's science classes for four consecutive years, spanning from the end of elementary school through middle school. She encouraged his development and nurtured his curiosity and self-esteem. Elisha credited Dr. Sterne for his first invention, acknowledging, "Without that, I wouldn't have done the solar cell in high school. But I guess I had enough momentum and, you know, a sense of empowerment to [innovate a solar cell for a science competition]."

Dr. Sterne's Perspective

Dr. Sterne was surprised that Elisha thought so highly of her and credited her for contributing to his foundational love of science. If anything, she believed her contribution was in the way she structured the middle-school classroom where she taught Elisha. She remembered him as a free-spirited student and hypothesized that the environment she set up helped stimulate his thinking.

> I wasn't going to scold him. He was going to have freedom of movement, freedom to work as quickly or as slowly as he wanted to do his homework. So, I think that may be part of what worked with him.

Dr. Sterne shared that when a student would ask a difficult question, her response would set the stage for students to direct their own learning. She would say:

> I don't really know that answer. I can look it up for you. But better still, I challenge you, when you are ready to be a scientist, this is a good topic for you to study because we don't know enough about that.

During Elisha's first year with her, Dr. Sterne taught the ecology unit. In sixth grade, they explored how to generate electricity. Because generators require a fuel source, the class talked about advantages and disadvantages of the (then-) current fossil fuels (oil, coal, and natural gas) and of emerging future fuels (nuclear, hydro, and solar power). The class charted the positives, negatives, and costs of each fuel. Then Dr. Sterne assigned them to talk with their parents about which type of power they preferred. She noted that not one child liked nuclear. In addition, because it was during a time of geopolitical challenges—and the school was connected to Israel—oil was a particularly challenging subject for the class. She encouraged the children to broaden their discussion beyond their families and asked them to bring in newspaper clippings to make them aware of what the world was thinking.

During Elisha's seventh grade year, Dr. Sterne focused on developing scientific techniques through chemistry. She remembered Elisha being stimulated by the questions and feeling empowered to investigate on his own because that was valued in class. Dr. Sterne had set up four concurrent experiments, complete with their materials—one in each of the classroom's corners. Each student was responsible (sometimes with a partner and sometimes alone) for conducting the experiments and writing up the lab reports. This design, Dr. Sterne explained, allowed students to work at their own pace—some a bit slower or faster than the others. When all the students completed Experiment 1, she would replace it with Experiment 5; when all finished Experiment 2, she would replace it with Experiment 6, and so on in a cycle. There were always four experiments set up, and the students were always moving forward at their own pace. The students were responsible for learning how to work in the lab, interacting with lab partners and classmates, and understanding the scientific principles.

Dr. Sterne acknowledged, “When you teach science, the kids wonder about [what they’re learning],” and she set up her classroom accordingly. The students could just “sit in the class,” “go here and there” around the classroom, or get a drink of water. They were allowed to talk with their friends “and, as long as it was quiet in the classroom and the other kids could work, that [was] okay.” Dr. Sterne shared, “I think being social in an educational environment works for some kids, especially a child [like Elisha] who is not sure that he wants to be an A student but just wants to do the work.”

Also, during seventh grade, they discussed pollution as a matter of both science and personal habits. Dr. Sterne maintained that it had to be the responsibility of every citizen to not pollute and translated her conviction to the classroom experience. Because their school lacked money, they needed to be resourceful and wound up recycling papers. They collected so much paper that they would exhaust the collection company at times.

Time to Play: Science Kits and Science Magazines

At home, Elisha routinely received science kits as presents for his birthday or Hanukkah. He recalled kits with test tubes—he would watch things bubble and change colors—emphasizing, “My parents didn’t even mind if things blew up or whatever.” He never got hurt. He recalled even receiving fireworks that he dissected with his younger brother, his primary playmate and co-science-kit-investigator. Elisha recalled the feeling of exhilaration when he and his brother built rockets from their science kits and launched them into the air. He categorized this type of support from his parents as a combination of mentoring and complete freedom and credited their parenting style for countless hours of free time to just play.

In 1979, then-President Jimmy Carter had solar panels installed on the White House (Biello, 2010). Elisha, 15 years old at the time, became excited. He recalled his reaction as, “Great! Now I get it!” During that era, Elisha regularly read the subscriptions his mother provided for him: *Popular Science*, *Popular Mechanics*, and a newsletter on solar power. His mother read *Scientific American*, and he paid attention to that, as well. He also loved his comic books because they were filled with imaginative scientific stories and superpowers. Elisha reflected on his comic books, “I guess it fuels imagination.”

Creating a Solar Cell for a Science Fair

Throughout high school, Elisha reported, “I had self-esteem around science. I had good teachers.” One day, he saw a notice on a bulletin board for a science fair competition and “without consulting parents or anybody, I entered a science contest with an invention for a solar cell.”

From everything Elisha had learned about solar power, he felt the efficiency was too low to be an economically viable option. He learned that most of the light that hit solar cells bounced off and so went unused. Elisha started thinking about how to harness this unused light. The low efficiency of solar-power mechanisms at the time seemed too weak to provide a solution to the problem vexing Elisha—the world’s dependence on oil. So, he reframed the problem. He simply asked himself, “Okay, what’s the problem?” and then started designing and building his first prototype to harness more of the sun's energy.

> I remember going into South Boston, buying some one-way mirror glass—having them cut it for me to build a pyramid, basically, of one-way mirror glass. And I had a mirror on the bottom. And, so, I designed this, and then I put a solar cell in the middle. And the idea was the light would come in—enter through the glass, hit the solar panel, and then go *boing boing boing boing boing*.

Elisha entered his pyramid-shaped solar cell into the science competition. His project won fourth place with an honorable mention.

> I remember coming home all excited. I had a little trophy. And I was convinced this was going to be the future. So, I began the process of filing for a patent. And this was pre-Internet. Somebody must have mentored me. But I spent a tremendous amount of time in the Boston Public Library down in Copley (this is in high school already), researching to see that no one else had patented this. And so that was really, really all mostly self-directed. . . . I think really just curiosity. Because it was going to solve the problem.

Elisha found no other patent applications for his idea. Excitedly, he filed the step that was prior to filing for a patent. He received a letter back from the office of trademarks and patents that gave him a year or two to officially file it. Elisha recalled that, because it would take thousands of dollars for the next step, he did not do it in time. His application expired.

After-School Job: Science Lab Technician

Because Elisha had performed poorly in most of his classes, in his transition to high school, he was put into a class below his capability in science. This upset him; he behaved like a “know-it-all” in his science class. His teacher, Mr. Ford, noticed his attitude and offered Elisha an after-school job as the science lab assistant. Through that job, Mr. Twomey, an elderly Irish gentleman in the backroom workshop, took a liking to Elisha and taught him to repair microscopes. Elisha became the microscope-repair technician for the whole science department and kept that job until he graduated high school. Elisha not only earned spending money, but also gained relationships with the “cool guys in the back,” including the janitor, who literally opened access doors for him. It was fun and felt “countercultural cool” to access the science department’s back rooms and hang out with the men who kept the place running.

“The job was an affirmation. It affirmed me in the same way that Mrs. Sterne affirmed me. But this entailed getting some responsibility, so it differentiated, and I guess I appreciated that.” Elisha enjoyed the freedom of having control over his time and money. He reflected that, during that time, he learned new skills quickly and increased his responsibility. He connected that to the world-influencing work he does now:

> You know that I’m doing lots of crazy things now. But there is a direct line to being taught, being given responsibility, and then being given more responsibility, kind of like moving up. Like from little things to bigger things to bigger things.

Activism: Civil Disobedience and Protesting for a Cause

To nurture Elisha’s activism, his mother one day took him to civil disobedience training in the basement of a church. The training was directly bound to his understanding of morality—that standing up for what is right in the face of immoral action, indifference, or oppression from authority might require the tools of civil disobedience. By the time Elisha graduated eighth grade, his education included an academic core, a foundation in Jewish values, and the fearless courage of civil disobedience training: “I wasn’t scared of attack dogs or water cannons or tear gas or police—totally had no fear. No fear.”

At first, Elisha was angry with his mother because she took him to the training but would not allow him to do anything so radical that he could be arrested. When he was older, he protested fearlessly for environmental and human rights causes. He recalled his first protest was environmentally motivated—to protect living things from the consequences of a nuclear accident caused by a nuclear power plant.

In college, he met his wife at an anti-apartheid protest at his university. She was impressed that he could give speeches without notes at the divestment rallies and amazed by his informative answers to reporters’ questions. He spoke like a well-seasoned visionary. Humbled by his authenticity, she started reading his column weekly. He used his column in a university newspaper to address world affairs and motivate people to take their moral obligations seriously. His wife described how he could astutely take in information and then address the world with a galvanizing sense of purpose. She recalled him at one divestment protest, willing to risk his scholarship. Despite concern that he could be kicked out of school, Elisha stayed at the protest and addressed the police and the press. When she asked him if was afraid of losing his scholarship due to his activism, he responded with a spiritual reference to the Torah that, as God-partners, “the world is our responsibility.”

Now, when Elisha visits war-ravaged countries to help them sustainably provide infrastructure via his solar innovation, he benefits from his civil disobedience training: “You need a good tool kit. I had a good tool kit early on, which included not being afraid of the things that normal people would be afraid of.”

Purpose and Motivation

When Elisha was a Jewish educator, he conceived a mission statement for the Jewish people.

> [It was] to be an ongoing distinctive catalyst for the advancement and evolution of [humankind and morality] . . . but no one understands that. . . . And then, you know, I’m standing in a solar field, and people will ask, “What’s the purpose of the Jewish people?” And I’ll be like, “To be a renewable light [upon the world].” And, *that*, everybody gets. That can go on a bumper sticker; the first one can’t. But the first one is the more detailed spiritual DNA. It has different pieces. You know, we’re God-partners in the universe. We’re doing a pretty bad job of stewardship.

Dealing with Failure

Elisha has faced failure routinely on both the technical and execution sides of his solar innovation. For the technical innovation, he partnered with a university to build a test site. The university expanded that site into a validation center for new solar-based technologies. “We’ve essentially built ourselves a technological Disneyland from which to experiment, to refine, to learn, to be smarter, and to demonstrate that we're always trying to be smarter." Elisha partnered with a powerful team with university backing to set up a system that practically reframes and capitalizes on failure as serial iteration.

After explaining his strategy for overcoming failures within the realm of technical innovation, Elisha listed five countries where he had made inroads but the execution innovation failed. With each failure, Elisha and his team developed a new testing method within the market, leading to an evolution in process. He described their persistence as a sort of optimism filled with fortitude:

> What we've been doing is "our success is on the way," filled with, you know, a thousand obstacles. And just like in technology, you have to keep trying new ways. You have to test a theory, see what works, see what doesn't work—advance if it works. It's a very similar kind of process to get to the deployment of the technology as it is in developing the technology.

Elisha shared three points he uses to scaffold himself in rising from failure: (a) keep the long view in mind, (b) keep the big picture of the mission in mind, and (c) the whole family is *all-in*—meaning every asset is leveraged—so failure is not an option. Elisha expounded on this third point, thinking of his family in it with him. "We never give up. I have to get up the next day and figure out how to succeed."

His third point expressed a moral stance for him. Now that his innovation has turned him into an entrepreneur, his job has taken on the new role of seeking investors. Morally, he claimed, he could not ask investors to believe in his work and invest if *he* did not fully invest and put everything he had on the line. He credited his parents and upbringing in a nonfundamentalist Jewish school for his strong commitment to moral living. He also thought his context of growing up in the 1970s—particularly in the Boston area, which was rich with cause-based activism—influenced his moral development. His father had attended Martin Luther King, Jr.'s "I Have A Dream" speech in Washington, DC—so being committed to cause-based activism felt like just a part of being Jewish.

Elisha's Recipe for Creating Eco-Innovators

Elisha applied his three points for dealing with failure to his recipe for creating eco-innovators. First, children need to learn to have the long view. They need to understand that they are inheriting an awful world, that we are part of the problem, and that they are stewarding the world not just for themselves but for future generations. Second, they need to understand the big picture. They need to understand what is happening in the world in terms of pollution and climate change and that we are morally complicit in our everyday actions. Third, they need to learn to take action and to be raised up taking action.

To this structure, Elisha proposed age-appropriate activities that give children the opportunity to figure out solutions at increasing levels of influence. Start small with little children (e.g., household recycling), he suggested, and increase the complexity of the actions and the sphere of influence each year. A child may learn and practice environmentally friendly behaviors in the home with one type of recycling and then move to a more expansive type of recycling and understand the behaviors and changes needed in the community, then the region, and then the state and country, and so on.

As part of this increasing sphere of responsibility, Elisha emphatically insisted that carbon-footprint math (the concept that people's lifestyle choices add or subtract relative amounts of greenhouse gasses into the atmosphere) should be taught when children are very young. He suggested teaching the concept of a carbon footprint as early as kindergarten—and then adding complexity, including the math, to that knowledge in subsequent grades. Elisha explained that children need to know the relationship between the good things we have and the bad things happening on our planet and offered that they understand weather. Noting the prevalence of children with asthma, Elisha suggested air quality as an appropriate area of study for children and promptly added "water" as a topic for in-depth study.

Elisha mentioned that with social media, numerous "amazing videos" have come out that contextualize and educate people on these issues. He referenced a video about plastic straws that showed the vast quantity of daily straw waste in America, showed how much one person contributed to the waste, and then gave a solution: a reusable self-cleaning straw that attaches to a key chain. His main point was that children need to understand that there is a very big problem and we are all inherently part of the problem—unless we actively work to be part of the solution. Elisha shared from his own experience:

> For our family, this means we will not own a car until we can own an electric car that we power with green energy. We are vegetarian and, thanks to my daughter who volunteered in Ghana at a school for runaway child slaves, now we will only consume fair-trade chocolate and coffee.

Hope

Elisha sees hope as integral to the Jewish people and written throughout Jewish history:

> The notion that the Romans and Babylonians—everybody like destroys your land—disperses you all over the world and you keep this dream alive that maybe one day you'll go back. Two thousand years of somehow keeping that idea alive and then being part of the generation that gets to see the fulfillment of that? That's built in. Who keeps the dream alive two thousand years and then realizes it? That's crazy.

Elisha's last point suggested that a shift in perspective may be a helpful tool for accessing hope. Ever the Jewish educator, he spoke of how the Jewish people mark time. He described how most of the world expresses that a day begins in the morning, at sunrise. Then, the day ends in darkness. Counter to that perspective, the Jewish day begins in darkness, when three stars are visible at night, then endures the long period of darkness before the light—and the day ends in light. It is a perspective shift that ends in brightness, in hope. As a practice, this perspective reinforces

> the idea that there is still an incredible march towards progress, towards longevity, towards a solution. . . . Part of what I love [about] walking around in Israel, especially in the desert [is that] sometimes, from a little bit of the rock, you have a green plant just sprouting out. I mean, the course of nature is actually towards optimism, not towards Armageddon. I've found myself to be a relatively hopeful person dealing with some of

the toughest places on the planet, and you meet the people and you see why.

Elisha's Mother's Perspective

Hannah, Elisha's mother, claimed that Elisha would have been an innovator no matter what field he chose. She remembered him as a little boy having a strong sense of himself. She described him as curious, adventurous, and imaginative. She also characterized him as an active risk-taker who made his own judgements.

Hannah shared a story of Elisha making his own judgements before he was a year old. He had started walking at 9 months old and, she recalled, he started talking early. She had just washed the kitchen floor, and Elisha came to the edge of the floor. Wearing only his diaper, he looked up to her with his curly auburn hair. Hannah said, "Do not walk on the floor. It is wet." She knew that he understood her. He bent down, touched the floor in a dry spot, and walked straight across the floor to his mother, looking straight at her. She could see his mind working. His walk across the floor was purposeful. She interpreted his expressive toddler face to be saying, "Nuh-uh. I felt it. It's not wet."

Elisha was creative as well as curious about how things worked. Once, he was given a little camera, he created a slideshow for Hadassah, a women's Zionist organization. Whenever he was near a piano, he would play it, creating his own music. Then, he would teach his tunes to children who could play the piano. He wanted piano lessons, but his parents could not afford them.

Hannah recalled that Elisha was an active child. She remarked, with a faint touch of sardonic humor, "Kids like him get drugged these days." Quickly returning to describing her son, she said, "He was always active and cheerful—unending cheerfulness and interactiveness," even as an infant in a baby seat. He kept her company, even when she hung laundry out the window on the clothesline, because he was such a merry baby.

Elisha's mother reported that he took after his grandfather, who was a strong influence on him. Elisha's grandfather had won a scholarship to an engineering college, then decided it was boring. Because he enjoyed fixing oil burners, his day job became delivering oil and fixing burners. At home, Elisha's grandfather tinkered in his basement on his inventions. He purchased an empty lot next door and turned it into an extremely fertile organic garden.

When Elisha was 3 until he was 5 years old, his family intermittently lived with his grandparents, where he spent time tending to the garden with his grandparents. Driven partly from poverty and partly by imagination, they recycled and composted before those ideas were encouraged widely as good ecological practice.

When he was 5 years old, Elisha's immediate family moved to Israel, living there from 1969 to 1972. They moved to Boston when Elisha's father was offered a doctoral fellowship at a university in the Boston area. Upon that return to the United States, they stayed with the grandparents, where Elisha cut out all the wires from his grandmother's electric blanket, thinking they could be "little bombs or something." In Boston, they frequented the Museum of Science.

During that time, Hannah worked full time. Her children would arrive home an hour before she did and took care of each other. They had rules and were good about following them. Often, Hannah would stop on her way home to buy groceries. One day, carrying a grocery bag on each hip, she climbed the three flights of stairs to their apartment and walked through the long hall leading to the kitchen.

> [There,] every glass thing we owned, plates and cups, were on a tablecloth on the table. And as I walk into the kitchen, Elisha whips the tablecloth out . . . and nothing breaks. Nothing moves, even. It's just [still there].
>
> And Elisha said, "Wow, that works."

According to Hannah, Boston at the time was a bit countercultural. When she divorced, she moved out of the third-floor walk-up and into "a conscious community" commune whose members were involved in political, social, and ecological action. Their weekly house meetings included the children. Those meetings exposed Elisha to the power of vocalizing his opinion as a child. With Elisha's mother and father separated, this community served as a source of adult support. It also exposed Elisha to people with different ideas who regarded him as an equally valid member of the community and taught him how to wield influence with adults. "While the image of a commune may conjure up more libertarian ideas, this community was more like a temporary family."

Elisha and his younger brother shuttled between living with their mother in the commune and with their father. According to Hannah, Elisha's personal idea of Tikkun Olam, the Jewish value of repairing the world, came from bridging his parents' different worlds—informed by living in the commune with his mother and by learning it from his father—and by Elisha developing his own sense of giving from all other influences in his life, such as school and temple.

Elisha's mother noted that his idealism was a constant throughout his childhood, as was his character—"very sweet, very hard working." Hannah saw his entire career through the lens of a political activism that tried to make the world a better place—to reach people and convince them of the need to act. Hannah viewed Elisha's unique type of activism as a blended inheritance stemming from his grandfather's self-directedness and her own social activism. The difference, she noted, was that Elisha had the ability to both inspire and gather people around him to realize his vision.

Hannah shared that Elisha had a global vision, and that vision partially stemmed from living in Israel. However, just as important, she noted his big-heartedness and a surprising ability to inspire. "Until age 12, he was sort of difficult to raise," she said, "because he was so into everything and so energetic about it—and so curious." When he discovered politics, he focused all that energy outward and became effective. For example, at age 16, Elisha gave a series of lectures about Middle East politics to adults.

Elisha wanted to get his master's degree in Jewish journalism, but neither of his parents could afford the financing. Undaunted, he campaigned a scholarship-granting organization to change their criteria to include the degree he wanted. His mother expressed incredulity: "How do you think of changing an organization? I don't know where he comes from."

Hannah stated that Elisha was driven—not by his ego but by his interests. "If I was going to advise somebody on how to raise an eco-innovator or even just a plain child, I'd say, 'Put them in a lot of environments. See what catches their interest.'"

A Sweet Reunion

Several weeks after completing the interviews for this case, Elisha posted a recent photograph of himself with his arm around Dr. Sterne as they sat side by side at lunch. Reunited, he captioned the photograph:

> In sixth grade, science teacher Mrs. Sterne set out before us all the different types of energy—coal, gas, nuclear, solar, wind, oil, hydro,

> waves and more—and we had to figure out the plusses and minuses of each. I began to doodle, invent green energy ideas—starting my solar and wind journey. Here we are, 40 years since graduating from my Jewish day school, reunited by a new friend's PhD on educating children for eco-innovation. Israel and Africa owe a big thank you to now Dr. Sterne!

Case 3: Jaffer and Leah–Team Eco-Innovators of a Water-Monitoring App

In 2018, two eco-innovators attended the same program in the United States—an Israeli-Palestinian Innovation and Entrepreneurial summer program (case pseudonym, Innovators for Peace or IFP). As part of IFP, these eco-innovators—Leah from Israel and Jaffer from Palestine—joined forces and created their product together: a phone-app-paired device that monitors the quality and quantity of water in rooftop water tanks. In Palestine, municipalities deliver water only a couple of times per week. To maintain a consistent water supply, the people must independently store their water and so they keep water tanks on the roofs of their houses. Typically, they check their water level or quality by climbing up on a ladder and investigating the water tank directly. Prior to Jaffer coming to IFP where Jaffer and Leah met, Jaffer's professor had fallen off his own roof while checking his tank and broke his back. This problem troubled Jaffer, who shared this concern with his IFP colleagues. Leah was moved by his story, and soon the two became innovation partners. Together, they created a water-monitoring system that enables a person to monitor their water storage remotely and, thus, free from physical risk.

This case includes both partners of a team. Thus, it examines their individual stories as well as their collaboration to learn what both background and collaboration can reveal about their influencing factors and conditions. Leah's backstory is presented first, followed by Jaffer's. Then, the case covers content about their collaboration and their ideas on eco-innovation.

Leah's Backstory

Leah grew up on a kibbutz in Israel where residents shared ideals, values, and a communal economy. Her kibbutz was situated on a vast open space filled with grass. Leah's home was surrounded by nature. She grew up walking barefoot, getting dirty in the soil, climbing trees, and plucking food from the wild. Leah explained, "You feel connected to this surrounding . . . and you feel you are creating something."

Leah's kibbutz also grew crops in their agricultural fields. A culture of working then fertilizing soil, planting seeds and trees, observing the growth of the plants throughout the seasons, and then enjoying the fruits and vegetables from the land framed her childhood. It was a regular part of the kindergarten on Leah's kibbutz to visit the fields and learn from the farmers. It was also part of everyday conversation to talk about the seasonal changes to the plants, such as the blooming, the ripening, and the harvesting. Leah referred to this as "following the wisdom of nature." She recalled, "I was always curious about this, and I really, really, really want to be very close to this during all my life."

Learning the *Cradle to Cradle* approach. During her senior year in high school, Leah majored in design. She discovered that she enjoyed creating beneficial things with her hands and with tools. For her senior project, she designed a dynamic barstool from an abandoned tractor spring she found on her kibbutz land. In her high-school design studies, Leah was exposed to McDonough and Braungart's (2002) *Cradle to Cradle* approach to design. She explained that the old way, the cradle-to-grave approach to design, was based on a linear conception. In that old way, a product would be created for consumers and, for its creation, raw materials would be taken from natural resources. The product would be manufactured. It would then be shipped, often across the globe, and shipped again—and many resources would be consumed in the shipping process. The product reaches the users and is finally used—only to be discarded, after a while, into some landfill. In contrast, the sustainable *Cradle to Cradle* approach (as introduced in Chapter 2 of this dissertation), imbues design with an additional purpose—feeding a new interest or new need when its first use is done. Instead of entering the landfill, the product or materials used to make the product enter a new process or life stage.

Referring to growing up on the kibbutz with agricultural fields, Leah explained how she internalized the *Cradle to Cradle* approach by observing nature. “You go outside and you watch this process from a very early age, [so] you are familiar with this. It’s also a create-to-create-things [process] in nature.” Through her upbringing and learning the *Cradle to Cradle* philosophy in high school, Leah incorporated this value and approach to her work as a designer and eco-innovator partnering with Jaffer.

Volunteer service. After high school, Leah volunteered for a year with an environmental sustainability organization. She lived in the desert and guided people, in the context of nature, through teambuilding and empowerment experiences. That summer experience made it clear to her that she had not only a love of nature and an appreciation for its wisdom, but also a love for the discipline of design. After this year of volunteer leadership in the field of environmental sustainability, she began her mandatory service in the Israel Defense Forces, where she worked in industrial design. After completing her military service, Leah attended university to study product design, where she focused on environmental and social design.

Sustainability-oriented design to help people. During college, Leah participated in a program that empowered people in rundown, impoverished neighborhoods in Jerusalem to design their public space. From this experience of working with the municipality and the people, Leah learned that incorporating end users into the design process makes for better solutions. Now, her innovation partner Jaffer is inherently an end user of their innovation because he comes from a community where his family and neighbors need the solution they are creating.

After college, Leah established herself as a professional designer focused on environmentally sustainable products and solutions that assist vulnerable people, such as people who are poor, disenfranchised, blind, or have Parkinson’s disease. A project dear to her heart is her work with a nonprofit group of blind Palestinian artisans who sell their wares in a heavily visited area of Jerusalem. Leah collaborated with this group to design aesthetically beautiful, environmentally sustainable products the artisans can make using their established techniques and sell to tourists to help fund their organization.

While working with this group, Leah saw the call for applications to the IFP program. It advertised equipping participants with the skills and knowledge, such as business management, business planning, marketing, financials, and taking something to scale, necessary for her profession. She recognized that it aligned with her values and felt compelled by the “very crucial and dominant opportunity to do this with a relationship with Palestinians.”

Jaffer's Backstory

Jaffer grew up in Palestine with his mother, father, and sister. During his first 11 years, his city was known for its optimism. Then, the Second (Al-Aqsa) Intifada—a period of violence and bloodshed between Palestine and Israel—started. Due to this heightened conflict, his family could no longer afford to remain in that location; they moved to a city with what Jaffer termed "a lower standard of living."

Jaffer recalled that he always cared about water. Growing up, all water-related activities, such as drinking, cooking, washing dishes, flushing toilets, cleaning, and hygiene, had to synchronize with a schedule issued by the municipal water supplier. With the paucity of water in the region, Jaffer's community did not receive water every day. Instead, the municipality divided the city into zones and erratically supplied each zone with water. At best, they delivered water twice a week—but sometimes twice in 10 days; occasionally once in 2 weeks; and, at times in the heat of summer, only once in 20 days.

> I remember one time where my family invited some friends over, and we literally ran out of water in the middle of the evening. We couldn't even use the bathroom, and it was very embarrassing. Like, we had to stay for a couple of days without any water. The toilets smelled really bad. Like we had no more clean dishes or glasses. It was something big.

The people kept water tanks on their rooftops to store water for the in-between days. Larger families with more people would routinely run out of water and so they would either stay without water or buy it from a private source. Jaffer explained that private water suppliers' prices were five times the normal price; bottled water was also "expensive, inconvenient, and contributed to the plastic problem. . . . So, I grew up with consciousness of like how valuable water is."

Jaffer's father had been a "hands-on" electrical engineer who kept a tinkering room in the house to "go there and play . . . and do things with his hands. . . . My love to do things with my hands comes from witnessing my father doing that." He recalled his father bringing him into the tinkering room. Together, they would derive mathematical equations by building something with cubes. As Jaffer remembered these hands-on lessons, he described his father as "a very patient person to teach me really small things. We did that a lot."

College years. Jaffer studied civil engineering at the university in his city. He discovered his passion for water when he took an interdisciplinary course on water. Deeply inspired through those lectures and conversations with the professor, Jaffer spent his last two university years focused on water engineering, water distribution networks, and water treatment plants. That professor was a part of the Palestinian team negotiating with Israel and was deeply involved in the politics concerning the Palestinian water issues. Jaffer explained,

> He shared stories with us about how complicated it is. But, at the same time, he would demonstrate how simple it would be to solve this whole water conflict. I learned from him how water can create inequality and, by providing water to everyone, you can make people equal. So that was kind of what inspired me the most. How can I make people equal? You provide them with water.

After graduation, Jaffer had a choice between two offers: one in Jordan or an opportunity with an Israeli Institute for Environmental Studies. Jaffer consulted his academic community and friends for advice. Overwhelmingly, they advised him to take the job in Jordan. Only Jaffer's father supported the riskier choice to go to Israel.

> I remember, my dad was so much up for it . . . and I believe that I definitely needed some support, and coming from my father was something that is so great. He thought it would be very beneficial for me on a personal level, such as, you know, improving my English and making connections and learning a new topic, which is the environmental sciences and water sciences.

Jaffer went to Israel and, at the Israeli Environmental Institute, learned entire bodies of knowledge anew. Besides the environmental engineering knowledge he had gone there to learn, he was immersed also in a different culture. "Everything was very shocking to me—learning about the other side, how people think, the culture, who I am, my identity, my culture. They all struck me and they made me question everything." Jaffer had never learned about the Holocaust and, in a parallel omission, found that the Israelis he met had not learned about Nakba.[3] As Jaffer said, "Looking at some dates in the calendar where they mean two different things for two different people. And that

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[3] Nakba, translated as "the Catastrophe," is an Arabic term for the exodus of the Palestinian people from their homes and land during the Palestinian War in 1948. It also marks Israel becoming a nation (Ibish, 2018).

was—that really struck me so much and that made me really question, 'So, what are the facts?'"

During his last 6 months at the Israeli Environmental Institute, Jaffer served as an intern and teacher's assistant for a course called, "Water Resources Management in the Middle East." Through that experience, Jaffer not only gained more water engineering expertise, but also learned how to argue, think critically, and convince people of an idea. He discovered the power of building understanding by "sharing your story and being open to hearing others' stories."

After a year and a half in Israel, Jaffer wanted to escape the Middle East. He "felt so desperate" and hopeless about the future of this conflicted area of the world. So, he applied for and was accepted to graduate school in the United States but lacked funding. He applied for scholarships. Despite sending more than 500 e-mails, he received only 20 responses—19 of them said, "No." One directed him to apply for the Fulbright program. Jaffer had never heard of the Fulbright Visiting Scholars Program but applied and, to his shock, received it.

Experience of making a difference. While waiting to go to the United States as a Fulbright scholar, Jaffer joined an Israeli–Palestinian humanitarian sustainability organization (case pseudonym, Middle East Sustainability or MES). This organization supplied marginalized West Bank communities, such as Bedouins, with electricity via wind turbines and solar panels. Using this power, the people could charge their phones, use laptops, and operate butter churns and other electrically powered farm equipment. After his first day of work with MES, Jaffer had an epiphany about the significance of water:

> I remember the first day I went home after my first working day. I turned on the tap, the faucet, and I find water, and I'm like, "Wait, but it's just a few miles away from me, they're like those Bedouin communities that they just do not have the privilege to have a tap of running water. Even if it's stored in the water tank." It really, really shocked me. And I remember it exactly the way I'm talking to you right now. . . . It was a bit dark, and I remember exactly like having my hand on the tap. And like thinking for like maybe 30 or 40 seconds, "Why do I have that privilege and other people do not—who are just minutes away from me, a few miles away from me?" So that really, really shocked me a lot: how many people will get sick just because [of] the water they drink—if they had the water in the first place.

Jaffer considered both MES founders to be among his mentors of a lifetime. One of them was harsh with him at times, but it was clear his intent was to make Jaffer learn and grow. The MES hired Jaffer to lead a pilot project to solve a water problem: The cisterns—rainwater-collecting holes in the ground—upon which the Bedouin communities depended for their water were inadvertently collecting sheep manure and other organic matter that sullied the water and sickened the people. To solve the problem, Jaffer led a team through a process that began with thinking about how to solve the problem, which led to developing the water-cleaning system. It took about five months to build and test the prototype. The specific type of filter he developed with the team was, as Jaffer said, one of the biggest innovations I've had so far. . . . And it reaches the World Health Organization's standards. So, it's kind of like the water that we can drink here in Boston, . . . it's very clean and safe drinking water.

I felt huge. I felt that was something that could absolutely make a difference. I remember every night I would go sleep after working all day. I would be like, "I can't wait for tomorrow to begin again." I was struggling a lot in my society. I was struggling with Israeli occupation. But, the joy and the sense of peace I would get just by working to bring clean water is something that I cannot really describe with words. . . . It's literally the thing that gives me most hope in the entire Middle East. It's like having this group of people working to get there, even during the summer of 2014, during [the] terrible war in Gaza. We continued to wake up every morning and go to work under the sun and install, and do maintenance, and help people.

I think that's been the mission of MES from day one. And I think keeping that spirit during the darkest days—like wars and days of violence—I think that's really what made me feel that, yes, I can make a change for people's lives! And I'm not a person that claims, "I'll change the world." I personally don't like that. I just don't agree with it, but I believe that individuals can create incremental changes. Again, it's a collective effort; the more people are doing these small steps, the bigger the influence is.

Jaffer worked with MES until he started university in the United States as a Fulbright scholar. He called his Fulbright experience, in which he earned a master's degree, an "amazing experience." Studying "policy and economics of freshwater resources" for 2 years, Jaffer learned that water plays a major role in numerous international conflicts. "Water is often the main source of strife and a threat multiplier in wars, such as in the conflicts between India and China or India and Bangladesh." Jaffer referred to Las Vegas: "They wanted to have water from the north, and people from the north of Nevada said, 'Over our dead bodies.'" In considering the role water has played in conflicts, Jaffer shared what seemed a somewhat-impromptu mission statement:

> I believe that bringing everyone in this world water would help them have that sense of convenience and security and safety that they will not need to worry about something that must be taken for granted by this century—by this period of time. I think we should have reached a point where this need is met for every human being on this planet. And I feel that's my mission in life. I may not be able to provide water to everyone, the way I wanted to during my lifetime, but I will do all I can, even if it's going to make any incremental change. I'll be very satisfied with that. I think if every human being believes in something and then they go after it, and they do what they think, we would be in a much better place in 50 years. . . . I believe that securing good and safe drinking water for everyone is a way to bring peace.

Jaffer seized extraordinary opportunities during his Fulbright term. He worked alongside a U.S. Congressperson for 7 weeks on a Congressional committee focused on environmental issues. He went to Guatemala with Engineers Without Borders for 20 days, designing and building water systems for communities that did not previously have access to water. He spent a summer in Washington, DC, participating in a special government program to equip Israelis and Palestinians with leadership skills to forge peace in their region. During this program, Jaffer met Malia, his host mother for that summer who also became one of his life mentors. These experiences gave him fresh hope for what he could accomplish in the Middle East.

Mentor Malia's perspective on Jaffer. Malia, a retired environmental protection lawyer, served as Jaffer's house mother during his participation in the summer program for Israelis and Palestinians to hone their leadership skills and engage in conflict-resolution approaches. It was the year after the Gaza War. Having two Israelis and a Palestinian under the same roof made for a potentially awkward living situation.

Malia remembered that the group got along very well and had a dark sense of humor. Jaffer spoke fluid Hebrew. Because the two Israelis had been in the military, he would greet them every morning in Hebrew, "Good morning, soldier." They would respond, "Oh, it's the terrorist again." She noted how they humorously played out the larger geopolitical conflict verbally all the time.

She remembered that Jaffer was playful. He had the ability to transcend assumed roles, reflect on them, and then make fun of them. Malia described Jaffer as "a total team player," pitching in to do any kind of housework. He also showed his capacity for relationships, leadership, and brainstorming as the crew organized events for the program over that summer. Malia described Jaffer as one of the most optimistic, yet serious, people she had ever met.

After Jaffer graduated with his master's degree in 2016, Malia visited him in Palestine. There, she gained a deeper understanding of his world. Jaffer showed her around the humanitarian water installations he had set up with MES. When they travelled to an area where he had put in a water purification system, Jaffer spoke of the inherent dignity the people there brought to their difficult living situations and was empathetic about their future. Malia explained, "It was an absolute miracle that he was as optimistic a person as he is. He avoided the pitfalls of anger that would certainly hamper me if I lived in that environment."

As Jaffer's mentor, Malia has made herself available for him whenever needed. She talked with him about practical elements of his work, such as how to take a business idea to scale. To support his career, Malia has introduced Jaffer to her good friends in the international aid community and in landscape and energy conservation. "He's of course, very personable. . . . It's very easy to advertise Jaffer, you know? You know, he's an easy sell."

Innovators for Peace

After completing his Fulbright scholarship, Jaffer returned to Palestine to start his life as a water engineer. After some time, Jaffer heard about IFP but worried it would be "one of those peace industry programs, you know, like Israelis and Palestinians, and it's going to be *cute*." He emphasized the word *cute* with disdain. So, he consulted with some program alumni. They assured him that IFP was a serious innovation-oriented program. Jaffer applied and was accepted along with 26 people he described as "a very great community that you feel proud to be a part of."

Hosted by a collaboration of universities in the Boston area, IFP was fully funded, covering all room, board, and transportation. The fellows lived together in dormitories close to the activities for the first weeks of the program. When the program's second phase started and emphasis switched to the innovation lab, the fellows moved as a cohort to a new residential space to maintain proximity to the new working quarters.

The IFP provided the participants a strategically designed support network that included individual mentors, team coaches, access to an innovation lab, and a $1,000 stipend each for materials to develop their prototypes. The program culminated with the teams presenting their ventures to the growth committee, the group of people who decided how to distribute the funds to support the ventures. The IFP designed these supports to continue for several years to help these start-ups thrive outside of the incubator in the often-messy context of the Middle East. Leah explained how it felt to have the extra layer of the peace-initiative goal embedded into the innovation program:

> Now, I feel like I have a deep relationship with Palestinians. We share values. We share—we are in the same point of view. We are face to face. And we have the same drive to create and to bring something new and to improve our region in general, and in a global way. And it was very exciting to me to meet these amazing, amazing fellows, both sides. We were 27 fellows—half Palestinians and half Israelis. The goals of this program [are not only] to initiate together the relationship and the trust between each other, [but] also to create and initiate social impact ventures. So, it's all about the entrepreneurship and to get skills about how to be a better entrepreneur. But also, to find this shared interest and to create

> together. . . . And, luckily, I [met] my business partner through this program.

Leah continued to contextualize their innovation program by sharing how it empowers them to take action as citizens on both sides of the Israeli–Palestinian conflict:

> We can always say that the government is not doing very well or they're doing this and this and this, and that's wrong. But instead of sitting in our house on couches [saying], "This is not a good situation," we can create and change from within the population with each other.

She explained that their innovation program fuels the approach to create change from within by creating joint Israeli–Palestinian businesses. Leah said their entrepreneurship coach encouraged Leah and Jaffer to "get dirty," meaning to try things, to actually do things—as opposed to just having a theory. She admitted that being hands-on, implementing their theory with actions, was the hard part. As they encountered challenges, they had to push themselves past frustration.

In just 9 weeks, Jaffer and Leah went from meeting each other to celebrating their working prototype. Jaffer could not hide his joy as he shared, "We just did the demo a couple days ago, and everything is great. So that's very exciting news for us. I mean lots of work to improve, but it works. It's like, ooohh, yeah!" After Jaffer and Leah presented, they were awarded $50,000 to pursue development of their water-monitoring venture in the Middle East.

Jaffer reviewed how the IFP program was designed to facilitate innovation. First, it occurred during the summer, when it was easier for working professionals to attend and for academic professionals to support the program. Second, for the first 2 weeks, the participants focused on ideation and theme construction, then shared their ideas and self-selected into teams based on interests and compatibility. This was where Jaffer shared the tragic story of the professor who had broken his back checking on his water. The Palestinians' need for a safe water-monitoring system so moved Leah, she joined forces with Jaffer to create the water tank monitoring solution.

Leah and Jaffer innovated a product to provide Palestinians the ability to monitor their rooftop water tanks remotely from an application on their smart phones. (Their minimum valuable product has a suite of truly innovative features. However, because their product is in the fledgling stages, those details are omitted from this case.) In her excitement to return to the Middle East with their $50,000 seed-funded business and her new "amazing" business partner, Leah reflected:

> This is something that we created during this only 2 months here. It was an amazing, amazing process. And I'm looking forward to go back now to the region to implement all our plans and concepts. For sure, we're going to face lots of difficulties and challenges—especially because we are a joint company and venture. But we're really looking forward to this.

Envisioning their future as successful water innovators in the Middle East, Leah forecasted that their innovation could be valuable on a larger scale and in other regions of the world that share the same problem.

Jaffer's Perspective on Iteration and Viewing Failures as Trials

When asked about how he dealt with failure, Jaffer responded with total dismissal of the concept of failure. "I don't want to sound sentimental, but I don't think they are failures." He continued to explain that when a prototype does not work, "You just try again using different ways to tackle the problem until you reach the goal. I wouldn't call it failure. I would say they're like circles of trials until you really reach something that is robust and sustainable." Jaffer referred to a filter he had created while in Palestine for the Bedouin people's water cisterns:

> That was kind of the cycle that I went through with my team . . . when we were developing this low-sand filter, that, you know, there's a problem here, a problem with the fitting, a problem with amount of sun to have, and like how many minerals and salts should be in the sand before we install the filter. And you know, like you just try to tackle them, problem by problem. Then you fix it here; it breaks there. And then, you know, keep trying and balancing things until you reach the final product.

Jaffer explained that he was able to persevere through multiple trials because, when innovating, he firmly knows it will ultimately work. "It's simple. It's that it's something you truly believe in. It's just a matter of time of how we can figure it out." He also acknowledged that having a good team is a key factor in persevering.

Jaffer and Leah on Motivation

Jaffer's drive to create his water innovations connects to the gratitude he feels for the opportunities and support he has received. When he described the latest innovation he created with Leah, he explained that, at the core, "we are talking about providing people with a product that will make them feel secure and safe, and less worried and concerned, and less anxious about their water source."

He also shared that, as a Palestinian, he feels a responsibility to give back to his community. As an accomplished top engineer, he would have no problem finding work in

Europe or the United States. However, he feels a conviction to "tackle a serious problem that people are suffering from." Jaffer continued, "Starting from a place where I come from is very important, very essential for me, because those are the people that I grew up with, and I feel that I owe them a lot."

He emphasized that a motivating factor for him in coming to IFP was the idea that he can bring what he is doing back home to Palestine—and bring back the igniting energy of, "What can we create together?"

Leah described the motivation she feels in working on this project with Jaffer as an "inner flame and drive" they both have for solving their issue. Leah credits this inner flame for pushing them and helping them to be brave amidst frustrations. She shared that when they become frustrated, they remind themselves that they are doing this not only for themselves, but also for many others and for the surroundings and for nature. Leah admitted that the environmental problems feel huge and endless but, in her inventive use of the English language, created a word to describe how she counters the behemoth threat of environmental issues: *believe-ness*.

> I think also the believe-ness, to believe that also small action . . . is good to do. Because if we're thinking, "OK, this is huge! This is much bigger than what I can improve," then nothing will happen. We need to choose these small actions. And when we will collaborate them all, it will bring a change. I believe.

Gratitude

Both Jaffer and Leah expressed overwhelming gratitude and delight in being able to work with the other. Jaffer enthusiastically described his collaboration with Leah:

> She helped me grow a lot. So, the process between us has developed, of course, from day one. . . . We have a very diverse perspective on things. You know, like my perspective and her perspective, I feel that they complement each other a lot. And that's very important—especially for business. And especially for young start-ups where you need any opinion, any observation, because the tiniest detail might be a great potential for something big. And I feel that this great opportunity for me to work with Leah has been enriching my knowledge and experience and insights about how I look at things now. . . . It has been truly amazing, and I'm very thankful.

Jaffer also spoke admiringly of Leah's creativity. He expressed that he was lovingly jealous of her creativity, but ultimately so grateful to have Leah's creativity invested in the design of this innovation.

When Leah spoke of Jaffer, she lit up with excitement and joy. She sat up taller in her seat, raised her eyebrows, and beamed a radiant smile. She expressed adoration and awe for him, just as he had for her. About Jaffer, she radiated as she effused, "He is an amazing, amazing, great person, and I really enjoy getting to know his personality and to find our shared interests."

Making the World Better Through Eco-Innovation

Leah admitted that, as eco-innovators, they can face much frustration. For starters, in eco-innovation, it cannot be solo work. "You need to be supported by more people to create a change," and if other people do not understand your goal and means, it can leave you going at it alone. Another frustration can be a lack of resources to make a change.

The problem itself can be so daunting, that you can feel like "such a small dot" compared to the problem, that "you fall into believing you will never bring the change." Frustration can also come from bad habits that are sown deeply into an industry, for instance, using plastics instead of sustainable materials in manufacturing. So many resources go into creating products that, if made of plastic or other toxic materials, can end up in a landfill somewhere, contaminating water or killing animal habitats. Without a healthy, sustainable design discipline, the creation of novel products to improve something can then harm the environment in multiple ways, including contributing to global warming.

However, Leah explained, awareness of these potential negative outcomes is essential to making the world a better place. In thinking about a recipe to create eco-innovators, she suggested to start with giving participants a sense of the problems we face today related to global warming. Then, she recommended guiding the participants to understand why it is necessary for people to address the issues and to create change. She also suggested that the classes in which students learn about these issues be nontraditional; for instance, an outdoor classroom can support different interactions between educators and students in terms of learning about the natural environment. In addition, to arouse more interest in environmental subjects, the topic should change to a new environmental subject each time—such as flowers one time and agriculture the next. Leah suggested that a part of this education should include showing models of excellent eco-innovation and having students study the good examples of sustainable environmental solutions, followed by a reflection and discussion about how to improve the situation.

Leah emphasized the importance of having the students create something novel. Exuberantly describing the process and joy of designing, she suggested that having students engage in the design process was crucial. “Once they feel the wondrous feeling of bringing something into the world from just an idea in their mind, they will be hooked on the amazing feeling.” Leah explained that the fact that their creations will improve life or the environment around them will greatly multiply the students’ feelings of success. The hands-on process lets the students feel the impact for themselves.

Additionally, Leah advocated for people learning how to work in multidisciplinary teams. She strongly prefers multidisciplinary teams because collaborating with people from different professions with different points of view leads to “the best outcomes” for design projects. She felt that partnering with Jaffer fulfills this need because he brings a different viewpoint, as well as engineering expertise.

In thinking about eco-innovation, Leah explained that designers should consider how their creations can make a better world—a better life for someone or better surroundings for all. Leah acknowledged that this is how she sees her role in the world. “It’s amazing to collaborate” with her colleagues at the program, especially Jaffer. Through eco-innovation, Leah hopes to “bring a change sooner *and* later.”

Quintain Analysis

Stake (2006) conceived of a quintain as the target or phenomenon of study. For this dissertation, the three essential questions that aimed to discern what factors and conditions go into the lives of eco-innovators framed the target. The three questions that guided this multiple case study were:

1. What do people who have produced ecological innovations, and others associated with them, report as the critical experiences, factors, and conditions in their development as ecological innovators?
2. What factors and conditions do ecological innovators suggest can inspire ecological innovation among their peers and young people?
3. What pathways towards ecological innovation and common experiences, factors, or conditions emerge from the stories of ecological innovators?

The previous section of this chapter presented each of the three case studies. This section analyzes the themes from those three cases as a whole to discern what the aggregated data and themes indicate about the quintain. This quintain analysis leads to the data synthesis section, which introduces the findings, followed by a summarizing chapter review.

Looking at the three cases as a whole makes it possible to discover how, where, and to what degree there may be consistency with the factors derived from the analysis of the "bright spot" ecological innovators depicted in Chapter 2, Table 1. The three exemplars from the literature review all had access to expertise, nurturance, or a mentor in their field of excellence; iterated or prototyped innovations; experienced a seminal moment or a key motivating drive; and demonstrated ecological concern or interest. Table 8 applies headings from the original table (Table 1) to the eco-innovators from this quintain. Like the exemplars, the eco-innovators from the cases also had access to expertise, nurturance, or mentors; iterated or prototyped their innovations; experienced seminal moments or a key motivating drive; and demonstrated ecological concerns.

By adhering to the procedure described in the *Gathering Themes from Cases* Section (see page 175), I used NVivo to analyze data from all three cases. Themes aimed at the targeted understanding, as guided by the three research questions, were measured by frequency of appearance. The nine most prevalent themes were (a) exposure to science, nature, and innovation; (b) response to vulnerability: motivation, seminal experiences, responsibility, and activism; (c) iterative, team-based problem solving; (d) care for the environment and sustainability; (e) mentoring; (f) optimism and hope; (g) childhood context; (h) creativity; and (i) cross-cultural experiences (Figure 6).

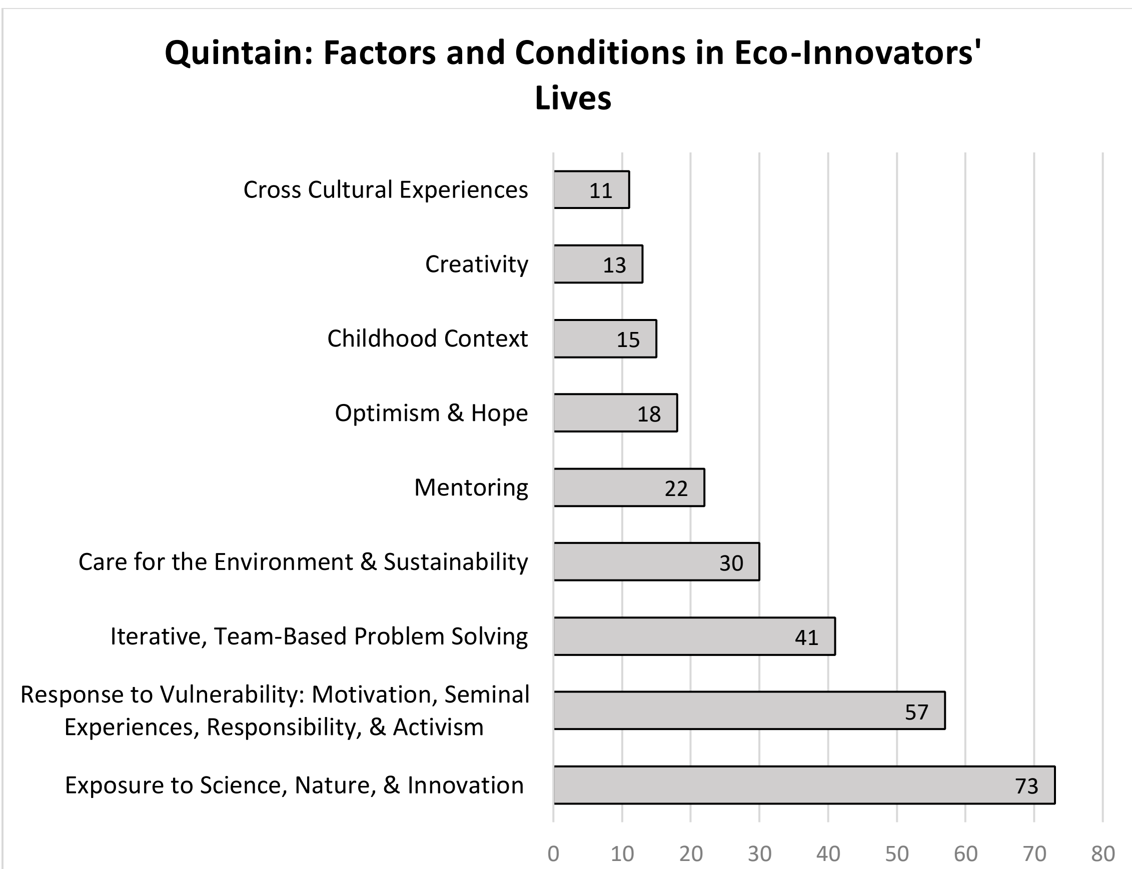

Figure 6. NVivo matrix coding of quintain: Factors and conditions in eco-innovators' lives.

Table 8. *Common Factors from the "Bright Spot" Eco-Innovators Exemplified in the Quintain Eco-Innovators*

Case / Eco-Innovator	Access to expertise/excellence nurtured/mentor	Iterated or prototyped innovation	Seminal moment or drive	Ecological concern/interest
1. Chaeli	Grandfather, camp counselor Seth, science camp mentors, fourth- and fifth-grade science teachers, science teacher Mrs. Wu.	Designed Pine-Condos as model to be prototyped. Experienced iteration at gardening camp.	Awe of Fibonacci sequence—applied pinecone model to condominium's solar panel design. Given impetus to create model through camp challenge to create anything using biomimicry.	Cares for environment by recycling, composting, volunteering for nature cleanups, gardening camp; wants solar panels on her house because "it's like photosynthesis."
2. Elisha	Mentored by men in the science backroom—mentored in fixing microscopes. Mentored at library to figure out how to file for a patent. Nurtured in activism. Professor charged him with: "You have the burden, the privilege, and responsibility of rebellion."	Continually. "It's all failure."	Saw cars lined up for gasoline during oil embargo—"We need to get off this oil thing." Experienced blazing heat in Israeli desert; felt shock and disbelief they had not yet powered everything with solar power.	Providing solar energy to communities with no power structure or that run power on dirty and corruptly provided fossil fuels.
3. Jaffer	Mentored by father, leadership mentor, Malia, mentors at MES, and mentors at IFP.	Dismisses failure; conceives of it as test—all information in the cycle.	Grew up with water insecurity Saw firsthand people without water access.	Access to clean water for all people. "Access to clean water brings peace."
3. Leah	Trained to be nature guide. Trained in design starting in high school. Mentors at IFP	Part of her routine design practice.	Had to give presentation on climate change; what she learned broke her heart. Heard Jaffer's story of professor breaking his back.	Leveraging her design skills to affect change by implementing *Cradle to Cradle* approach to tend to vulnerable people, communities, and creatures.

Exposure to science, nature, and innovation, the leading factor in terms of frequency, is explored in detail first in the following analysis of themes. Next in number of coded data points was *response to vulnerability*, an overarching theme that includes the subthemes of motivation, seminal experiences, responsibility, and activism as ways in which the eco-innovators engaged with others' vulnerability, as well as the vulnerability of earth's life and systems, such as ocean life or fresh water supply. *Iterative*, *team-based problem solving* was the third-most coded theme throughout the quintain. These topics are presented as collapsed together because they often occurred together in the cases. Next were the themes of *care for the environment and sustainability*, followed by *mentoring*. I sought and confirmed these themes because they had been prominent in the literature review and exemplar cases. The next theme to emerge from the cases was *optimism and hope*. It came out strongly in Elisha's case as a motivating factor woven throughout other aspects of his case, including his activism, iteration, and childhood context. It also appeared in the other eco-innovators' cases. The next theme was *childhood context,* followed by *creativity* and *cross-cultural experiences*. Creativity was an expected theme because it was evident in the "bright spot" innovators' lives; however, the strong role that cross-cultural experiences played in two of this study's cases emerged as unpredicted data. The following section provides examples or synopses from the cases to further elucidate the nature of how these themes emerged from the data.

Exposure to Science, Nature, and Innovation

Exposure to science, nature, and innovation was the most abundantly coded theme throughout the quintain. All cases contained evidence of at least one influential science educator. Chaeli, Elisha, and Leah reported a strong affinity for nature. Chaeli, Jaffer, and

Leah experienced innovation programs, and both Elisha and Leah started engaging in self-directed innovation in high school—Elisha with his solar cell and Leah with her dynamic spring-based stool. Table 9 shows the different ways in which the eco-innovators were exposed to science throughout their lives, followed by more elaborate descriptions of how these exposures took place in the eco-innovators' lives.

Table 9. *Eco-Innovators' Exposure to Science*

Exposure	Chaeli	Elisha	Jaffer	Leah
Mentioned science educator positively	X	X	X	-
Participated in innovation program or camp	X	-	X	X
Self-directed innovation in high school	N/A	X	unknown	X
Mentored by tinkering adult family member	X	X	X	Unknown
Engaged in iteration	X	X	X	X
Engaged in creative problem solving	X	X	X	X
Grew up experiencing nature and expressed strong affinity for nature	X	X	-	X
Grew up going to science museum regularly	X	X	-	-
Had access to makerspace or other type of materials-rich construction lab	X	X	X	X
Engaged in hands-on science both in and out of school	X	X	X	X

Chaeli's exposure to science, nature, and innovation. I asked Chaeli, "Please tell me the story of your life as you see it, leading to the creation of your ecological innovation(s). You have as much time as want." In response, Chaeli listed her entire science education chronologically. She started by recalling how she learned about science in Special Start, where she attended preschool with her brother. She then talked about growing up with gardening in her elementary school. She mentioned her fourth- and fifth-grade science teachers and her summer science camps. All mention of science from kindergarten through third grade was based on the school garden. Then, she sped through the chronology of her story:

> In fourth grade, my science teacher was kind of great. We learned about lightbulbs and we went outside and stuff. And then, in fifth grade, we grew plants in bags, and my plant died because it had too much sun exposure. And then between that period of time, between fifth grade and sixth grade, I had a garden camp, the same camp that I'm going to this year. At that garden camp, they also had a science camp, so I signed up. And that's where I made my invention thing with two other girls.

Over the course of her interview and through the entirety of her case, Chaeli's exposure to science, nature, and innovation came up repeatedly. Her community context of environmental stewardship and celebration of science and innovation; her family's educational background, including her parents' majors in college; her grandfather's career and his mentoring; Chaeli's play with LEGOS® and on the iPad, which exposed her to global ecological problems such as the Great Pacific Garbage Patch; her family vacations with science enrichment experiences; her family's enrichment time through their memberships to the local science museum and the Audubon Society; her family's nightly dinner "Questions of the House" game, which boosted curiosity and inquiry; tagging along with her brother as he engaged with mentoring for his love of rockets; her play in the makerspace; and her summer science and gardening camp experiences all contributed to her experience of growing up with the themes of science, nature, and innovation as part of her normal experience.

Mrs. Wu, Chaeli's sixth-grade science teacher, gave Chaeli and her classmates the opportunity to research pressing relevant environmental problems in a self-directed manner and then present their projects to their peers. Chaeli shared about her topic, space junk, during the interview. She had an unusual wealth of knowledge and ideas for solutions to the looming problem of space debris.

Out-of-school science. From a young age, Chaeli encountered hands-on science activities from many arenas of her life. Her grandfather's demonstrations, her time at Special Start, her visits to and play at the local science museum, the science-oriented vacation activities her parents orchestrated, and engaging with hands-on science exploration, were just part of Chaeli's normal life.

Chaeli learned about the Fibonacci sequence in her Math Olympiad Club 2 years before participating in the science camp. Years later, out in nature searching for natural models for the science camp's biomimicry challenge, she found a pinecone, which led her to incorporate the Fibonacci sequence into her design. The introduction of the Fibonacci sequence in her third-grade Math Olympiad club had made an indelible impression on her. During the interview, Chaeli reached for pencil and paper to freehand sketch a model of the Fibonacci sequence and explained how it appears in nature.

Chaeli also remembered two distinct experiences that influenced her care and concern for the environment: one, seeing a lonely panda in the zoo and feeling very sad for it because she perceived it was lonely; and two, learning about the Great Pacific Garbage Patch through an app on her iPad.

The primary life experience that nurtured Chaeli towards making her first eco-innovation was attending a camp that specifically challenged her to create something using biomimicry. Without this experience, she might not have designed her first eco-innovation before she entered middle school, so the girls' science camp was a critical and foundational pathway for her designing her innovation. The camp used an intentional process and series of lessons to set up the campers to imagine and construct objects based on biomimicry.

Chaeli had other unique life experiences that nurtured her development, interest, and confidence as a learner and leader. She attended Space Camp at the Kennedy Space Center and Seaquarium camp, where she swam with dolphins and learned about ocean conservation. Her entire elementary school experience included increasing exposure and responsibilities in the school garden. She attended garden camp for two consecutive summers, and then was invited into a leadership position for the city's gardening program.

Chaeli's complete immersion in science both in and out of school seemed to influence her approach to life. She naturally effervesced a stance of wonder, inquiry, critical thinking, trying things with an attitude of iteration, and creatively constructing solutions to problems.

Relationship to nature. Chaeli's camp counselor Seth intentionally worked to facilitate Chaeli's relationship with nature through the gardening camp activities and experiences. Seth explained,

> Setting up that relationship between them and the environment so that they really care about it—that's the number one step. So, whether or not that's giving them experiences, or they're having fun or discovering something new about the environment is important.

Seth also shared that part of the mission of the camp is to "have them learn more about the garden and what it means to be kind of connected with your environment and what it can provide—and how you have to take care of it. Kind of being environmental stewards."

Chaeli's parents also have been nurturing both Chaeli's and her brother's relationships with nature purposefully over the course of their lifetimes. Lily shared, "We've always done like hikes and earth cleanup days and bike rides." Lily and her husband pursued nature-oriented activities on their vacations; involved their children in sustainable practices in their home, such as composting and recycling; joined the Audubon Society and participated in its volunteer activities; and modeled characteristics of environmental stewardship they want to see in their children.

Lily described Chaeli's empathy towards nature: "My daughter is very sensitive to things like endangered animals and things that harm the environment, because harming the environment means we're affecting all the creatures that live, you know?"

Chaeli demonstrated a deep love for animals and shared that her interest in the environment started with her love for animals. She shared a plethora of photographs she had taken of creatures in nature. Lily provided her understanding of why Chaeli enjoyed taking pictures of animals:

> I would say that most of our vacations tend to be eco-centered, you know, going to places where the kids get to learn about nature and the environment. So, my daughter has actually done a few camps where she's gotten to like swim with dolphins or seals or manatees with all kinds of science themes like conservation. So that's why she loves to keep taking photos of animals.

When ideating the program she would create to initiate children into eco-innovation, Chaeli spoke with conviction:

> Taking them to someplace beautiful shows them that nature is pretty, that nature is amazing, and that, you know, nature is awesome. But to contrast that, to take them someplace horrible will show them what will happen to nature if we keep doing stuff like this.

Elisha's exposure to science, nature, and innovation. Elisha felt competent in science and enjoyed it both in and out of school. Regarding his school-based science education, his science teachers made the most impact on his development.

Relationship with science teachers. Elisha spoke very highly of his "phenomenal science teacher" Mrs. Sterne, who was so passionate about education that she later pursued her Doctorate in Education at Lesley University. He repeated six times how encouraging she was. He even got tears in his eyes when he credited her for inspiring him to pursue his life's ultimate trajectory and concluded, "Yep, it's all about her." Dr. Sterne taught Elisha for four consecutive years (fifth through eighth grade), so they had continuity of relationship. Because she valued investigation and curiosity, she structured her class to nurture these values with consistent self-paced, self-directed, hands-on learning and time and space to wonder about the things they observed and discovered. With multiple concurrent hands-on science labs through which her students could cycle, the students had the control to learn at their own pace, without shame for being slow and without restraint for being quick. Even the quickest students always had something to do.

Dr. Sterne taught ecology. She then built upon that foundational knowledge with a historical but timely interdisciplinary unit on power generation. During the 1973–1974 oil embargo, she challenged her students to investigate the advantages and disadvantages of each type of power. The students investigated fossil fuels, coal, nuclear, and natural gas, as well as types of power that would be available in the future, such as hydro and solar power. The students formed opinions based on their research, interviews with adults, and reading of current events. They then presented and debated the relevant issue.

Dr. Sterne also put the students in charge of the school's paper recycling. "I remember having kids in charge of the trash and carrying the paper out. That was really very early—the very beginning of recycling papers." She explained, "Their job was to go around to all the classrooms, go through the wastebaskets, take out all the paper, and collect it and organize it so we could send it off."

She also volleyed students' scientific questions back to them. If they asked her a question, especially if she did not know the answer, she would challenge them to be a real scientist and investigate that question. She challenged them with her encouraging belief in them to carry out that work.

Elisha also mentioned his high school science teacher, Mr. Ford, who realized Elisha was underchallenged in his class and gave Elisha the opportunity to be the science lab assistant. That assignment opened a world of special access to and responsibility for the science materials and equipment and engagement with adult mentors, which built Elisha's confidence and practical skills.

Out-of-school science. Outside of school, Elisha routinely engaged with science. He would self-educate, testing scientific principles on his own. He frequented the Museum of Science in Boston and played with science kits, often with his brother. He sent away for science kits advertised in his comic books or received them as presents. He had science magazine subscriptions and a solar energy newsletter, starting at the age of 10 years. When he saw a notice on a bulletin board about entering a science contest, he entered and got to work creating his first pyramid-shaped solar cell. That contest provided a challenge with a deadline, competition, and, in Elisha's case, award at the end.

Relationship to nature. Although Elisha felt his affinity for nature had been nurtured more contextually in Israel, he also had experiences that fostered his relationship with nature in the United States. Throughout his upbringing, swimming at the beach, hikes, festivals in the woods, ritualistically planting trees for the Jewish Tu BiShvat holiday, and engaging with his grandparents as they gardened and composted supported his relationship with nature.

Jaffer's exposure to science, nature, and innovation. Jaffer's exposure to science started early, tinkering with his father. Jaffer credited his father for passing on the love of working with his hands. His father guided him through hands-on conceptual learning over the years of side-by-side tinkering in the basement workshop. Outside of home, though, Jaffer was quite dissatisfied with his elementary through high school experience, calling it “discouraging.” He said, “I don’t really remember having any supportive environment during school.” Even in his first university experience in Palestine, Jaffer recalled,

> There wasn’t that space of helping each other and supporting each other and growing and pushing people to succeed. . . . That’s why, when you see people who manage to succeed, they succeed *a lot* because they know how difficult it is to succeed. And when they are having this opportunity to be supported and to achieve some success, they just go crazy with it.

Jaffer’s educational experience took a turn for the better when he met an inspiring water engineering professor at his university.

> I learned from him how water can create inequality and, by providing water to everyone, you can make people equal. That was my interpretation for his lectures and his talks throughout, like, you know, a couple of semesters at their embassy. So that was kind of what inspired me the most. How can I make people equal? You provide them with water.

After majoring in water engineering at his university in Palestine, he pursued a graduate program at the environmental institute in Israel. After that, he applied for a Master’s in Water Engineering program at a university in the United States, which he attended as a Fulbright scholar. After graduating, he pursued employment for a while, but then applied to the IFP program where he met Leah and designed the water tank monitoring innovation.

Leah's exposure to science, nature, and innovation. Growing up on the kibbutz, Leah had complete immersion in nature, which has shaped her outlook on the world. She references "the wisdom of nature" as her guide in her design work. Through her work in design, she has partnered with a variety people and groups, including biologists, geologists, and engineers. With each new project, she gained hands-on, immersive, scientific understanding related to that project. Leah shared that she has always enjoyed working with her hands. While talking about herself as a designer, she said, "I really like to create and make with my hands or with tools and to bring something new to this world that will affect or improve people or surroundings."

Leah and Jaffer's innovation program. Leah and Jaffer's program, IFP, was designed to foster innovation. At IFP, they received materials, a makerspace-type innovation lab, mentors, and financial support for working in that lab. Leah said that their IFP mentor encouraged them to "get dirty" by implementing their theory with hands-on action.

It was clear in the IFP application process that the goal was to create new ventures through the program, although not necessarily *eco*-innovations. The program was structured so that participants (a) had a goal; (b) were supported with materials, access to an innovation lab, mentors, and spending money; (c) had a deadline; and (d) participated in a competition for seed money. New ventures received ongoing mentoring and support for at least 1 year following the program. The IFP shared models and success stories with their participants. The program also paired teams with coaches and mentors to support them with a well-rounded and vetted team of innovation experts to help with their ventures. It pushed the participants to not only develop a theory, but also test their theory practically. The IFP built intimacy and trust among the Palestinian and Israeli participants. The higher goal was to bridge peace between those two groups by creating several new Israeli–Palestinian businesses.

The preceding descriptions and Table 9 show the myriad ways the eco-innovators were repeatedly exposed to science, nature, and innovation in a variety of places, including home, school, and the surrounding community throughout several development stages.

Response to Vulnerability

The eco-innovators in this study all encountered other people more vulnerable than themselves and situations that caused vulnerability to individuals, groups, and humanity. Chaeli's case held many examples of her engaging with and responding to others' vulnerability. She directly responded to her brother's specific vulnerability by assuming responsibility for him, often publicly, and more broadly, through her activist role advocating for the rights of people with Down syndrome politically and socially. She assumed leadership to get others on board with her, raising awareness and money to support issues that affect people with Down syndrome. Chaeli has also responded to creatures' vulnerability by acting to clean up and steward the environment, helping creatures live with less human detritus.

Elisha's life story is rich with examples of his fearless and generous response to others' vulnerability. Elisha risked his own freedom by protesting and advocating for those who were unjustly imprisoned. He designed his solar solution to provide power to communities that, up to this point in time, have languished without access to power and fallen behind the rest of the world in access to healthcare, food, water, and education, among other basic, dignifying rights.

Leah's design career is focused on solutions for those who are vulnerable, such as people who are blind and benefit from her room-orienting designs; people with Parkinson's disease, who benefit from her specialized body-worn gadget; disenfranchised city dwellers who, prior to Leah's design intervention, had no say in the design of their urban environment; the blind Palestinian artisan community; and, most recently, the people of Palestine who must rely on dangerously accessed rooftop storage tanks for their water.

Like Elisha and Leah, Jaffer has dedicated his life to transforming life for vulnerable populations. Jaffer does this by bringing water to people in the world who do not have it. His response to this grave vulnerability, along with the other case protagonists' responses to vulnerability, is examined in the subthemes of motivation and seminal experiences, responsibility, and activism.

Motivation and seminal experiences. This dissertation's definition of a *seminal experience* includes Nakamura and Csikszentmihalyi's (2003) description of the "pressing existential problem encountered early in life (e.g., poverty, marginality, social injustice) [that] inspires first a process of meaning construction, and then the channeling of energy into a sphere that is construed as addressing the problem" (p. 262) and can lead to fueling one's motivation to solve that problem. In addition to this grim but effective impetus for motivation, the definition includes positive moments of awe or stunning moments of clarity, such as an epiphany.

Elisha's seminal experiences. Initially, Elisha did not pursue a scientific career but a life of activism and influencing people through Jewish education. Only in his adult life, when he moved back to Israel and felt the searing heat on his skin even at sundown, did he feel compelled to harness solar energy to benefit society. This seminal experience of feeling the intense heat and emotionally bearing the shock of Israel wasting that solar energy—when it claimed to be a world leader in solar energy—connected to Elisha's earlier seminal experiences around solar energy.

Elisha mentioned three seminal moments related to his interest in solar power: (a) his epiphany moment when he was looking out from his third-floor window at the stream of cars lined up for gasoline during the OPEC oil embargo and he felt deeply that humanity needed to "kick" their dependence on oil; (b) the first time he saw a solar cooker and he inquisitively observed it for a long time while asking many questions of the man who brought it to the nature festival in the woods; and (c) "when Jimmy Carter put solar panels on the White House." Elisha described his response to that news: "I was like, 'Great! Now I get it.'"

Leah's seminal experience. During Leah's service year before entering the Israeli Army, she put together a presentation on global warming to educate the people who came to her nature preserve. While doing research for that presentation, the direness of the situation struck Leah:

> I felt like I wanted to cry. Like, seriously, it did something very strong inside my, like, with my feelings. And I was very worried. I was just, for a moment I just realized how bad things are going now in this globe. And for us as humans on this on this planet, there might be or must be an action

> to do right by changing these behaviors which are very wrong. And I think from this spot and on, this attraction to nature, it was not only the curiosity and me loving nature, but also my worry about nature and wanting to keep this alive, not only for me, but for many others that will come after I [die] and take a part with this nature, hopefully. But I really hope there is still something that we can do to change this.

Jaffer's seminal experience. Jaffer's seminal experience was touching the tap in his home and realizing how fortunate he was to have it—given that he was serving the Bedouin people who had no clean water at all. It launched him into a 5-month commitment of innovation filled with trials, tweaks, retrials, and continued iteration until the water filter functioned well. Jaffer's description of his period of building the water filter for the Bedouin people was one of extreme challenge, joy, and motivation.

Jaffer's motivation. Jaffer's specific and direct motivation to make his most recent innovation, the water tank app, was to prevent anyone else from falling off a roof while checking a water tank. Jaffer's professor had fallen from his roof while checking water levels. That incident spurred a fiery motivation in Jaffer to solve the problem and prevent more suffering caused by the complex geopolitical situation that created the need for Jaffer's people to keep rooftop tanks. Tied to his sense of responsibility, Jaffer communicated that he is deeply motivated to alleviate the suffering of his people because he feels he owes them:

> I think as a Palestinian—there are lots of issues in the Palestinian community. And I have always had two options in front of me: either stay in Palestine and work on one of those issues or just leave. And I can say it

> with confidence, that I can find a job in the US or in Europe, I would say very easily. But I am not 100% sure that's what I want. I think what I want is to really tackle a serious problem that people are suffering from. And I think starting from a place where I come from is very important, very essential for me, because those are the people that I grew up with, and I feel that I owe them a lot.

Jaffer is deeply connected to the need for water because, as a Palestinian, he grew up experiencing water insecurity his whole life. Then, when he spent the summer investing his talents in the Bedouin people who had no indoor plumbing or clean water, his passion intensified. He described feeling an incredible sense of purpose that brought him joy and hope. During the 5 months he was prototyping the water-filtration system for the desert cisterns, his sense of purpose gave him the joyful motivation to get up and work in the desert heat every day—even during a time of war and violence. Doing that work and feeling that sense of purpose, Jaffer explained, "is literally the thing that gives me most hope in the entire Middle East."

Jaffer articulated his sense of purpose in terms of his beliefs: "I believe that securing good and safe drinking water for everyone is a way to bring peace." He elaborated, with even more conviction:

> I believe that bringing everyone in this world water would help them have that sense of convenience and security and safety that they will not need to worry about something that must be taken for granted by this century. . . . And I feel that's my mission in life.

Jaffer shared that he wants to make big change. He wants to help water-poor communities all over the world gain access to clean water. Even with his global aspirations, he said that he would be happy with making just a small change. In his work, he must toggle his perspective between the very small and the very big. While he is focusing on the small tweaks and iterations of his water innovations, he must keep in mind how those tweaks will affect the innovation as a whole and the innovation's purpose within the community context.

This habit of zooming in and out plays into the design of the innovation he created with Leah. Their latest innovation addresses the need of a single user, but also has features that benefit an entire community. The ability to focus on a single person's life experience while being mindful of the bigger picture of transforming how communities and nations access clean water demonstrates Jaffer's agility in shifting perspective. Metaphorically, it is as though he carries with him a microscope, wears missional bifocals, and has binoculars around his neck. He can be mindful of the most proximal and most distal aspects of his mission at the same time.

Jaffer believes that making a big difference will require a collective effort. Even as he wants to make global change, his perspective on his ability as a single person to make that magnitude of difference is bounded by his stance that one person alone cannot change the world:

> I don't buy it. I don't accept it. I just don't agree with it. . . . I believe that individuals can just create incremental changes. Again, it's a collective effort. The more people who are doing these small steps, the bigger . . . the bigger the influence is. Like, it's as simple as this to me.

Responsibility. Responsibility, along with activism, was the fifth-most coded theme in the quintain. This theme was not anticipated at the outset of the research but emerged from the eco-innovators' stories.

Chaeli's responsibility. Through gardening camp, Chaeli had the opportunity to be responsible for living and growing things. She described one element of the daily routine: "We have a journal prompt every day. So, we do the journal prompt and then we take care of the garden for like a half hour. We water it, we weed it—we do stuff like that." Lily added, "Composting is part of it, recycling is part of it, healthy eating is part of it."

Chaeli's gardening mentor Seth explained, "[We] have them learn more about the garden and what it means to be kind of connected with your environment and what it can provide and how you have to take care of it—kind of being environmental stewards." He described how Chaeli played a role at the camp that inherently carried responsibility—she often translated the educator's instructions to her peers and served as a model of how to engage in the camp:

> She's kind of more advanced than most kids there in terms of her education. So, the concepts or ideas that we try to teach, she's able to kind of communicate those to the kids which helps, because sometimes it's easier to learn [from] their peers than [from] a teacher, necessarily, or an older adult. And I think that she cares a lot about it, too. So that's another thing. And just like having the other students see her in that process, like caring so much and also being a little more advanced, I think gives them something to strive for or look for.

The extra responsibility Chaeli demonstrated at gardening camp put her in the unique position of being invited onto the gardening camp's youth leadership team, which entails Chaeli gaining more responsibility for the direction of the camp. Seth explained:

> Some of the ways . . . we will continue to nurture [Chaeli] is we have a youth leadership team that meets during the school year that helps [our gardening camp] improve its own program. [It] also gives the students opportunities to learn and grow in terms of STEM learning and gardening, as well. There are opportunities for them to present their ideas and presentations to our board members and other adults to make funding for ourselves. [This] also [helps] them to learn and grow through these other projects.

In addition to the responsibility she took on through gardening camp, Chaeli also grew up bearing some extra responsibility for her older brother with trisomy 21. Seth commented on Chaeli taking responsibility for Ryan at gardening camp:

> I think just like with her brother—just helping him, like helping him get back on track. If he's not chopping something correctly, [she will] just show him the right way to do it but not kind of chastising, but just saying, "Look, this is a better way to do this" and then showing it and seeing if he does it or not, and then if he doesn't, [she gives] him time to kind of switch to where he can.

Admitting she sometimes fights with her brother, Chaeli shared a typical instance that would start their sibling spats. Giggling, she shared:

> Like my dad will ask me to bring him upstairs, and he'll be like playing with his BeyBlades or something, and I'll ask him to come upstairs, and he'll say no. And I'll like grab his arm and try to pull him upstairs.

Mrs. Wu volunteered that for Chaeli, "Growing up with a sibling with special needs has given her a heightened sense of compassion towards others and also a sense of wanting to right perceived injustice. She is very protective of her brother."

Elisha's responsibility. When Elisha was given responsibility in his first job as science lab assistant, it made him feel important. The responsibility increased his autonomy and freedom. The increased responsibility was paired with new privileges, which he enjoyed, and so he took his job seriously. Because he did well with responsibility, he was given more. His behind-the-scenes responsibilities gave him an initial understanding of how organizations work—an understanding he built upon in the following years. Elisha described how his ever-increasing spiral of responsibility played out in his life to the current day—as he confers with heads of state to discuss meeting their infrastructure needs with green energy. Elisha also imbued this theme of incrementally increasing responsibility into his suggestions for how to educate children to grow up with the potential to be eco-innovators.

Reiterating his concept of increasing measures of responsibility, Elisha exhorted that children need to experience responsibility for the environment and for stewarding the environment. As they take on responsibility, then they experience the cycle of increased responsibility.

Jaffer's responsibility. Chronologically, Jaffer's first mention of bearing responsibility was when he was being mentored in leadership in Palestine. "I was active in a program—one of the biggest institutions in Palestine—where I was responsible for running some summer camps with international volunteers and local volunteers, all doing work with refugee camps and university students."

Jaffer revealed in his speech at the Capitol to members of the U.S. Congress the moment he took on responsibility for the Palestinian peoples' water infrastructure. He emphasized that this moment triggered him to start his career in water engineering. It occurred when Jaffer was sitting in his university hydraulics class. One day, his professor was agitated while teaching. At the end of the lecture, the professor explained, "I am a part of a water project about a water master-plan for seven communities in the eastern part of Jerusalem. . . . Water experts from Europe are conducting this $3.5 million project." Jaffer then shared his reaction:

> Honestly, I don't remember anything he mentioned after these two sentences. I zoned out and started wondering, "Why do we need experts from outside to plan and manage our water resources?" I become angry and mad. Can't we do it ourselves? I speak with two of my classmates, and we all decide on doing a similar project for our city. We knew it was a big challenge, but we accepted it. And guess what? We did it.

Jaffer's sense of responsibility took on more weight when he expressed his intense sense of responsibility to the Palestinian people and to people without access to clean water. He spoke of this during his interview for this research, as well as in his speech to members of Congress. The following excerpt from his speech conveys the intensity with which he feels responsibility to the people of his homeland:

> After working for [MES] for 9 months, I was so lucky to go to the only school in the US that does water sciences solely. I'm not mentioning this for sake of pride, "Oh look at me guys, I'm that person," no. What I'm trying to show you is the big responsibility that I'm holding on my shoulders. I will go home soon. And I know I will convey all these experiences and skills that I have gained here to these communities who are suffering from not being able to access clean water. I am lucky. Yes, I am very fortunate. I am saying this because I know what I have done so far is the dream for so many other Palestinians who I believe are much smarter and skilled than I am. It just happened to be me. Hence, I am responsible for making that change.

Leah's Responsibility. During Leah's volunteer service year, she was responsible for leading groups of people through the wilderness on leadership training expeditions. That responsibility required 3 months of training before she could fully step into the role. Later, through her career in design, Leah's projects assumed responsibility for making life better for vulnerable people groups, such as people in impoverished communities, with Parkinson's disease, or who are blind. Leah's design approach not only assumes responsibility for the wellbeing of her clients and the community in which her designs will "live," but also to the earth and to future generations. When she was learning to be a designer, McDonough and Braungart's (2002) *Cradle to Cradle* approach strongly influenced her. Now, it directs her approach to all her work, including her partnership with Jaffer.

Activism. The last subtheme among all participants' responsiveness to vulnerability is activism. Unexpectedly, activism was a part of all four eco-innovators lives. Their activism was both for issues related to their eco-innovations and for causes not directly related to their eco-innovations.

Chaeli's activism. Chaeli's main area of activism was advocating for people with trisomy 21. Because her older brother has trisomy 21, she participated, along with her family, in going to the State House on Down Syndrome Advocacy Day and attended the March for Life in Washington, DC. Lily contextualized Chaeli's involvement: "Because we're involved in the disability community, it has instilled the sense in all of us that it's really important to give back and to advocate for things."

Mrs. Wu reported that as a new sixth grader to the school, Chaeli gave a speech to the whole school in which she challenged the student body to sit with a child who is sitting alone. Chaeli shared a heartrending story about her brother with trisomy 21 dealing with that at his school. As a seventh grader, she initiated a successful trisomy 21 awareness and fundraising campaign, getting her fellow classmates to purchase and wear mismatched socks on March 21, World Down Syndrome Day. Engaging in activism has developed in Chaeli a sense that she can make a difference by doing something for the causes she cares about. On engaging in pro-life activism, Chaeli said, "I think it was a good experience for me because just like being there made me feel like I was doing something." Chaeli's mother Lily shared her perspective on the potential connection between Chaeli's activism and her eco-innovation:

> I wonder if there is something to be said for if you grow up in a family that really values—that you're not so inwardly focused and you see the

> importance of other things around you including *life* and just an appreciation for *life,* which kind of ties to the pro-life thing. There might be a connection there . . . but certainly my daughter is very sensitive to things like endangered animals and things that harm the environment because harming the environment means we're affecting all the creatures that live, you know?

Chaeli has also engaged with environmental activism through volunteering in nature clean-ups for the Audubon Society. On the whole, her activism has focused on advocating for those who are vulnerable.

Elisha's activism. Elisha's faith, moral fiber, and leadership intertwined with his activism throughout the case. Foundationally, his identity is based on his role as a God-partner, living his mission as a member of the Jewish people, as a "renewable light [upon the world]." He called for the next generation to grow up in a context of learning how to take action.

Elisha repeatedly advocated for the oppressed, those less fortunate, or the environment and galvanized others to act with him. The essence of this theme, Elisha said, is pairing urgency with hope. A speech Elisha gave, after he had been introduced honorifically by some of the awards and titles he had received for his leadership, well demonstrated this complexly braided theme. The following excerpt is paraphrased (for his anonymity) from the last few moments of his presentation:

> Here is an inhabited island park set aside to preserve nature. It hosts numerous endemic animal species; however, it has been fueled fully by diesel, which, unfortunately can, and has, spilled. Our solution: We're

> going to transform this landfill into a solar field and stop this park's need for diesel fuel. This is how we improve the world. Isaiah, the prophet, gives us direction. He commands us to feed the hungry and take in orphans. So, everyone should have food. Everyone should have water. Every orphan should be adopted. All this is predicated on everyone having green energy. So, together, we can serve as renewable light upon the world.

One way Elisha achieved his activist goals was by teaching others. He has been teaching others for decades. His mother reported that he taught lectures on the Middle East to adults when he was only 16. As a Jewish educator, Elisha has transmitted the themes, values, history, and spiritual relevance of his religion to others for years. As the face of his organization, he has taught people through writings, public speaking, lectures, television interviews, fundraising pitches, collaborative visits to solar sites, and numerous meetings about the importance of his solar innovation.

Leah's activism. Leah has leveraged her skills in design to contribute products and phone applications that facilitate environmentally and socially just change. Her designs adhere to the *Cradle to Cradle* philosophy and aim to either serve vulnerable people or connect people to each other and to the earth in community. By taking the firm stand of producing only items that adhere to her sustainability principles and by focusing on producing items or applications that tend to the vulnerable or facilitate socially just change, she has turned her design practice into a means for affecting change. Leah's phone apps include one that facilitates grocery shoppers purchasing items that minimize food waste and environmental harm, and another that bridges farmers and consumers to help support the farmers' sustainable wages. Her design work with the blind Palestinian artisan group also demonstrates her unique approach to activism.

Jaffer's activism. Jaffer's desire for peace and justice in the world drove his activism. His belief that all people should have access to clean water by this point in world history and his conviction that access to water brings equity drove him to serially innovate and engage in creating water solutions for people who need them. It was clear through his life choices, stories, words, and conviction with which he spoke that he cares immensely for those who are suffering. Jaffer's desire to ameliorate others' suffering evolved into an ardent passion to make water accessible to those who do not have it. His work with MES innovating water-filtering systems for the Bedouin people was one way he lived out his activism. His volunteer work with Engineers Without Borders brought him joy, hope, motivation, and inspiration to bring what he learned back to the Middle East. Another significant way he practiced activism was by advocating for the Palestinian people in a speech he gave to members of Congress:

> Politicians, with all respect, have failed to meet the needs of these people who are in urgent need. How did [the] Geneva Convention help in meeting the basic needs of these people? How did [the] Oslo Accords improve people lives? Three one point billion dollars the U.S. government transfers to Israel. And around $500 million are also transferred to the Palestinian authority. All that did not satisfy the basic needs for the Palestinians. I'm calling on you to support these communities. I'm calling on people, members of Congress, to have a plan of budgeting $15 million for the next 5 years, only for scholarships, to help build the technological capacity of

> the Palestinian community. I don't want to see smart people leaving Palestine. Palestinians are smart, resourceful people. They make the most of a bad situation. But I want my story to be sent. To send a message that engineers and architects can be peacemakers. And that unless people experience a better quality of life day to day, and their families where they just want what is normal for all of us here, then the peace deals or roadmaps are meaningless.

Iterative, Team-Based Problem Solving

All the eco-innovators had experiences with iterative, team-based problem solving. Even if they experienced iteration as a solo experience, more often, the eco-innovators told stories of innovation as part of a team. Their instances of problem solving were both directly related to their eco-innovations and in other areas of life as well.

Chaeli's experience with iterative, team-based problem solving. At the gardening camp, Chaeli engaged in projects through which she gained practice working with an iterative design process. Seth explained:

> We do STEM learning specifically—like engineering, like the food/egg drop or the water tower. There's a process where it's, like, (1) identify the problem, (2) think, (3) come up with a solution, (4) design that solution (so, design the water tower), (5) test it, (6) gather feedback (so, prototype it basically), (7) improve, (8) present your ideas—your final design—to your viewers for either your final [presentation] or [for] further improvements. . . . They can continue to improve it or they can say, "This is what solved the necessary problems I have, and that's all I want to do."

> If they do want to improve it, usually that has to be done on their own time—like, they go home and do it themselves. But that is an option.

That process is repeated for each project throughout gardening camp. Seth recalled that Chaeli chose to take her projects home to continue to improve upon them.

The science camp where she innovated Pine-Condos matched Chaeli with two girls to create their project. She partnered and iterated with them when they were present. She described what it was like when they were absent: “I felt kind of lonely, I guess. Yeah, I had nobody to pitch my ideas to, so I didn’t know if they were good or [not].” As a circumstantial benefit of her partners’ absence, Chaeli benefitted from extra mentoring from the camp counselors who stepped in to collaborate with her.

In redesigning her house with LEGOS®, Chaeli directly attempted to solve the problem that their house was not equipped for a third child. She expressed clear understanding that the developmental needs of the baby would change over time by proposing modular repurposing of the architectural components she was introducing into their home. Each function addressed a specific problem that Chaeli either experienced or anticipated, such as adding a sink in the room so people could wash their hands after changing the baby. The sink would serve dual purpose—Chaeli could use it to brush her teeth or put in her contact lenses without competing with her brother for the bathroom.

Elisha’s experience with iterative, team-based problem solving. Elisha’s description of iteration was filled with hope as he explained what it was like for him and his team:

> It is pocketed with not-yet successes. Like, what we’ve been doing is “our success is on the way,” filled with, you know, a thousand obstacles. And

> just like in technology, you have to keep trying new ways. You have to test a theory, see what works, see what doesn't work, advance if it works. It's a very similar kind of process to get to the deployment of the technology, as it is in developing the technology.

As part of staying hopeful through the process, Elisha explained that he devised several strategies to keep himself going because much of his work is based on learning from failure. A major strategy he has employed to persevere through the arduous iteration cycles is to not go at it alone—Elisha has gathered partners and team members who help him persist through failure. He has also partnered with a university, which gives him strong backing, collaboration, and resources for serial iterations towards the goal.

With his team, he has a shared purpose, and they have evolved their process to reframe and capitalize on failure to inform their learning. Elisha explained that the team performs small tweaks. When a tweak succeeds, they use it and build on it. When a tweak fails, it does not ruin the larger innovation because it is a small adjustment. The team views this tweaking and testing as an innovation-testing cycle that makes them smarter.

Persistence is vital to get through the cycle. Elisha introduced this as an equation: *Persistence = Optimism + Fortitude.* To stay motivated through failure, Elisha intentionally stays mindful of his perspective. He keeps in mind the long view—the long view being the future generations—and the mission's big picture—to be a renewable light unto the world. He gives himself no out. Elisha has leveraged his whole family towards the goal, so he has no option but to persist.

As noted earlier in Elisha's case, when he was a teenager entering the science competition, he learned that most light that hits solar cells goes unused because it just bounces off the cells. This problem vexed Elisha because, as long as solar cells were inefficient, solar power could not save the world from its dependence on oil. Thus, Elisha started framing the problem for himself, simply asking, “Okay, what’s the problem?” He then started designing and building his first prototype.

Elisha was and is obsessed with solving a *big* world problem. When he was in school, he seized an extracurricular opportunity to compete in area of innovation. Part of what motivates him to solve large problems is that he believes there are solutions. He also described problem solving as an experience of solving smaller problems and then leveling up to larger, more important problems.

Jaffer and Leah’s experience with iterative, team-based problem solving. Both Jaffer and Leah talked about the importance of having good partners and a shared purpose with a team. They both valued having different perspectives on the team. Jaffer acknowledged that their diverse and complementary perspectives help them. Leah described how she values interdisciplinary teams:

> I find it more . . . it’s not only fun—fun is very shallow to say—but I feel like I fulfill myself more when I am there with a team, rather than alone. It can be biologists, scientist, engineers, designers, and architects. It’s the matter of what we are working towards. I really see this is the right thing to do, because you’re missing a lot of information, knowledge, and professional [expertise] if you stick to only one narrow corridor.

Jaffer claimed that a good team supports forward movement because having teammates committed to solving the problem supports tenacity among the group. He credited his MES team with helping him persevere through 5 months of development, which resulted in a successful water purification system. On how the team helped him persevere, he said, "It's just a matter of time of how we can figure it out. . . . Having a good team is a key success to reach that. Without the good team, yes, you may easily give up."

As a professionally trained engineer, Jaffer adopted iteration as a mindset. When innovating, he does not consider failures to be failures but "circles of trials until you really reach something that is robust and sustainable." Every time Jaffer described iteration, it was in the context of a team. He described this process of serial fixes: "You fix it here; it breaks there. And then, you know, keep trying and balancing things until you reach the final product." Similarly, in describing his prototype for the app and device for rooftop water tanks, he referred to his and Leah's invention as a "working prototype," implying they would make fixes and improve it over time. Jaffer explained that when he is working on an innovation, he believes it will work, and that belief fuels the innovation process.

Jaffer's description of iteration and teamwork, as quoted previously in the case, showed how he does not take failure into his being: "I don't think they're failures." Instead, he conceived "failures" as trials that are part of the design process. Malia described Jaffer as a "total team player [who] is also really good for team leadership and for brainstorming." Teamwork was also at the foundation of the case about him and Leah.

Even as their partnership was loaded heavily with teamwork, iteration, and problem solving, both Leah and Jaffer benefitted from rich experiences in those areas prior to partnership. Before meeting Jaffer at IFP, Leah partnered with several client groups and communities as an eco-designer, including the community of blind

Palestinian artisans and members of the community garden to solve issues with which they were dealing. Leah also had a history of guiding others in teamwork skills through her volunteer work as an outdoor educator.

Prior to meeting Leah, Jaffer engaged in iteration with several teams: one team to design the Palestinian water project, another team to design the cistern water filter for Bedouin people, and a team in Guatemala with Engineers Without Borders. Jaffer’s experience with problem solving included the Bedouin’s water problem. The method involved leading a team through a process of thinking about how to solve the problem and then developing the water cleaning system. It took about five months to build the prototype and then test it, but it led to perfectly clean drinking water. Jaffer’s work with MES to solve the Bedouin’s dirty-water problem also gave him experience leading teams.

Malia, Jaffer’s host mother and mentor, spoke of his leadership qualities:

> He’s really good for team leadership. He’s really good at brainstorming and then hoping people coalesce around the concepts. I watched him do it as they organized different events for the summer leadership program, and it’s obvious that that’s a part of what he does for work. He has that wonderful ability to work well with others and gently lead them. He’s a very gentle leader.

Care for the Environment and Sustainability

During the interviews, I posed questions to learn if the case eco-innovators’ lives were consistent with lives of the “bright spot” eco-innovators, who all showed care and concern about the environment. Chaeli, Elisha, Leah, and Jaffer had all created innovations to solve an environmental problem so, clearly, they already had some awareness and concern for the environment. To determine the story behind that environmental concern, I asked the question:

> If you were to tell me the story of your life history through the lens of your relationship to the global environment, please tell me that story. Please think back to your first memories of becoming aware of the environment and your first memories of becoming concerned about the environment. When you're ready, please start telling me that story.

Chaeli's care for the environment and sustainability. Chaeli shared two instances in which she remembered first caring about the environment. The first instance was when she felt sad for the panda "all alone and sad" at the zoo; the second was learning of the Great Pacific Garbage Patch for the first time while she played a game on her iPad. Those two instances initiated her ever-growing love for animals and increasing commitment to stewarding the environment. Her love of nature was nurtured further by her family's nature-oriented vacations, nature hikes, and volunteerism through the Audubon Society.

Elisha's care for the environment and sustainability. Elisha's commitment to environmental stewardship was firmly rooted in his faith. Some of his first memories of environmental stewardship were associated with Tu BiShvat, the Jewish tree-planting holiday. His conception of himself as God's partner to steward the earth fueled his work and many of his conscientious lifestyle decisions. In addition to all the low-bar practices, such as recycling, composting, and avoiding plastics, Elisha engaged in an ever-growing palette of more demanding environment-stewarding practices. For example, he saved up to own one of the first hybrid electric cars in the United States, which was very expensive at the time but, for Elisha, worth it for the sake of his environmental principles.

Now that he lives in Israel, Elisha refuses to own a car until he can power it on 100% clean energy. Currently, Elisha advocates for people to cut their beef consumption because that industry contributes to carbon emissions, his family eats chocolate and coffee only if fair trade certified, and he offsets his carbon footprint with organizations that plant an equivalent number of trees to counter the carbon emitted into the atmosphere by his airplane travel.

Leah's care for the environment and sustainability. Having grown up fully surrounded by nature and experiencing it with all her senses, Leah dedicated her life and career to creating designs and solutions that steward the environment. She follows what she calls the "wisdom of nature." When Leah designs objects, she considers the entire process, the energy needed to create the object, and the materials—both those that end up in the product and those used to manufacture it. She also thinks about how the object will affect the environment in its intended state and how its materials might contribute a second life to something else when its intended use is done. In that way, the materials avoid a landfill and contribute to some other environmentally friendly purpose. She bases this thinking on the *Cradle to Cradle* and *Upcycle* paradigm shifts McDonough and Braungart (2002, 2013) introduced.

Jaffer's care for the environment and sustainability. In contrast to Chaeli's, Elisha's, and Leah's appreciation for nature, Jaffer's environmental stewardship had a different genesis. Growing up with an acute awareness of his people's lack of clean water informed his sense of environmental stewardship. "I grew up with consciousness of like how valuable water is." The circumstances that conspired to deprive Jaffer and his people from water served as "a pressing existential problem encountered early in life" that inspired Jaffer's "meaning construction," which led to his "channeling of energy into a sphere that is construed as addressing the problem" (Nakamura & Csikszentmihalyi, 2003, p. 262).

Leah and Jaffer's shared commitment to design for sustainability. Leah and Jaffer's shared commitment to sustainability undergirds their work as eco-innovators. Designing with sustainability in mind requires that they consider the materials and natural resources used throughout the fabrication process and how the innovation may affect the environment in its production, its use, and its disposal after it has served its intended purpose. Both Leah and Jaffer were influenced by their education and work experience to value sustainable practices. Leah's design philosophy exhibits her consistent commitment to sustainability throughout the case. Jaffer, too, came into the program valuing sustainability and mentioned it as part of the goal of his design process. He found his greatest hope for the Middle East in helping people sustainably access clean water. The Israeli institute where Jaffer studied water resource management was built from a mission of peace amid conflict through responsible environmental protection and sustainability.

Mentoring

Just as mentoring was in all the "bright spot" exemplar eco-innovators' lives, so too did mentoring show up in all of the study cases. Three of the eco-innovators were mentored by a family member in scientific matters such as tinkering, experimenting, or gardening during their early childhood. They also received mentorship from other people, in other fields, and in direct relationship to the creation of their eco-innovation.

Mentorship in Chaeli's case. Chaeli's grandfather, a chemical engineer and seasoned science mentor through a science museum, intentionally connected with Chaeli through hands-on science activities that he prepared. Seth, her gardening camp counselor, also mentored Chaeli in gardening and environmental stewardship. Seth discussed intentionally supporting Chaeli's relationship with nature, her practical experience with iterative design, and her cooking and gardening skills. Counselors at her girls' summer science camp also mentored Chaeli when her partners were sick, and so Chaeli benefitted from the extra attention and guidance when developing her Pine-Condos prototype.

Mentorship in Elisha's case. Elisha received positive role modeling and mentoring from his inventor grandfather. Elisha's mother said, "To understand Elisha, you have to understand my father. . . . He was an inventor in his basement. He loved growing things." She described how her father purchased and transformed an empty lot of stone and glass into

> the most fertile organic garden within 80 miles. . . . That was part of Elisha's early life, being in the garden, watching his grandfather and grandmother take care of that and eat the food. They even had chickens. . . . They composted way before the recycling thing. . . . They reused, repurposed, and ate organic food. . . . But that was very unusual and that was part of Elisha's background.

Elisha credited his parents for mentoring him in activism—his father by example, and his mother by taking him with her to activism events. Elisha also said that, at the library, he was mentored through the process of researching how to file a patent for his first solar cell. The backroom cadre of men at his high school mentored Elisha, training him to be the lab assistant and microscope technician. Later, in college, he established important relationships with influential professors and Jewish community leaders who influenced his activism and sense of purpose.

Mentorship in Jaffer and Leah's case. Both Jaffer and Leah credited their innovation program for matching them with one-on-one mentors to support them in their water app eco-innovation and business, as well as in their relationship with each other. The IFP listed this mentoring as part of the program's "what to expect" literature. Additionally, Jaffer spoke of several mentors who invested in him over his lifetime. Early on, his father played a mentoring role when they tinkered in the basement workshop. His father modeled hands-on problem solving when he showed Jaffer how to solve algebraic problems using cubes. "My dad is a very, very hands-on person. I think I learned from him. My love to do things with my hands comes from witnessing my father doing that."

W. B. Johnson and Ridley (2004) explained that one role mentors play in their protégés' lives is as a provider of encouragement and support. Thus, evidence of encouragement and support equates to evidence of mentoring. Jaffer's father was the only person who encouraged and supported his risky decision to attend a program in Israel. Because no one else backed him in that decision, his father's encouragement and support meant a lot to Jaffer and brought the two men closer to one another.

Jaffer mentioned Malia as a personal mentor. She talked with him about environmental law, intentionally made connections for him, and continues to support him in his career. Malia's actions are evidence of the mentoring habit W. B. Johnson and Ridley (2004) described as "opening doors" (p. 12) for mentees that they would not have access to otherwise. Jaffer counted both MES founders as mentors, but one of the founders more specifically:

> He is the smartest person on earth. He is the one who was harsh on me many times to make me learn and grow, and I did. And if I would think of one person that I would like to identify as a mentor, it would be him. . . . Whatever he says, I believe. It’s like my Bible. Having those people and maybe some others in my life, I don’t think I can thank them enough. I think that I just want to finish this interview and go and thank them through emails now. It’s amazing how much contribution they had in my life. . . . You know, it’s easy to build this network of people to invest in you. I think this is amazing.

Optimism and Hope

Optimism and hope came to the fore in each of the cases, in some ways tied to their childhood context, in some ways tied to something intrapersonally deep such as spiritual faith, and in some ways connected to a mindset. However, as it appeared in the eco-innovators’ lives, it seemed to fuel their tenacity and connect to their sense of purpose.

Chaeli’s optimism and hope. Chaeli’s mother Lily explained that their household is deeply optimistic. Because Chaeli’s older brother was born with Down syndrome, Lily rearranged her life to advocate for him and set him up to have the best life possible. As she invested and advocated for him, he continued to exceed expectations, bursting through any limiting preconceptions of what he could do. Chaeli’s family lives out the reality that a person with Down syndrome can do much more than educators, physicians, and society at large previously thought possible. Thus, the notion of "anything is possible" has strongly influenced the family mindset, and Chaeli has taken it as her own.

Elisha's optimism and hope. Elisha's story, demeanor, and mission resonated with the value of hope. His optimism seems to have been constructed in his life by a series of unlikely but deeply meaningful wins that instilled in him the sense that "anything is possible." It started with growing up in Israel in the era just after Israel won the Six Day War and continued throughout his life. In college, he held onto hope as he protested for divestment from South Africa—despite the personal risk that he may lose his scholarship. This hope was later rewarded when Desmond Tutu came to thank his university for their influential divestment.

Elisha's home and school life reinforced both urgency and hope. He pointed to the dyad of urgency and hope as an essential condition that contributed to him becoming an eco-innovator. Upon earning a prize for his solar cell, Elisha was convinced that solar power was the clean energy of the future. This future-mindedness gave him purpose, electric with hope. Elisha has worn the word, *Hope*, on an armband for more than a decade. His adherence to hope undergirded his optimism and fortitude through challenges as weighty as throwing in his lot with those recovering from genocide. Hope certainly kept him going when he faced failures.

Elisha explained how his daily practice of counting time according to the Jewish tradition marks every day with the dawn of hope. As an adult living in Israel, his relationship with nature has provided him with profoundly motivating symbolism. He described nature pointing towards optimism as he witnessed a plant growing from a desert rock. He interpreted that as “the actual sprouting of life and progress and hope that I think is the natural progression.”

Leah’s optimism and hope. Leah’s demeanor was contagiously optimistic. She used the word *amazing* to describe several experiences in her life: Her volunteer year focused on educating others about sustainability was “amazing”; her college program in design was “amazing”; and taking the risk to be a freelance designer turned out to be “amazing” because it allowed her to stick to her principles and work on a variety of projects of her choosing. She described that year and reiterated that it was “amazing.” The IFP was “amazing.” She conveyed her awe and joy in working with the blind Palestinian artisan group, using “amazing” four times to describe different aspects of the project. She doubled up to describe her peer innovators at IFP as “amazing, amazing fellows, both sides” (Israelis and Palestinians), and Jaffer as an “amazing, amazing, great person.” Besides her mannerism of enlivening a conversation with optimism and hope by joyfully describing her life experiences and treasured people as “amazing,” she expressed the sense of an inner flame that keeps her going. In the face of the daunting ecological problems of which she is very much aware, she keeps herself going with her sense of “believe-ness” that a series of small changes can make a difference.

Jaffer’s optimism and hope. Malia, Jaffer’s mentor, described him as one of the most optimistic, yet serious, people she has ever met. Describing the land where he grew up, she exclaimed, “It was an absolute miracle that he was as optimistic a person as he is. He avoided the pitfalls of anger that would certainly hamper me if I lived in that environment.”

After receiving a Fulbright Scholarship, Jaffer had to wait to travel to the United States. During that time, he started working with MES. At the end of his first day there—after a day of helping the Bedouin people—he had an epiphany. He touched his sink tap and felt overcome with compassion for people whose access to water was so much worse than his. “So that really, really shocked me a lot: how many people will get sick just because [of] the water they drink—if they had the water in the first place.” That moment catalyzed his passion to ensure less fortunate people had access to clean water and directly preceded his work to create his first innovation—a water-filtration system for cisterns. In collaborating with a team to innovate a solution to give people access to clean water, he felt hope in his homeland, even as it suffered through the war in Gaza. Encapsulating that experience, Jaffer professed, “It’s literally the thing that gives me most hope in the entire Middle East.”

Speaking about the weight of responsibility to the Palestinian people he metaphorically carries on his shoulders, Jaffer added that he hoped collaborating with his new-found Israeli friends, whom he referred to as family, would bring about change through innovation:

> What brought me here [to the innovation program] is the idea of what we can do back home—me, as an individual, and us—this family [of Palestinians and Israelis] that we are shaping right now, together. What can we create together?

Elisha and Jaffer: “Getting up the next day.” Elisha and Jaffer used a similar expression, “Getting up the next day.” It conveyed their optimism and hope while both men were in the process of iterating their innovations. Elisha used the expression to describe the perseverance needed to proliferate his innovative solar power grid throughout the developing world:

> Failure is not an option. You have to get up the next day and figure out how to succeed. . . . If I'm not willing to show that I believe in it, then asking other people to take the risk without us didn't feel morally correct. So, you just have to get up the next day.

Jaffer used the same expression to convey how the process of creating a water solution for people who desperately needed it kept him motivated through the trial of war:

> I was working in the water field and developing this whole water system. And it took about five months probably to build the prototype and test it. . . . I remember, every night I would go sleep after working day—I would be like, "Well, I can't wait for tomorrow to begin again." I was struggling a lot in my society. I was struggling [with] Israeli occupation. But the joy and the sense of peace I would get just by working for [Middle East Sustainability] is something that I cannot really describe with words. It's something. It's literally the thing that gives me most hope in the entire Middle East. It's like having this group of people working to get there, even during the summer of 2014, during terrible war in Gaza. We continued to wake up every morning and go to work under the sun and install and do maintenance and help people. . . . And I think keeping that spirit during the darkest days, like wars and days of violence, I think that's really what made me feel that *yes*, I can make a change for people's lives!

Childhood Context

The case innovators grew up in very different contexts, as they grew up in three different countries with different family situations and different faith backgrounds. Despite the variety in their socio-cultural surroundings, their contexts seemingly steeped them in similar values that invigorated different developmental attributes, such as trying, advocating for those more vulnerable than themselves, taking responsibility, and engaging in self-directed discovery.

Chaeli's childhood context. Chaeli grew up in a context of optimism, advocacy, environmental stewardship, and the celebration of science. Lily described her daughter as one who values life:

> To be life affirming is to be optimistic. She is definitely really optimistic and has hope for the future. That is a product of the child's environment. If you also have parents who are future-oriented and hope-seeking, they will instill that in you. They say that love, hope, and faith are the things you need, and I feel that those three things she's exhibited.

In concert, Chaeli's contextual conditions of home, school, and city promoted environmental stewardship and scientific inquiry. Her city started collecting compost weekly along with the garbage and recycling pick-up, so her family routinely composts and recycles. Their city has invested heavily in reducing fossil fuel emissions by restructuring to make the streets more hospitable for bike transportation, reducing parking spaces to promote a one-car-per-household norm, and providing clean, affordable, and reliable public transportation. The city also supports the schools' science and gardening programs, including the programs Chaeli attended, so all children in the city grow up with gardening experience in their schools. The city funds summer programming, allowing children to attend programs such as gardening camp and science camp for free—or even receive a stipend to attend. It hosts annual weeklong science festivals with activities geared towards children and youth, including those themed around the environment and sustainability. Chaeli's city and surrounding area host more than one science museum and several other child-friendly museums. In the summer, the city closes off a major thoroughfare to encourage outdoor recreation by the river.

Chaeli's family values and invests in education. Both parents majored in science for their undergraduate studies—her father in environmental science—and both parents earned master's degrees in business. Family vacations often centered on nature exploration or science-based camps, such as an animal camp or space camp. As donating members, Chaeli's family participated in Audubon Society events such as nature clean-ups.

Chaeli's older brother is fascinated with rockets and is particularly inquisitive. She tagged along in many of his rocketry investigations. She learned alongside him at dinner, as the family turned her brother's inquisitiveness into a game called "Questions of the House," in which the family guesses and investigates emerging curiosities, such as "Where did basil originate?" In addition to that game, Chaeli has grown up playing with LEGOS® and her classic doll house. As a burgeoning teenager, she has given away most of her toys, but she has kept the LEGOS® and her doll house.

Chaeli's parents intentionally nurtured Chaeli and her brother's curiosity and enrichment. Even though they support and provide opportunities, Lily explained, they do not push:

> So, to be honest, I don't really feel like we pushed her that much, and that works well for some kids. It happens to work well for her. Because I think the independence piece, . . . giving her the tools and the freedom to be creative, has kind of propelled her.

As part of encouraging her areas of interest, Chaeli's parents let her sit in on the architectural meeting for the redesign of their house to accommodate the new baby. "So, my daughter has an interest in design. So, she was involved with some of the initial meetings with the architect." This led Chaeli to learn more about materials, as well as to construct her house remodel from LEGOS® to present her ideas to her family. Her parents welcomed her ideas and took them into consideration, thus validating Chaeli's input.

Through her advocacy work, Lily has modeled some of the traits seen in Chaeli's disposition. Lily stands up for the vulnerable. She advocates for all students with special needs in the school system. "A lot of that work I think has allowed me to understand school systems, because that's part of what we do. We consult with school districts on how to better meet different learning styles of kids with complex needs."

In addition to Lily's advocacy, both of Chaeli's parents volunteer at the school. This has strengthened their relationships with the school and helped them advocate for Chaeli:

> One of us, sometimes both of us, participate in school field trips—both mom and dad. We want to. . . . Also, I think because of advocacy at school, part of it stemming from advocacy related to Ryan, but by natural extension—because those relationships have been developed—then it's

> easy to also advocate for Chaeli to have other opportunities. So, she's had a lot of those at school, too.

One unique developmental life experience was growing up as a close-in-age younger sister of a bright and inquisitive boy with trisomy 21. Chaeli's mother has been a fierce advocate for her son, making sure he receives every support and opportunity to thrive, including a full schedule of early intervention services. From her infancy, Chaeli received those early intervention services alongside her brother, even though she did not need them. Her mother believes this intentional curriculum to support neurological development, along with learning ASL as a co-first language, "supercharged her brain."

Elisha's childhood context. Elisha grew up in two countries, and his family structure shifted from one household to two. Through it all, activism, optimism, and the sense that "anything is possible" remained his contextual constants. Elisha grew up with free time and often played with his science kits with his younger brother. Because he lived in two countries, he experienced everything that goes with cross-cultural experiences and speaking two languages—although his parents' choice to live in a predominately Jewish neighborhood when they returned to the United States mitigated some of that. Given that he grew up in a Jewish neighborhood, his parents were Jewish activists, and he attended a Jewish day school, Elisha experienced much of his learning with complete immersion—relevant geopolitical issues were discussed rigorously all around him: in his community, at home, and at school.

Growing up in an era of protests, wars that affected his homeland, and emerging environmentalism shaped Elisha's understanding of the world. He explained:

> Growing up in the 70s, in particular in the Boston area, a lot of this stuff is in the air about, sort of cause-based activism. That was normative, at least in the places where we spent time in our circles.

Environmental festivals and activism were very much a part of his context. Given the omnipresent Judaism of his life, Tu BiShvat was something everyone in his world celebrated. Planting trees was the norm. He also experienced a magnified sense of Earth Day as the parade and festival took over his street with booths and hordes of people focused on celebrating and tending to the earth.

Elisha told the story of a seminal experience that contributed to his becoming an ecological innovator in solar power. When he saw the long line of cars to get gas during the OPEC oil embargo, he experienced an epiphany. When he shared the story, it was as though he was reliving that childhood moment, seeing the scene with his imagination: “There’s a continuation of war below my bedroom window. We have to get off this oil thing.”

Elisha’s father modeled civic engagement, serving on the town government. Elisha proudly recalled how his father had been in Washington, DC for Martin Luther King, Jr.’s “I Have a Dream” speech. Dr. Sterne described Elisha’s father as supportive and forward thinking.

Elisha’s mother brought him to civil disobedience training, purchased subscriptions to his scientific magazines, attended festivals and protests with him, and raised him in a conscious commune, where he could exercise his voice and opinion among a community of adults.

Jaffer's childhood context. The context of Jaffer's upbringing included at least one major change in his family's home circumstances. Until he was 11 years old, he lived in a city known for its optimism. Then, due to the conflict with Israel, his family was forced to move to another city in Palestine where water did not come regularly. His family ran out of water once, and living in their house for days without water was a viscerally horrible and embarrassing experience for him. It seared in his mind the pain of not having enough water. He lived with the ever-present awareness of the conflict in the Middle East and an ever-present fear of running out of water. "Running out of water is like a big monster everybody's seen and wants to avoid."

Before Jaffer took the opportunity to go to Israel to study, many people in his life—including his leadership mentor—had great disdain for Israel due to the living conditions the ongoing conflict caused. Jaffer's context was one that lacked peace and made him feel hopeless. He wrote 500 emails applying for scholarships so he could escape it. "I felt so desperate, I felt that there's no hope . . . like, it's going to be a terrible place to be—like the whole Middle East. So, I was just looking to go, to leave the Middle East."

Leah's childhood context. Leah's childhood was filled with days of freely exploring nature on her kibbutz with fields and crops all around. She grew up among a community of people with shared values and a shared economy. At her school on her kibbutz, people regularly spoke of seasonal changes to the crops. For high school, she transferred to a different regional kibbutz school where she majored in product design. Through that high school program, Leah learned about the *Cradle to Cradle* approach to sustainable design.

As an Israeli citizen, Leah was required to serve in the Israeli Army. Prior to entering the military, Leah volunteered for Israel's social services for 1 year as an outdoor team-building instructor, guiding groups of people through nature. "I did this because of my big passion [for] nature and [for] being outdoors and really getting to know the nature from the source and the roots and then to bring this knowledge to other people."

Creativity

Creativity featured in all three cases. Jaffer even lovingly expressed jealously over Leah's creativity. In Chaeli's case, her grandfather talked about her creativity as he shared about watching her perform in the theater. Lily also beamed about Chaeli's creativity, as she urged Chaeli to talk about her LEGOS® exclaiming to her daughter, "You are so creative!" In response, Chaeli described how she designed a remodel of her house to accommodate her soon-to-be-born baby sister. She picked up a pencil and paper and sketched the layout of her house and redrew elements of her redesign to explain it. Chaeli also played violin, designed a ceiling-to-floor set piece for her school play in which she acted, designed pillows in her school makerspace, and sang with her school choir. In designing her eco-innovation, she made a three-dimensional model with the materials the camp supplied. Often after school, Chaeli could be found creating things in her school's makerspace.

Elisha's mother also gushed about her son's creativity. Hannah reported that he "was very creative" and told stories of some of his creative activities as a child. For example, when he received his first camera, he created a slide show for her Jewish women's organization. When he was at a piano, he would play it and make up melodies.

Although he never had lessons, he would create tunes and then teach other children how to play them.

In reflecting upon his youth, Elisha recalled loving comic books because they were filled with imaginative scientific stories and superpowers, which, he surmised, fueled his imagination. Elisha's creativity served him as a burgeoning eco-innovator when he started sketching his solutions to wean the United States off oil. He first sketched a solar-powered car and then an underwater wave machine to collect wave power.

Leah's creativity blossomed in high school under the continual nurturance of her design program. At university, Leah invested further in her creative skills by majoring in design. Upon graduation, she chose to be a freelance designer instead of a corporate employee so she could have the freedom to choose her projects and maintain her commitment to sustainable design.

Throughout her career as a designer, Leah has felt a great sense of passion and purpose for her creative work because she has consistently chosen projects that improve life for people. She credited McDonough and Braungart's (2002) *Cradle to Cradle* design philosophy for providing the foundation for her earth-conscious design decisions.

Cross-Cultural Experiences

Jaffer, Leah, and Elisha had significant cross-cultural experiences that informed their lives as eco-innovators.

Elisha's cross-cultural experiences. Elisha's cross-cultural experiences started when he was young, living in two countries and then in two distinct household types as an adolescent. As part of his role as leader of his organization, Elisha speaks with heads of state and brokers deals with nations particularly in the continent of Africa. He noted that his childhood civil disobedience training helped him have courage during a few harrowing circumstances he encountered while engaging with communities that did not have an energy infrastructure but had an empowered and weaponized milieu of corruption: “I found myself to be a relatively hopeful person dealing with some of the toughest places on the planet. And you meet the people and you see why. You meet the people on the ground.” The hope and purpose Elisha experienced from his cross-cultural experiences outshined any apparent risks.

Leah’s cross-cultural experiences. Studying and living as a designer opened cross-cultural experiences for Leah. Through design, she gained opportunities to work with Palestinians, as well as different groups of people within Israel. Those experiences prepared her for her greatest-yet cross-cultural endeavor—moving to the United States for the summer to work with the cohort of half Palestinians and half Israelis, where she teamed with Jaffer.

Jaffer’s cross-cultural experiences. Jaffer’s first major cross-cultural experience to Israel caused significant disequilibrium in his understanding of the Middle East. That experience opened him to understanding that the world was much more complex than he had previously thought and activated his critical thinking, listening, and empathy skills. His subsequent cross-cultural pursuits continued to open opportunities for him.

Jaffer’s perspective continually evolved as a natural consequence of seizing opportunities to participate in programs that required him to live abroad. When Jaffer moved to Israel to attend the water management program, he was immersed in a completely different culture. It opened his eyes to things he had not known. That disequilibrium seemed to lead to a transformative period of psychosocial growth:

> I was very, very exposed. My core beliefs were very, very much challenged. [There were] things that I started to learn about from zero: things like all that military service is mandatory for all Israeli civilians, especially Israeli men; things like about the Holocaust, for instance. I didn't learn about it in school, the same way that Israelis do not learn about Nakba in school. Looking at some dates in the calendar where they mean two different things for two different people. And that was—that really struck me so much and that made me really question, so what are the facts?
>
> So, facts became questionable to me, and that's not easy because we usually like to be anchored to facts. So, we feel that there is something that we can, you know, have us stable. And when you question those facts, you're actually questioning your stability and inner peace as a result. So, but being there in Israel, for . . . I lived there for about a year and a half. . . .
>
> I learned so much about myself. Even the simple things like how you can have an argument; how can you talk to people; how can you convince people of your idea. And it's not about convincing them, it's about understanding. So how you can share your story and how you can be open to hear others' stories. I know in theory this sounds very easy, but like going through that is never an easy thing to do. And it requires a lot of

> energy, in my opinion. And I think the biggest challenge there is that when you actually go back home, to where you come from, and then you find yourself to be a different person. And then you start asking yourself, "Who are you?" and "Who am I?" and "What is my identity, now?" And "Did I change? What happened to me?" These are not easy questions to ask. And finally, an answer for that may take up to years.

After that period, Jaffer continued to gain cross-cultural experiences by working with the Bedouins, moving to the United States for the Fulbright, volunteering in Guatemala with Engineers Without Borders, living in Germany, and then returning to the United States for the IFP. With each new cross-cultural experience, he gained knowledge, experiences, a broader and deeper understanding of the scientific and geopolitical systems at play in relationship to water, and increased capacity for empathy for the different peoples of the world. As Malia described, "He definitely has empathy for people and cultures. . . . Empathy is a very strong presence with Jaffer."

Findings

The three cases examined the lives of four eco-innovators from a variety of informed perspectives. In exploring the quintain, all three cases were considered as a whole to discern what the entire body of cases revealed about the lives of eco-innovators. Through analyzing the quintain, some unifying themes emerged. The themes were synthesized to develop the following 11 findings. Some findings answered more than one guiding question. The three guiding questions for this study were:

1. What do people who have produced ecological innovations, and others associated with them, report as the critical experiences, factors, and conditions in their development as ecological innovators?
2. What factors and conditions do ecological innovators suggest can inspire ecological innovation among their peers and young people?
3. What pathways towards ecological innovation and common experiences, factors, or conditions emerge from the stories of ecological innovators?

Given the crossover, Table 10 displays the findings in connection to the specific guiding research questions they answer, as well as which cases contributed to that finding. The findings, along with some explanatory content for each, follow Table 10.

Through the voices of people interviewed and the supplemental data, the three cases revealed a plethora of critical experiences, factors, and conditions that occurred in the lives of the eco-innovators that answered the first research question. These factors and conditions are represented in Findings 1 through 10. Findings 7, 8, 9, and 10 also answered the second research question, aimed at the eco-innovators' suggestions to promote increased ecological innovation among their peers and in society. Findings 10 and 11 answered the third research question, revealing distinct pathways towards eco-innovation. As a unified whole, the quintain revealed the following 11 findings.

Findings: The Eco-Innovators in this Study:

1. Had sustained, immersive, and tactile exposure to scientific exploration in and out of school.

The exposure began when the eco-innovators were in early childhood. In the lives of three eco-innovators, exposure was a feature of a personal attachment to a family member. All four eco-innovators benefitted from rich experiences in the sciences. Chaeli, Leah, and Elisha had this rich exposure to nature and science before kindergarten. Jaffer reported not having much exposure to nature throughout his growing-up years; however, his early childhood experience consisted of tinkering with his father and learning how to solve algebraic equations manually with cubes. Jaffer shared that his rich, immersive, tactile exposure to water engineering started in his university years and built from that point.

Table 10. *Visual Representation of Research Questions Each Finding Answered and Cases that Contributed to the Finding*

Finding	Guiding research question (RQ)			Case		
	RQ1	RQ2	RQ3	Chaeli	Elisha	Jaffer and Leah
1	X			X	X	X
2	X			X	X	X
3	X			X	X	X
4	X			X	X	X
5	X			X	X	X
6	X			X	X	X
7	X	X		X	X	X
8	X	X		X	X	X
9	X	X		X	X	X
10	X	X	X	X		X
11			X	X	X	X

2. Internalized beliefs and perspectives over time that oriented them towards stewardship of the earth and environmental sustainability.

Chaeli, still a child at the time of this study, routinely tended to the recycling and compost at home and at gardening camp. Her mother reported that when Chaeli was away from home, she would hold a recyclable can or bottle until she found an appropriate container for it, rather than discard it as trash.

Elisha's Jewish faith fueled his fervent stance of stewardship of the earth. He viewed himself as a God-partner in taking care of the planet. He gathered wisdom and inspiration to tend to the earth and its creatures from the history of the Jewish people, Bible stories, and the morals and values of the Jewish faith tradition.

Leah and Jaffer applied McDonough and Braungart's (2002) *Cradle to Cradle* philosophy to their design, which is evidence that they internalized this sustainability-oriented philosophy in their innovation work.

3. Benefitted from relationships with mentors who invested in their development and inspired and challenged them.

Chaeli had her grandfather, Seth the gardening coach, and her science camp counselors. Elisha had his grandfather, Dr. Sterne, the library patent-search mentor, the science lab men, and his college professors. Elisha also described his mother and father's parenting style as a combination of mentoring and free-range parenting. Jaffer received mentoring from his father, his leadership mentor, the two leaders of MES, Malia, and his assigned mentors through IFP. Leah also spoke of mentoring from her assigned mentors at IFP.

4. Engaged in activism, begun for two of the participants while they were still children.

This early activism involved standing up for a cause in which they believed or for people who were disenfranchised, oppressed, or otherwise incapable of advocating for themselves; only in one case was it directly based on environmentalism.

Chaeli engaged in activism primarily around the issue of Down syndrome and how that connects to pro-life activism because this directly related to her family. Elisha engaged in activism through protest, public speaking, journalism, petitioning, and influencing others to act. Jaffer spoke on behalf of the Palestinian people to members of the U.S. Congress, advocated for investment in educating the Palestinian people, and volunteered his time and engineering skills for people who need access to clean water. Leah took the risk to be a freelance designer so that she could stick to her principles of designing only projects that would definitely help people and abide by the *Cradle to Cradle* and *Upcycle* design philosophies (McDonough & Braungart, 2002, 2013).

5. Maintained a stance of optimism and hope in the face of suffering or witnessing others' suffering.

Chaeli's mother and Mrs. Wu described Chaeli as optimistic. Lily explained that living with Ryan has made their family a very optimistic and hopeful unit because they are intimately involved in Ryan's repeated surpassing of expectations as he overcomes limitation after limitation that society has put on him. Hope is also a foundational aspect of Chaeli's Christian faith. As Lily summarized, "They say the things you need are love, hope, and faith, and I feel that those three things she's exhibited."

As a child, Elisha experienced the emotional suffering of his country at war. Consequently, he connected the idea of the embittered wars with the world's economic addiction to oil. From his place of optimism and hope, he designed his first solar cell and has been building upon it since. As increasingly more developing countries adopted his community-powering solar-power innovation, Elisha witnessed increasingly more suffering. As he saw the suffering, he also saw the people's beauty and hope, which kept him going. Elisha's faith-based connection to hope delivered the necessary staying power to endure the suffering and press towards ecological innovation.

Jaffer grew up with the stress of water insecurity. More empathetically, he experienced the suffering of others who had no access to water, which pushed him forward in his design of the water-filtration system. Later, Jaffer witnessed his professor's suffering with a broken back after falling off his roof while checking his water. In the face of that pain, Jaffer held onto his optimism and hope that he could make things better.

Leah connected empathetically with the suffering of others, which fueled her designs for the poor, disenfranchised, sick, and blind. When Jaffer shared his story of his injured professor, she emotionally internalized the suffering but also expressed great hope that their joint innovation would solve the problem for many people.

6. Participated in team-based iteration applied to a concern for an environmental problem.

Team-based iteration was seen in Chaeli's and in Elisha's cases; however, the strongest example came from Jaffer and Leah's case. Jaffer led his team, who were all concerned for the people's lack of water, through 5 months of iteration for the cistern water filter as their pathway to eco-innovation. Similarly, in the teamwork between Jaffer and Leah, they iterated their innovation over the course of their program. That project was based directly on a concern for the environmental problem of not enough water and unsafe rooftop water-tank conditions.

7. Assumed responsibility for things beyond themselves.

All four eco-innovators bore more responsibility than their age-similar peers for other people's and living creatures' wellbeing. When asked about their ideas for preparing youth to become eco-innovators, eco-innovators suggested that giving young children responsibility for environmental stewardship, and then systematically increasing that responsibility, would lay the groundwork for future eco-innovation.

Chaeli expressed and demonstrated feeling responsible for her older brother, animals, and the garden. Elisha experienced responsibility for the science lab and microscopes in high school and grew into the responsibility of educating adults about Middle Eastern politics. In college, through spearheading protests, he took responsibility for leading his student body to take a stand for ending apartheid in South Africa. As an adult, he assumed responsibility to advocate for several human rights causes, as well as for bringing green energy to villages throughout the world that do not have access to a power grid.

Jaffer expressed feeling the weight of responsibility for the Palestinian people upon his shoulders because he received the opportunity to leave and obtain an education; thus, he wants to do everything he can to bring the best back to his people.

Leah experienced being responsible for groups of people in the desert wilderness and expressed her sense of being responsible to design only things that follow the wisdom of nature.

8. Experienced self-directed engagement with creative problem solving and design.

All four case eco-innovators experienced self-directed engagement with creative problem solving that involved inquiry, exploration, experimentation, and creation and advocated for giving young people opportunities to solve real-world environmental problems, including engaging in the design process from ideation to prototype.

Chaeli demonstrated this by creating the home redesign with LEGOS®, as well as with her design process for Pine-Condos. Elisha experienced this through science kits, through designing his solar cell for the science competition, and through his solar innovation company. Prior to meeting Leah, Jaffer experienced self-directed engagement with creative problem solving and design in creating his water-filtering mechanisms. Prior to meeting Jaffer, Leah experienced it through her career as a designer. As a team, Jaffer and Leah experienced it together.

When asked for their suggestions to promote eco-innovation among youth and their peers, all four eco-innovators offered different ways to give students real-world experience in solving authentic environmental problems. Chaeli suggested an entire camp-type program to expose students to environmental problems, then challenge those students to solve those problems. Elisha stated that students need to know that there is a "big bad" problem out there in the form of climate change and suggested that children start calculating their carbon footprint as early as kindergarten. Jaffer stated that students should have the opportunity to think about real world problems in school, and Leah enthused that students would get hooked on the thrill of creating earth-saving designs if they were given the experience of the entire design process from ideation to prototype.

9. Had at least one seminal experience that ignited their motivation to solve or overcome an ecological problem.

The eco-innovators shared stories of seminal experiences as they spoke about their motivations. They suggested that exposing children to ecological problems, and pairing this understanding with models of ecological solutions, would inspire further ecological innovation.

Chaeli demonstrated a deep understanding of the power of seminal experiences as she suggested bringing youth to see areas of nature that are both strikingly beautiful and heartbreakingly ravaged by human action. Elisha spoke of looking out at the line of cars lined up for gasoline and experiencing an epiphany moment of understanding that humans needed to kick their dependence on fossil fuels. He also said that children need to know that there is a big problem of climate change and they need to understand that problem. He further suggested that students learn how to calculate their carbon footprint so they can start engaging with solutions. Jaffer described his moment of understanding how fortunate he was to have a tap for water in his home as he reflected on his day serving the Bedouin community with no access to clean water. Leah described her experience of researching and reporting on the consequences of climate change upon the earth and how it broke her heart, which motivated her to dedicate her career to sustainable design. Both Jaffer and Leah gave ideas for pairing understanding of ecological crises with exposure to models of excellent innovation.

10. Participated in innovation-focused programs, camps, or school courses.

This is the "If you build it, they will come" finding (Robinson, 1989). The eco-innovators suggested that participating in innovation-focused programs could inspire others towards eco-innovation. In all three cases, the programs, camps, or courses the eco-innovators participated in served as pathways towards ecological innovation. Chaeli, Jaffer, and Leah experienced innovation-focused programs and built eco-innovations at those programs.

Although Chaeli's camp encouraged participants to build anything using biomimicry, it did not need to be an *eco*-innovation. Similarly, the innovations from Jaffer and Leah's business incubator program did not need to be environmentally oriented. However, the innovation-focused programs allowed those who were predisposed to care about the environment to create environmental solutions.

11. Had lives that indicated the presence of three intertwining, integrated pathways towards eco-innovation drawn from the preceding themes: scientific exploration, positive relationships, and empathetic and empowered response to vulnerability.

Three pathways—scientific exploration, positive relationships, and empathetic and empowered response to vulnerability—occurred throughout the cases in unique ways that intertwined and overlapped. Hence, I entitled them, "Three *Integrated* Pathways to Eco-Innovation." I use the modifier *intertwining* to honor the complexity of interaction among these factors and conditions. I chose to display these factors and conditions simply under the pathway that best encompassed that element rather than show every connection and thus risk obfuscating comprehension. Figure 7 presents the elements of these pathways, comprised of this study's findings.

Positive relationships are situated in the center, because they were often influencing and generative factors for the other two pathways. The eco-innovators experienced different elements from all three pathways in a myriad of ways. The camp, classroom, and innovation programs in which the eco-innovators participated exemplify what can happen when all three pathways converge. Those programs offered scientific exploration; provided positive relationships through mentoring, coaching, and teamwork with peers; and promoted empathetic and empowered responses to vulnerability through a variety of means.

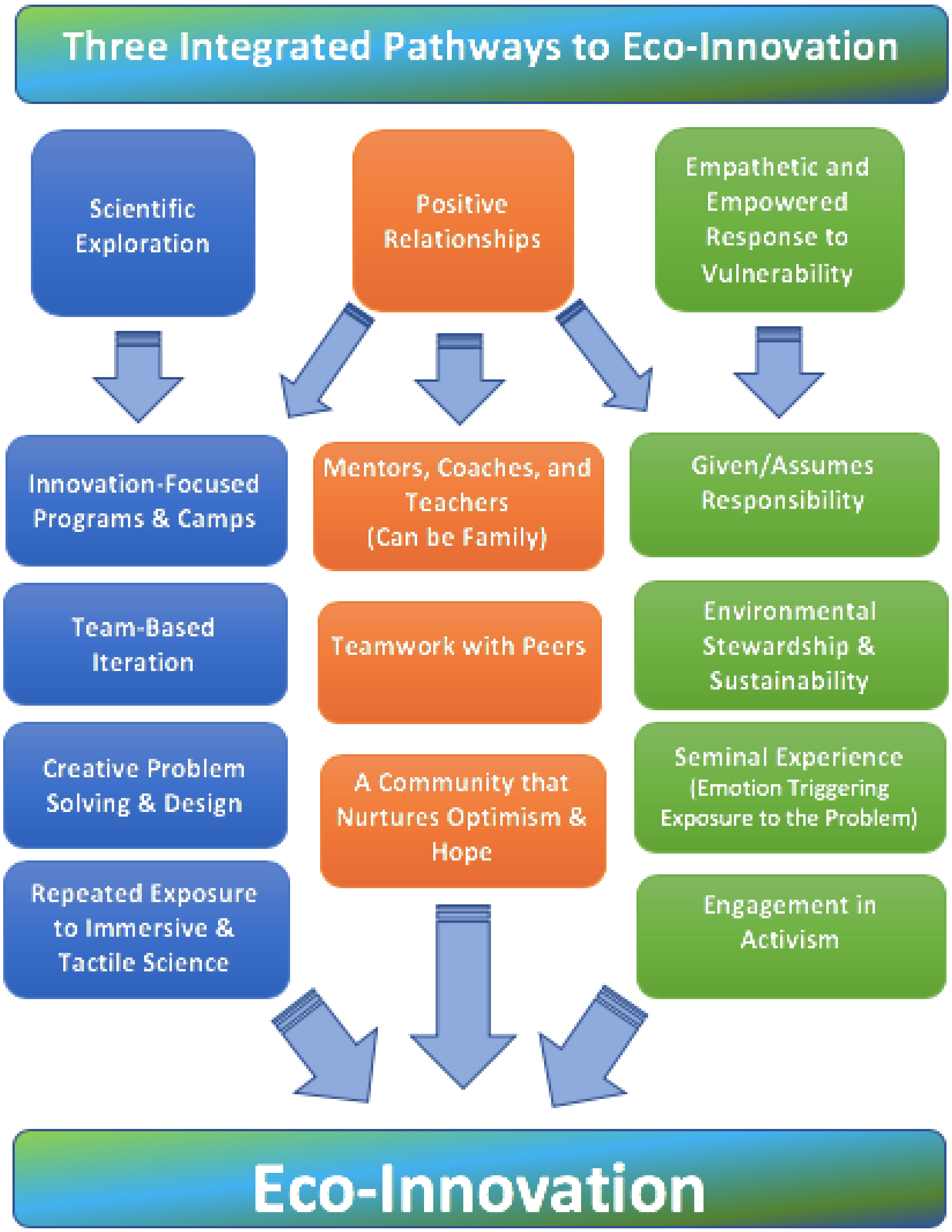

Figure 7. Three integrated pathways to eco-innovation.

Chapter Summary

This chapter presented three cases, followed by the quintain analysis. First, Chaeli's case explored the factors and conditions that went into her life as a young eco-innovator who designed an architectural model for a green energy condominium of the future, Pine-Condos. Second, Elisha's case conveyed the factors and conditions that went into his life as an eco-innovator who started as a teenager with a unique design for a solar cell and now leads an innovation company that brings solar power to communities that lack power infrastructure all over the world. Third, Jaffer and Leah's case delved into the factors and conditions that went into both Jaffer's life as a serial water eco-innovator and Leah's life as an eco-designer. Then the case explored their combined story as a team of eco-innovators.

Following the three cases was the quintain, which analyzed themes from the cases with respect to their individual case stories, as well as their meaning as part of the whole. After the themes were presented and analyzed, they were funneled into findings that answered the guiding questions for this study. The chapter ends with a synthesis of the data into key findings and considers how these findings relate to the three research questions.

Chapter 5 addresses the implications of these findings. It also proposes further research and action steps to leverage these findings to support the nurturance of eco-innovation in our schools, local communities, and as a global community racing against the clock of climate change.

CHAPTER 5

Discussion

Introduction

This final chapter concludes this dissertation with a study review, discussion of the findings with implications and suggestions for practice, study limitations and suggestions for future research, recommendations, and final reflections. The study review summarizes the work to refresh the reader on vital points from the preceding chapters. This overview grounds the reader in the purpose of the study to provide a foundation for the discussion of the findings. The discussion contextualizes the findings within the study, as well as explores implications for practice related to each finding. Next, study limitations and suggestions for further research are provided, followed by concluding thoughts and a final reflection on this doctoral research experience.

Study Review

As an educator and researcher, I was driven to conduct this study in an effort to contribute meaningfully to education's role in equipping students to effectively address the rapidly encroaching negative effects of climate change and environmental pollution that together threaten this planet and the life it sustains. The purpose of this multiple case study was to seek deeper understanding of the developmental life experiences of ecological innovators. These experiences could reveal relevant factors and conditions that contributed to their formation as ecological innovators. Additionally, an overarching goal of this study was to deepen awareness of the multiple pathways that led them to innovate environmental solutions, which may be evident in their lives. The following three interrelated research questions guided this multiple case study:

1. What do people who have produced ecological innovations, and others associated with them, report as the critical experiences, factors, and conditions in their development as ecological innovators?
2. What factors and conditions do ecological innovators suggest can inspire ecological innovation among their peers and young people?
3. What pathways towards ecological innovation and common experiences, factors, or conditions emerge from the stories of ecological innovators?

I based this research upon a bricolage of frameworks (Maxwell, 2013). Wagner's (2012) "framework for developing the capacities of young people to become innovators" (p. 58) provided a foundation for the bodies of literature researched prior to designing the study, as well as the original idea to pursue this research through a case study methodology. Bloom's (1985), *Developing Talent in Young People*, informed the specific way the case study methodology was applied to this study, as it provided the model for including auxiliary participants in addition to the primary participants to help illuminate the eco-innovators' developmental stories. Finally, Pascale et al.'s (2010) concept of positive deviance led me to seek exemplar eco-innovators to learn from those who model the desired outcome.

The literature review explored key fields related to the interdisciplinary topic of ecological innovation. Following Pascale et al.'s (2010) concept of positive deviants or bright spots, I identified common factors among exemplar ecological innovators. I combined these with findings from this study to identify topics that served as the basis for the literature review: nurturing excellence, motivation, ecological education, creativity, the maker movement, mentoring, and educational leadership. This comprehensive literature review laid the foundation for the case study and informed the construction of data collection instruments.

The following literature on nurturing excellence and motivation support the key findings of mentoring and seminal experience: Bloom's (1985) research on nurturing excellence led to a survey of the literature on motivation that touched on self-efficacy (Bandura, 1977, 1982, 1997), self-determination (Deci et al., 1991), intrinsic motivation (Deci & Ryan, 2000), self-realization (Dewey, 1893, 1902; Maslow, 1943), flow (Csikszentmihalyi et al., 2005), and the connection between motivation and creativity (Nakamura & Csikszentmihalyi, 2003).

The literature review revealed the importance of ecological education that emphasized ecological competence, ecological literacy (Orr, 1992), human interdependence and impact on earth's ecosystems (Daloz, 2004), and systems thinking (Senge, 1990). Louv's (2009) concept of *nature deficit disorder* and McDonough and Braungart's (2002) *Cradle to Cradle* approach to design supported the importance of exposure to nature in developing a sense of environmental stewardship. Together, this body of work appeared in two findings from the study: repeated exposure to immersive and tactile science, and environmental stewardship and sustainability.

Using the phrase "learn or die," Goerner (2007) asserted that creativity is essential to survival. Lubart and Guignard (2004) and Runco (2004) affirmed that creativity can be cultivated and supported in home and school environments. Csikszentmihalyi's (1999) model for the systems view of creativity contextualized innovation within culture, society, and personal background. Csikszentmihalyi (1996) also explored paradoxical dimensions of creativity that creative people tend to possess concurrently. Richards

(2007) indicated ways that adults either nurture or squelch children’s creativity, and Eisler (2007) conveyed that love is a foundational force for nurturing creativity. Eisler described humanity as the species capable of “innovative, creative thought and action,” positing that “our most urgent creative challenge is building a sustainable future” (pp. 261–262). Together, these selections on creativity bolster the finding of creative problem solving and design, connect to the pathway of positive relationships, and undergird the overall focus on innovation.

The maker movement was explored as a means of cultivating innovation. Resnick and Rosenbaum (2013) contextualized the maker movement and makerspaces as an integration of Dewey’s progressivism with Papert’s constructionism. They heralded tinkering as a vital practice towards thinking creatively to innovate solutions to unexpected situations. Dougherty (2013) advocated adopting a “maker mindset, . . . a can-do attitude” that empowers people “to take their ideas and turn them into various kinds of reality. It is the process of iterating over a project to improve it” (p. 9). Dougherty (2016) described how makerspaces promote innovation and a culture of mentoring (p. 28). This section of the literature review connected to the findings on innovation-focused programs and camps, team-based iteration, creative problem solving and design, and repeated exposure to immersive and tactile science. Additionally, the topic of mentoring in makerspaces led to a deeper investigation of the literature on mentoring.

The exploration of literature on mentoring directly related to the finding about the case eco-innovators’ mentoring experiences in that the literature revealed that mentors spend time getting to know, teaching, coaching, encouraging, supporting, affirming, expecting excellence from, and making connections for their protégés (W. B. Johnson & Ridley, 2004). Ensher and Murphy's (2005) *Power Mentoring* encouraged mentors to focus on long-term succession planning and to invest in the next generation (pp. 31–32). They encouraged people to build relationships with multiple mentors from a variety of fields, as Jaffer from the third case did. Dweck (2015) and W. B. Johnson and Ridley (2004) showed that as mentors foster a growth mindset for their mentees, they nurture the protégés' self-confidence. Lerner et al. (2014) linked mentoring to six indicators of positive youth development and provided suggestions for mentors to nurture those outcomes in their mentees. Wagner (2012) found that mentors of innovators were innovators themselves (p. 99) and promoted "(a) collaboration, (b) multidisciplinary learning, (c) thoughtful risk-taking and trial and error, (d) creating, (e) intrinsic motivation, and (f) play, passion, and purpose" (p. 200). The mentoring literature provided several theoretical descriptions of the positive relationship pathway that the case eco-innovators' mentors practically fulfilled.

The literature review concluded by investigating educational leadership in relationship to the inquiry of this dissertation. This included an overview of Scheffler's (1985) conceptual framework of human potential; school improvement leadership; 21st Century skills; civic engagement in a democratic society; SAAs in relationship to education for democracy; and supporting creativity, motivation, and innovation in schools. This section of the literature review informed the implications and recommendations.

Scheffler (1985) provided a framework for understanding potential to help educators in guiding their students to realize their potentials. Bryk et al. (2015) proposed the PDSA cycle for educators to improve schools using an iterative process that parallels the engineering design model, as well as natural selection. Heifetz and Linsky (2002) advised understanding the difference between technical and adaptive challenges and introduced the concept of “getting up on the balcony” as a metaphor for the continual reflective analysis required of educational leaders making any sort of adjustments to their practices or system, which is also a helpful tool for iteration and systems thinking related to ecological innovation. The Partnership for 21st Century Skills contributed a framework for 21st Century learning to prepare students to succeed in stewarding the world. Suggested skills included problem solving, collaboration, and “creativity and innovation” (Kay, 2010, pp. xx, xxiii). Westheimer and Kahne (2004) introduced a framework for educating students to effectively participate in a democratic society. Westheimer (2015) built upon this work by investigating how schools could support students becoming effective democratic citizens. Like Westheimer, Levinson (2012) also explored ways in which schools can prepare students “to be empowered democratic citizens” (p. 259). Both Westheimer (2015) and Levinson (2012) argued that the ways standardized testing has become the focus of schools has harmed students’ learning and crowded out other forms of vital learning such as authentic civic engagement.

Piirto (2014), Kettler and Sanguras (2014), and G. W. Johnson (2014) all introduced several concepts and techniques for educators to bolster creativity for students in the classroom.

Pink’s (2009) suggestions for schools aligned with his recapitulation of Deci and Ryan’s (1985) self-determination theory, which stated that humans have three motivating drives: the drives for autonomy, mastery, and purpose.

The final literature review topic explored innovation in schools. Isaksen and Akkermans (2011) suggested that for innovation to thrive in an organization, the leadership must promote a climate that supports innovation. Relatedly, Jacobs and Alcock (2017) charged educational leaders to support innovation in schools. Their proposed shift called for changing policy to hold schools accountable for innovation.

This comprehensive literature review laid the foundation for the case study and informed the construction of data collection instruments.

Chapter 3 provided details about this qualitative study's design. The research design as a multiple case study approach allowed me to investigate and analyze Chaeli's, Elisha's, and Jaffer and Leah's cases as discrete entities, as well the targeted understanding in a corpus of data called a *quintain* (Stake, 2006). This design allowed me, as the researcher, to gain a deeper understanding of the phenomena tucked into the eco-innovators' life stories. That understanding would not have been possible without investigating their stories individually. Similarly, had I not leveraged Stake's (2006) concept of the quintain, I would not have been able to yield generalizable findings from analyzing the quintain as a whole.

Chapter 3 revealed my bias and background as a researcher and explained my role as the biographer and interpreter of data in this study. It also connected the selection criteria to the study's delimitations. The criterion-based sampling method (Creswell, 2013), required primary participants to meet criteria displayed in Chapter 3, Table 3.

This multiple case study was designed to gather qualitative data in the form of interviews and supplemental materials. The primary participants referred their auxiliary participants, who were people willing to be interviewed about the related primary participant. Thus, I obtained multiple perspectives on the eco-innovators through interviews with the eco-innovators themselves, from the auxiliary participants who shared relevant information on the eco-innovators' development or innovation processes, and from supplemental sources of information such as videos, articles, and online content about the eco-innovators or about the programs or institutions of which they spoke. Then, I used all the information to compose cases, which I verified through the participant-checking process.

The primary participants were the eco-innovators covered in the cases in Chapter 4: Chaeli, who used biomimicry to design a model of a solar-powered condominium; Elisha, who developed a patentable solar cell as a teenager and grew up to be a solar-based innovator and entrepreneur; Jaffer, who developed more than one water innovation to help people in developing or ostracized communities gain access to and monitor clean water; and Jaffer's partner, Leah, who has innovated several different sustainable solutions through her career as a sustainability-oriented designer.

Supplemental data collection included news articles, speeches, drawings, and published materials related to each eco-innovator. All data were collected, stored, and backed up using secure password-protected technology.

The data analysis process took place in eight steps, detailed in Chapter 3. The process used both NVivo and a case-quintain analysis process that involved theming the data and analyzing cases as unique entities, as well as considering them as a whole (Stake, 2006). The holistic *eclectic coding* method incorporated in vivo, descriptive, pattern, hypothesis, and versus coding (Saldaña, 2016). Chapter 3 also detailed the case-writing process and addressed qualitative validity, ethical standards, limitations, and field issues.

Chapter 4 presented the three case and their emergent themes, followed by the quintain analysis. The NVivo analysis of the quintain themes was displayed graphically and then organized according to the guiding research question they addressed. The following discussion of the findings further explores the findings' implications and resultant recommendations for practice.

Review of the Findings

The multiple case study method with quintain analysis yielded 11 findings. As recapped in Table 11, Findings 1 through 10 respond to guiding Research Question (RQ) 1, Findings 7 through 10 also respond to RQ 2, and Findings 10 and 11 respond to RQ 3.

The following discussion provides implications for the findings and situates the findings within the literature. The implications have the potential to apply to more than one audience, including educational leaders, teachers and educators, and parents, guardians, and adults who care for children. Educational leaders can use their levers of vision casting, priority setting, policy construction, funding, professional development, and curriculum to respond to the implications. Teachers can use their resources, classroom authority, and unit and lesson design creativity to respond to the implications offered. Parents, guardians, and adults who care for children can set priorities and make choices to respond to the implications in a manner suited to their lifestyles, contexts, and their children's ages and interests.

Table 11. *Review of Findings by Research Question Answered*

Finding (abbreviated)	Guiding research question (RQ)		
	RQ 1	RQ 2	RQ 3
1. Exposure to scientific exploration	X		
2. Environmental stewardship and sustainability	X		
3. Relationships with mentors	X		
4. Activism	X		
5. Optimism and hope	X		
6. Team-based iteration	X		
7. Responsibility	X	X	
8. Creative problem solving and design	X	X	
9. Seminal experience	X	X	
10. Programs, camps, and school courses	X	X	X
11. Three integrated pathways towards eco-innovation			X

Discussion

The literature review (Chapter 2) explored nurturing excellence, motivation, ecological education, creativity, the maker movement, mentoring, and educational leadership in preparation for this research. These domains helped shape the interview questions, and evidence of these domains showed up across the case studies in different ways. The case studies revealed several critical experiences, factors, and conditions in the eco-innovators' development that the eco-innovators had in common. Despite the several similarities, the eco-innovators' experiences were also unique, dynamic, complex, and nuanced. For instance, they grew up at different times in different countries, with incomparable geopolitical events influencing their life stories, and vastly different family and habitational situations. They had unique specific interests and complexly layered individual influential life experiences. As such, these findings should be interpreted as informational data about the factors and conditions that were present in the lives of eco-innovators and not as causal factors and conditions. The next section presents each guiding research questions followed by the findings that answered that question.

Research Question 1. What do people who have produced ecological innovations, and others associated with them, report as the critical experiences, factors, and conditions in their development an ecological innovators?

Findings 1 through 10 provide information about the factors and conditions that were part of the eco-innovators' lives. Analysis of the data reveals that even though the eco-innovators had very different lives in different countries, with different types of schools, and family circumstances with parents who did things differently, they all experienced a set of 10 congruent factors and conditions. The following 10 factors and conditions are present across the three cases and respond to Research Question 1. The eco-innovators in this study:

1. Had sustained, immersive, and tactile exposure to scientific exploration in and out of school.
2. Internalized beliefs and perspectives over time that oriented them towards stewardship of the earth and environmental sustainability.
3. Benefitted from relationships with mentors who invested in their development and inspired and challenged them.
4. Engaged in activism, begun for two of the participants while they were still children.

5. Maintained a stance of optimism and hope in the face of suffering or witnessing others' suffering.
6. Participated in team-based iteration applied to a concern for an environmental problem.
7. Assumed responsibility for things beyond themselves.
8. Experienced self-directed engagement with creative problem solving and design.
9. Had at least one seminal experience that ignited their motivation to solve or overcome an ecological problem.
10. Participated in innovation-focused programs, camps, or school courses.

The fact that there were 10 unique but interrelated findings in response to the first research question suggests no single experience, factor, or condition led to eco-innovation. Instead, the sum of the experiences, factors, and conditions prepared the eco-innovators to respond to ecological problems with a mind-set of solving the problem with innovation.

Research Question 2. What factors and conditions do ecological innovators suggest can inspire ecological innovation among their peers and young people?

The eco-innovators in this study made suggestions as to what can inspire ecological innovation among their peers and young people. They provide the following four suggestions, embedded in Findings 7 through 10, to inspire ecological innovation among their peers and young people:

1. Give young children responsibility for environmental stewardship and then systematically increase that responsibility.

2. Give students opportunities to solve real-world environmental problems, including engaging in a creative design process from ideation to prototype.
3. Expose children to ecological problems and pair this exposure with models of ecological solutions.
4. Provide children with camps, programs, and courses that directly promote innovation and ecological innovation.

These four suggestions, as a whole, indicate that eco-innovators have confidence that exposing youth to real-world issues while giving them opportunities to solve those problems in teams with supports and inspiring models can actually empower youth to make the world a better place through eco-innovation.

Research Question 3. What pathways towards ecological innovation and common experiences, factors, or conditions emerge from the stories of ecological innovators?

All four eco-innovators' lives indicated the presence of three integrated pathways towards eco-innovation. These three pathways, comprised of elements of all the other findings as a whole, are scientific exploration, positive relationships, and empathetic and empowered response to vulnerability. Figure 7 in Chapter 4 depicts these three pathways, differentiated by color. The leftmost column in blue represents scientific exploration, the center column in orange represents positive relationships, and the rightmost column in green represents empathetic and empowered response to vulnerability. Each case eco-innovator experienced a context, such as a camp, innovation program, or classroom setting, in which all three pathways integrated as part of the experience that preceded eco-innovation. Given the significance of this finding, which encompasses all the other findings, the implications for this study are organized by the pathways.

The Pathway of Scientific Exploration

This first section discusses the implications of the findings that appear along the scientific exploration pathway. Figure 8 displays the aspects of the findings that comprised the eco-innovators’ experiences along this pathway.

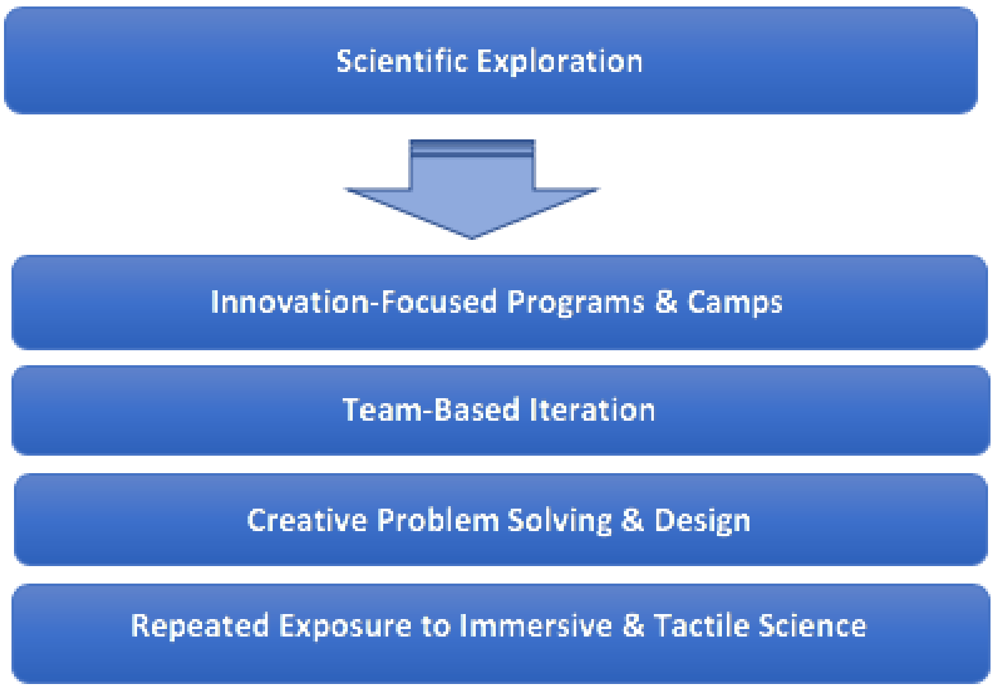

Figure 8. Scientific exploration pathway.

These findings suggest that repeated exposure to immersive and tactile science is central in the lives of eco-innovators. This study shows that conditions and opportunities that inspire and drive ecological innovation include problem solving and design, team-based iteration, and innovation-focused classes, programs, and camps both in and out of school settings. A culture of problem solving and iteration supports an ethos that welcomes and encourages failed attempts, first-draft thinking, and provisional answers. As in the case of Chaeli's camp, Elisha's science class with Dr. Sterne, and Jaffer and Leah's innovation program, educational contexts that champion these pedagogies encourage students along the pathways toward ecological innovation by directing resources to enable development, and employing ongoing assessment of the effects of such practices. This study shows that educators who facilitate immersive scientific experiences that focus on child-curiosity-led scientific exploration, design thinking, and authentic problem-solving support eco-innovation, as well as invite the children into fascination, familiarity, and facility with science.

Learning about complex ecological systems and the dynamic scientific phenomena of climate change requires an interdisciplinary and integrated approach (Davison et al., 2014). Davison et al.'s (2014) found that a distributed leadership model with empowered communities of practice supported interdisciplinary practice among educators when it comes to teaching the ecological interdisciplinary content of climate change. The distributed leadership model facilitated "acts of initiative, innovation, vision, and courage through [the educators'] group interactions" (p. 2). Whereas Davison et al.'s research applied specifically to educators of climate change, Jacobs and Alcock (2017) encouraged educators and policymakers to shift to a distributed leadership model among teachers and administrators to collaboratively lead the profession forward in a manner that fosters innovation among students and educators alike. Jacobs and Alcock suggested that teachers need to model how to fail "with style and dignity right in front of student learners" (p. 190), so that students learn how to engage in iterative problem solving, a key finding of this study.

Makerspaces embody many of the factors and conditions comprising this pathway, making these venues a powerful and well-equipped context for team-based environmental-design challenges. Although the review of the literature on makerspaces for this study did not reveal strong alignment to ecological competence, these hubs are ideal learning spaces to support ecological innovation.

This study's findings indicate a need to regard students as wonder-filled explorers, investigators, idea generators, testers, innovators, and creative people capable of contributing to society. Chaeli offered a six-step process to promote more ecological innovation among her peers, including asking children what they know and think about ecological problems, as well as prompting youth to journal about their experiences of engaging with creative problem solving around ecological problems. Jacobs and Alcock's (2017) third tenet backs up Chaeli's suggestion, in that it calls for students to engage in investigations that take extended time and require them to "compile findings, create the narrative, revise the text, and employ a range of sources to reflect depth of insight and rigor" (p. 177). Examples that align with her recommendations include leveraging scientific fieldtrips, going on observational nature walks, and creating data-recording journals such as a school-year-long tree journal, seed-planting journal, or observational moon journal to arouse and sustain scientific curiosity (Duckworth, 1987; S. Rauchwerk, personal conversation, May, 2018).

This current study's findings also show that educators who offer students the opportunity to solve real-world problems when they are young, and repeating these opportunities frequently throughout development, create conditions that support the development of eco-innovators. Scheffler's (1985) warning against the narrowing of potential that occurs when educational moments are missed or thwarted, never to appear again, supports this. The case eco-innovators engaged with problem-based learning in a variety of ways. As Chaeli's camp experiences show, problem-based learning provided her with "'ill-structured' problematic scenarios that embody the major concepts to be mastered or understood" (Barrell, 2010, p. 178). Problem-based learning challenges students to engage with "real-word problems that foster inquiry and embody key concepts like change, equality, and environment" (Hopper, cited in Barrell, 2010, p. 179). Problem-based learning requires students to exercise a host of skills identified as key findings in this study, including critical thinking, collaboration, iteration, inquiry, planning, and decision making (Barrell, 2010). Jaffer had multiple experiences with problem-based learning, including partnering with community organizations that already engaged in solving real-world environmental problems. Dr. Sterne in Elisha's case created curriculum focused on a long-term investigation of environment-based current events that gave her students the opportunity to learn how to think about and solve a real-world problem, which eventually informed Elisha's eco-innovation years later.

Educators can create, support, or participate in innovation or environmentally based programs themselves and encourage students to attend programs that have the ideal of fostering innovation, ecological literacy (Orr, 1992), or both.

Modeling family engagement in nature and science, supporting children's natural wonder-fueled exploration, and providing materials and experiences that nurture scientific exploration and creative problem solving supported the participants in this study along the scientific exploration pathway towards eco-innovation. These findings suggest that such actions can cumulatively influence a child's life and support their future engagement with scientific activities that could lead to ecological innovation.

Sosniak (1985) referred to this type of free and exploratory play as the initial step into the field that the exemplars of greatness in Bloom's (1985) study experienced. Experiencing multiple influences in this arena connects to Lubart and Guignard's (2004) finding that all these factors in combination can contribute significantly to developing creativity. Experiences in nature, including school gardening programs, connect to Louv's (2009) work on combatting nature deficit disorder and Doris's (2010) assertion that children learn science by doing. Just as Lily gave Chaeli choice over her own summer program, giving students freedom to choose summer and enrichment experiences autonomously accords with Deci et al.'s (1991) work that showed when a child feels his or her autonomy is valued, the child is more likely to gain "conceptual understanding, flexible problem solving, personal adjustment, and social responsibility" (p. 342).

This study's findings show that eco-innovators benefit from direct exploration of scientific phenomena. As Doris (2010, p. 12) asserted, "Real familiarity with the natural world can't be absorbed from textbooks or lectures. Children need firsthand experience with materials, organisms, and natural phenomena. Opportunities for direct investigation are essential." As seen in Chaeli's case, parents are in a position to support attendance at innovation programs and facilitate reflection on their youths' responses to real-world issues. What would happen if parents, guardians, and adults who care for children actively encouraged their children to ideate, create, and implement solutions to real-world problems?

The Pathway of Positive Relationships

This section discusses the implications of the findings that appear along the positive relationships pathway. Figure 9 illustrates eco-innovators’ experiences along this pathway.

Figure 9. Positive relationships pathway.

Findings in this study suggest that educational leaders who provide mentoring programs, internships, and service learning will create conditions that support the development of eco-innovators. Research has shown that partnership programs benefit teachers, and “school leaders can help teachers and their unions understand how partnership approaches can be of a direct benefit to them” (Henderson, Mapp, Johnson, &

Davies, 2007, pp. 8–9). It is important to involve teachers in planning from the start of constructing a mentoring program because they can serve as "powerful allies for expanding the connections among schools, parents, and community members" who would be involved in any partnership, such as a mentoring program (p. 8).

Educational leaders in the out-of-school setting, such as makerspace managers, are in a position to set up a program to vet, train, and hire mentors so that there is a helpful ratio of trusted mentors in the space to support amateur makers. Dougherty (2016) encouraged leaders of makerspaces to nurture a culture of mentoring because amateur makers need "access to mentors or to people who just know more" (p. 28).

Establishing school and educational cultures of optimism and hope aligns with standards for teaching around high expectations and, as seen in all three cases, provides an important mental and emotional foundation for the development of eco-innovators.

Team-based iteration practices that allow development of positive relationships is another crucial condition for the development of eco-innovators. For example, in Chaeli's case, the camp program leaders provide professional development for the staff to support problem-based learning and team-based iteration around environmental concerns. As in Chaeli's and Jaffer and Leah's cases, it is in educational leaders' purview to support special programming that provides opportunities for collaboration-based science and creativity teams that encourage scientific learning while developing positive peer, coach, and mentor relationships.

Parents and members of the community, likely mentors for in-school and after-school mentoring roles, can provide essential positive relationships for children that nurture them along the pathway toward ecological innovation. Mentors who help develop students’ potential by believing in them and showing them how to master new skills fulfill Scheffler’s (1985) claim that adults (such as mentors and teachers) can facilitate students to achieve mastery by demonstrating faith in the students’ potential. Scheffler explained that children absorb “the belief of their elders as to what they can do. The thrill of new mastery often springs from the confirmation of potential that the child did not believe [he or she] had” (p. 66).

Teachers and educators are uniquely situated to model and nurture optimism and hope in the classroom, as well as showcase stories of empowered optimism and hopefulness. Studies have shown that it is possible to nurture and develop hope, optimism, and resilience as psychological assets (Snyder, 1995; Youssef & Luthans, 2007). Developing hope was based upon a conception of hope that conveyed hope as “an enduring disposition that is subjectively defined as people assess their agency and pathways related to goals” (Snyder et al., 1991). Youssef and Luthans (2007) reported that developing hope involved coaching participants through a process of setting goals, creating stepped subgoals, generating realistic pathways towards the goals, emphasizing an approach towards desirable results rather than avoiding undesirable ones, and creating contingency plans for countering potential obstacles. During this hope training, participants also developed an optimistic explanatory style, “as negative events were anticipated and plans for avoiding or managing them were created” (p. 794). As participants built their positive psychological assets of hope and optimism, indicators of their resilience were strengthened as well. Those indicators included confidence, social support, contingency planning, and the ability to adapt cognitively, emotionally, and behaviorally.

To support students towards eco-innovation along the pathway of positive relationships, teachers and educators can provide team-based iterative challenges for students that are based on environmental problems, just as Seth provided for Chaeli and her peers at the gardening camp. This implication is specific in that it involves pairing two aspects of learning; thus, it overlaps pathways. Problem-based learning provides a structure to create these sorts of learning scenarios (Barrell, 2010). Collaboration, an essential and frequently studied human skill, was part of every case and promoted throughout the literature (Anderson, 2012; Csikszentmihalyi, 1996/2013; Dougherty, 2012, 2013; Goerner, 2007; Jacobs & Alcock, 2017; G. W. Johnson, 2014; Kay, 2010; Lynch, 2018; Martinez & Stager, 2013; Roslund & Rodgers, 2014; Sheridan et al., 2014; Wagner, 2012). The literature also covered *iteration*, the practice of continual improvement upon a design, from more than one angle (Bryk et al., 2015; Dweck, 2015; Kay, 2010; Resnick & Rosenbaum, 2013; Wagner, 2012). In sum, the literature provided much evidence that collaboration and continual improvement through iteration yields positive outcomes. Taking this teamwork and focusing it on solving environmental problems may yield legitimate (or approximations of) ecological innovations.

Brand and Vossen (2014) proposed that adults who mentor children “encourage, support, and listen to children to better evoke a constant sense of wonder . . . [and] listen more than talk,” so the children will be open and receptive to mentoring (para. 7). As Chaeli’s mother Lily exemplified, those who care for children can set the tone for, and highlight stories of, optimism and hope while reducing or eliminating negative media inputs that promote attitudes counter to optimism and hope. Parents, guardians, and adults who care for children are in a position to nurture hope in their children, which was found to be an important element of the development of the eco-innovators in this study. Because hope is foundational for resilience and positively connected to optimism, it is worth investigating Snyder's (1995) strategies for nurturing hope (Appendix K).

Snyder et al. (1991) asserted that people with high hopes assess both their sufficient agency and the viable pathways towards their goal. Supporting children's participation in programs and opportunities that promote team-based iteration can support the construction of a pathway towards ecological innovation.

The Pathway of Empathetic and Empowered Response to Vulnerability

This section discusses the implications of the findings that appear along the empathetic and empowered response to vulnerability pathway. Figure 10 displays findings that comprised the eco-innovators' experiences along this pathway.

Exposing students to environmentally contextualized seminal experiences, such as inviting real-life eco-innovators to school-wide assemblies and supporting supplemental programming and partnerships, will expose children to conditions that support the development of eco-innovators.

Figure 10. Pathway of empathetic and empowered response to vulnerability.

DuFour (1998) emphasized that “one of the most important and effective strategies for shaping the culture of any organization is celebration” (p. 1). Celebrating people who take responsibility for more than themselves highlights and increases this desired behavior in the community. “Celebration provides living examples of the values of the school in action, and encourages others to act in accordance with those values” (p. 1). DuFour also encouraged school leaders to “make celebration everyone’s responsibility” (p. 2) by getting the entire community on board to identify people who deserve recognition for making valuable contributions through taking responsibility for some aspect of community life. Educational leaders have the positional authority to support student activism. In his book, *The School Leaders our Children Deserve*, Theoharis (2009) explored how exemplar school principals who advance equity and social justice in their schools incorporate social responsibility into the school curriculum. Theoharis found evidence of the leadership's influence on the school community: "Both students and faculty were embracing and discussing ideas of collective action [including] community organizing, class lessons about social movements or grassroots organizing" (p. 71). At another school, Theoharis found "courses designed to connect students to communities not only in order to create meaningful learning, but also to reinforce a connection to something larger than oneself" (p. 72). He explained, "A critical component to creating socially just classrooms and schools is teaching students the skills and responsibilities to create their own social change" (Theoharis, 2009, p. 72, drawing on Ayers, Hunt, & Quinn; Freire; and Purpel). Educational leaders can also make sure that there are plenty of opportunities for students to test their mettle at activism—and support teachers who take on the responsibility of supporting those students.

To emphasize the empathetic and empowered response to vulnerability pathway, educational leaders, like Dr. Sterne in Elisha's case who facilitated her students to initiate and take responsibility for the school's recycling program, can support sustainable activities that promote behavioral change, community partnerships, and retrofitting (U.S. Department of Education, 2019).

Nakamura and Csikszentmihalyi (2003) researched how people transformed a seminal experience, such as encountering "a pressing existential problem . . . early in life (e.g., poverty, marginality, social injustice)" (p. 262), into creative responses or solutions to that problem. There is a need for educators to understand such seminal experiences so they can recognize and respond to their students when they do occur. Reflection activities, such as journaling, can foster purposeful internalization of the seminal experience. Nakamura and Csikszentmihalyi found that people who had overcome adversity first encountered a process of meaning construction and then focused their energy to address the problem.

The findings suggest that youth who come into contact with a current environmental issue are supported along the pathway of empathetic and empowered response to vulnerability by seeing a model of an excellent response to that problem. Maintaining a hopeful perspective also helps forward one along. The findings also suggest that having students take responsibility for things outside themselves furthers them along on this pathway. Celebrating when students take responsibility for something outside themselves can support their development in responsibility. Doing so will both increase their motivation for this behavior and serve as an exemplar for others to emulate (DuFour, 1998). As seen in both Chaeli's and Elisha's cases, creating opportunities for students to take on responsibilities within the classroom, in the school yard, and in larger school context, especially environmental stewardship responsibilities, can facilitate students along on this pathway towards eco-innovation.

According to Westheimer and Kahne (2004), civic engagement focused on creating participatory citizens increases students' sense of "responsibility to help others," understanding of their "social capital," and "leadership efficacy" (p. 19). Further, civic education aimed at empowering justice-oriented citizens increases students' political interest, awareness of contextual and systemic factors contributing to issues, and ability to think critically about the contributing factors to society's problems.

Teachers who showcase current examples of peer-age activists and support students' efforts towards activism, promote students' movement along this pathway towards eco-innovation. A current exemplar, Greta Thunburg, the 16-year-old Swedish girl who protested at Sweden's parliament to draw attention to the importance of climate action (Ramzy, 2019), has ignited an ongoing international movement of climate strikes. The strikes started with the first International Youth Climate Strike of March 15, 2019, which involved 1.4 million youth from 2, 233 cities in 128 countries (Carrington, 2019).

All the case eco-innovators were supported in their civic engagement and had opportunities to stand up for causes in which they believed. Supporting students in meaningful civic engagement could include: backing student organizations that provide opportunities for students to stand up for a cause in which they believe; facilitating discussions about their purpose in taking those action; and providing opportunities to safely engage and reflect on that civic engagement. Leading discussions in and out of the classroom about sustainability philosophies, such as Orr's (1992) concepts of ecological literacy and ecological competence or McDonough and Braungart's design principles conveyed in *Cradle to Cradle* (2002) and *Upcycle* (2013), nurtures the development of factors and conditions important to eco-innovation.

Investigatory research projects on issues that matter to students and that contain activism as part of the narrative, may yield exemplars of standing up for what is right. If a topic inspires a student to take a stand for a cause (as long as the students do not harm themselves or anyone else), and their cause is authentically meaningful for them, then teachers are in a unique position to support the students. Class discussions about activism—about small acts and grandiose acts—may also nurture students' capacity for activism.

As suggested by the cases, supporting students' environmental stewardship involves weaving sustainability into coursework and class practices, arranging for students to witness environmental problems directly, meeting with practicing environmental stewards and ecological innovators, and bringing students on field trips (physical and virtual) to experience sustainable and unsustainable practices. Educators can practice sustainability in and out of the classroom by incorporating Orr's (1992) concepts of ecological literacy and ecological competence, and the design principles introduced by McDonough and Braungart's in *Cradle to Cradle* (2002) and *Upcycle* (2013). Educators can expose students to sustainable practices by example. For instance, Tobe Stomberg, an environmental science teacher in Cambridge, Massachusetts, challenges herself and her students to fill only one small garbage can of trash for the entire school year by eliminating trash producing products from her life (Personal Communication, Sept. 2015 - May, 2019).

The findings of this study illuminate how worthwhile it is for parents, guardians, and adults who care for children to welcome, seek, or otherwise arrange for cross-cultural experiences, emergent outdoor adventures together, and authentic exposure to real-world environmental issues, while understanding that such experiences cannot be forced and not all circumstances are appropriate or safe. Encouraging reflection on such experiences can also encourage the potential for these experiences to formatively affect youth development.

Instilling a sense of responsibility for age-appropriate environmental tasks around the home (such as the child being responsible for recycling) can help develop the habit of "transforming [the child's] moral knowledge into moral action" (Li, 2016, p. 2493). Li (2016) researched chores as a means of developing strong parent–child bonds. In a context of parental love, moral reasoning, and habit-building discipline, chores can help facilitate gratitude in children and may serve as "an incubator for a strong parent–child relationship" (p. 2498). Pink (2009) asserted that chores instill a sense of responsibility to the family but warned not to pay children for their housework. Doing so nullifies the child's purposeful contribution to the family. Instead, Pink encouraged parents to give children an allowance, which provides autonomy, and to assign chores—but to make sure the children understand the allowance and chores are independent of one another.

All the eco-innovator case participants also had experience in activism in fields both related and unrelated to science, ecology, and sustainability. Practices from their childhoods influenced their innovation efforts as they matured. Scheffler (1985) explained how development in one field can create potential in another: "New feelings of confidence may contribute to potentials for other sorts of learning as well. . . . The mere enhancement of potential in one area may moreover facilitate enhancement in another" (p. 12). This suggests that parents, guardians, and adults who care for children can offer a wide array of opportunities that will support the development of activism in eco-innovators.

Synthesizing the Three Pathways

All eco-innovators in this study experienced combinations of factors and conditions within and across each pathway prior to eco-innovation. This combining suggests that if educators and people who invest in children wish to equip them to have the potential to become eco-innovators in the future, then conceiving of the three pathways analogously to essential food groups will be helpful: Every “meal” (which would be analogous to a course, camp, program, or home life) should contain representative experiences from each pathway. The integrated three-pathways chart (Figure 7) can serve as a provisional guide to support educators who wish to instill in their youth the potential for future ecological innovation.

Suggestions for Future Research

This study is rich in ideas from the literature review and from the innovators. The following recommendations, centered on study methodology and content, are provided as potential future research topics to investigate.

Future research could replicate this study to see if these findings still hold, if some findings turn out to be more significant than others, and if new findings emerge. Repeating this study with different delimitations or a larger sample size would offer greater breadth. A case study of a team throughout the innovation process from ideation to working product would offer depth beyond what this study was able to achieve. Repeating this study with a mixed-methods approach could add a level of validity to the findings that this study did not attempt. Surveying a large population of environmental engineering students using the factors and conditions identified in this study could offer statistical evidence that would further illuminate this study.

Although this study did not aim to gain information about the eco-innovators’ dispositions, the interviews revealed a great deal of data about their personalities. A study that builds on this work by focusing on dispositional personality traits related to eco-innovators could incorporate existing personality trait research and greatly expand our understanding of the factors and conditions that support the development of eco-innovators.

The fact that all case eco-innovators in this study had participated in activism suggests an exploration of activism in relationship to eco-innovation. Such research could discover whether any correlation or causal relationship exists between those two activities in a person's life.

Studies focused on the role that mentoring plays in developing eco-innovators, or exploring specific programs that influenced participants in this study, such as Chaeli's summer camp or Jaffer and Leah's IFP program, might reveal findings about how specific aspects of the programs promote eco-innovation, continued environmental stewardship, or activism beyond the attendance timeframe. A case study of an eco-innovation team throughout the innovation process from ideation to working product could reveal information about the social dynamics of team-based eco-innovation.

Recommendations

Allocate Time for Mentored, Team-Based, Iterative, Real-World Problem Solving

Responding to the implications and suggestions related to the findings would require dedication of time away from an already intricately orchestrated school schedule. Given that time is already limited in schools, this recommendation echoes Levinson's (2012) suggestion to reduce SAA measures for the sake of teachers having freedom over their own classrooms.

This research challenges the emphasis on standardized testing in schools and its unintended consequences for students' learning. G. W. Johnson (2014) alleged that standardized testing kills creativity because it creates a context that punishes students for being creative. Levinson (2012) charged that high-stakes testing has had a nullifying effect on empowering students to put their learning into practice as involved citizens because standardized testing inherently restricts entire educational domains and strengths not covered by the standards. Acknowledging that the culture of standardized testing has buried the foundational educational goal of learning to be productive citizens in a democratic society under a routine of test preparation, Westheimer (2015) encouraged educators to reorient their focus towards preparing students for their future civic responsibilities. Jacobs and Alcock (2017) posited that "those who vote on policy seem to have a kind of blind spot, not seeing that the forces of legislation and money are setting our education system backward" (p. 166). They go on to outline "four detrimental outcomes of standardized testing" including (a) the "misuse of data" (p. 168), which leads to the displacement of "the cultivation of talent and intellectual achievement" (p. 170) of students; (b) the "misuse of time and money" (p. 170); (c) the "suppression of innovation and creativity" (p. 172), which is antithetical to what today's students need to survive; and (d) the discouragement of teamwork and support of isolation among teachers (p. 173), which leads to teachers leaving the profession (Bonato, 2019).

Standardized testing works against the promotion of valuable learning activities revealed by seven of the 11 findings in this study. What if the emphasis placed on standardized testing were diminished significantly, and the hours of time formerly spent on test preparation were available for teachers and students to collaboratively pursue endeavors the findings in this study suggest? They might engage in authentic, real-world, science-based problem solving; hands-on scientific explorations; field trips with the possibility for seminal experiences; or mentoring programs that give students the chance to learn valuable skills from nurturing adults who believe in them. They could develop activities that put all these together into mentored, team-based, iterative, real-world, problem-solving challenges. Then, having repeated practice in approaching similar problems with the necessary mindset, skills, and understanding to persevere through the necessary iteration to create effective solutions, students would be better equipped to take on the ecological challenges they will face. Imagine the benefit to humankind that would arise from transforming once-stress-laden busywork preparing for standardized tests into often-fun and rewarding practical preparation to solve the world's approaching and very real ecological problems.

Renew Emphasis on the Power of Polymathy

Both Elisha and Jaffer, with their deep knowledge in multiple fields, approach life as polymaths. Elisha possesses an ever-growing expertise in solar power, geopolitics, business development, political activism, philanthropy, and ecology. Prior to creating his solar innovation company, he was a journalist and writer on Jewish family culture. His increasing knowledge in any of these fields supports his knowledge in other fields and helps him as a visionary team and community leader. Jaffer studied several aspects of engineering before focusing on water engineering, and his host of knowledge and skills serve him in solving problems with an innovative approach. Jaffer, a multi-linguist, has also developed himself as a community leader, political activist, and expert on geopolitical history—particularly as it relates to water and human rights. His versatility supports his innovation in terms of thinking and design, as well as his relationship building, team management, and communication with politically important figures about his work.

The stories of their lives that emerged from the cases suggest a return to the nurturance, cultivation, and celebration of *polymathy*, the mastery of more than one field of knowledge or practice. Cultivating polymaths takes time, patience, humility, and investment from a broad cohort of mentors and educators. It demands a flexible mindset—it esteems expertise in a given field but not at the sacrifice of mastering other disciplines. From the learner, it requires willingness to endure a longer-than-average investment in education because it takes time to develop expertise in multiple fields.

Polymathy inherently leads to integration, seeing how things interconnect and understanding how separate entities affect one another. Therefore, it both requires and reinforces systems thinking. For any modern-day ecological innovator, attempting to solve an ecological problem without inadvertently initiating some unintended consequence requires teamwork, collaboration skills, and facility with an iterative-design process. Additionally, a basic understanding of several fields, with greater expertise in one or two, is essential for effective communication and comprehension among an interdisciplinary team.

Alexander von Humboldt’s integrative methodologies (Wulf, 2015) support integration of self-designed interdisciplinary investigation and presentation within education practice. Interdisciplinary practices that emphasize systems thinking can liberate students to follow their curiosity. Such inquiry-led learning allows students to choose an area of inquiry and integrate their learning from other class subjects, along with novel content they would not otherwise research or encounter, and thus connect their learning across multiple fields.

This type of interdisciplinary investigation benefits from community support in the form of mentors, exemplars, and internships. It requires educators to collaborate across their fields to create integrative, interdisciplinary challenges for their students to explore and execute. To further imbue these experiences with meaning, students should have a culminating experience of presenting their work to their peers or to a larger community (Jacobs & Alcock, 2017). Education leaders taking on such a challenge will benefit from an iterative implementation design. To that end, employing Bryk et al.'s (2015) PDSA cycle will help facilitate this practice's continual improvement. It is iterative. If it does not work the first time, tweak it, and try again.

Final Reflection

Early in my doctoral program, I was told that PhD research is "standing on the shoulders of giants." Three giants stand out as lifelong inspirations to me:
Robert E. Stake, whose multiple case study methodology provided a type of wireframe for me to conduct my research; Alexander von Humboldt, who was my subconscious theoretical framework, although I did not know that (or him) until the work was mostly finished; and Charles Richard Snyder, whose seminal work on hope will certainly serve as foundational literature review material for any follow-up research I do connected to this dissertation.

During my analysis process, I came across Stake's (2006) offer to share his case analysis worksheets. I took him up on the offer and emailed him to ask for his worksheets. I was delighted and a bit star-struck when he emailed me with the worksheets attached. It was as though I could feel the heat from the torch he has been carrying.

Andrea Wulf's (2015) book, *The Invention of Nature: Alexander von Humboldt's New World*, introduced me to Alexander von Humboldt, the father of ecology. As a world-traveling botanist, on February 7, 1800, Humboldt wrote about the evidence he saw that humans were wreaking havoc upon the earth. He foresaw human-induced climate change and warned that humankind's actions across the globe could affect future generations. Humboldt understood that nature is interconnected. He urged humanity "to understand how the forces of nature worked, [and] how those threads were all connected [because] humankind, he warned, had the power to destroy the environment and the consequences could be catastrophic" (p. 68).

As a polymath, Humboldt leveraged artistry to represent his view of nature's connectedness. He was the first to conceive of all of Earth's life as connected—so much so that his ideas about the connectedness of the continents preceded the concept of Pangea introduced more than a century later. Humboldt also contributed the concept of isotherms to "visualize global climate patterns" (Wulf, 2015, p. 211). His innovation of visualizing climate data with isotherms is used still today to "understand and depict climate change and global warming" (p. 211). The way Humboldt thought holistically, with his consideration of the whole planet—with an adroit integration of "a scientific method that included art, history, poetry, and politics" (p. 396)—validated me as a thinker in how I perceive, process, and understand the world.

As I researched hope to better understand my findings, Snyder's (1995) copious writings on hope deeply inspired me. Given my previous luck with connecting with

Stake, I figured I would reach out to Snyder to thank him. I discovered that he passed away in 2006. What a loss! As I read about his life from his colleagues' tributes, I gained a profound sense of the power of legacy. From his obituary, I learned that "he wrote or edited 23 books and 262 articles" (Lawrence Journal-World, 2006). No wonder I found his name everywhere in the hope literature. His work on hope helps me understand the findings from my own research.

This is what it means to stand on the shoulders of giants. I did not get here on my own. My contribution to the literature would be nothing without the contributions of at least 100 other researchers whose works I cited and whose works influenced mine. Each of those researchers stood on their own set of research giants' shoulders. I am just part of a repeating pattern that has gone before me and will continue long after me. I hope this, my work, has legacy—that the stories of my case eco-innovators spark inspiration for future innovators and researchers. I hope the findings are graspable and implementable and contribute practically to an ever-inspired set of eco-innovators filled with hope and equipped with the skills to restore our home, planet Earth, to its vibrant, healthy, fecund state of being—teeming with life and fertile with hope.

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APPENDIX A:

INTERVIEW PROTOCOL: INDIVIDUAL, GROUP, AND FOLLOW-UP

Note: Additional interview questions may be generated in response to information gathered in interviews.

About the Ecological Innovation:

Please tell me the story of your ecological innovation.

While the interviewee is responding, I will be looking for answers to the following questions. If I don't hear the answers, I may ask them as follow-up questions.

Please describe your Ecological Innovation to me. What is its purpose?

What was your motivation for building it?

Did you make this alone or part of a team? Tell me about that.

Were you specifically challenged (like with a contest or assignment) to build this, or did you make it up on your own?

What are your hopes for this innovation?

Why do you care about that?

When did you start to care about that?

Was anyone involved in showing you or teaching you about that issue? Tell me about that.

Environmental/Ecological Education Questions

Please tell me about your first memories of becoming aware of the environment and how you became concerned about the environment.

While the interviewee is responding, I will be looking for answers to the following questions. If I don't hear the answers, I may ask them as follow-up questions.

Would you say that outside of this specific ecological issue you have concerns or care about the environment? If so, what issues?

Do you do anything to further your knowledge or activism on that issue?

Have you cared about the environment prior to this innovation?

Please tell me about how you learned about this subject matter. Please include all contributing factors: classes, books, mentors, documentaries, etc.

Did you take specific classes or read specific books to support you in this innovation?

When do you recall your first moment of interest in this subject? What was the context? How was your interest further cultivated?

How you do you believe you started caring about the environment?

Please describe the natural environment in the home you've grown up in.

How much time do you currently spend in nature (outdoors in woods, meadows, mountains, streams, etc.)?

How much time did you spend in nature as a child?

What philosophy about the environment do you believe you grew up with? Who contributed to that philosophy and how did they do that?

Getting Participant's Take on The Process

If there were a "recipe" for making an ecological innovator, what would be the key ingredients?

While the interviewee is responding, I will be looking for answers to the following questions. If I don't hear the answers, I may ask them as follow-up questions.

Of the ingredients you just listed, what would you say is the most important? What would be #2 and #3?

Does the order of occurrence of the ingredients you listed matter? Please explain.

If you were to propose a theory of how one becomes an ecological innovator, what would you propose?

Influencers to the Innovator:

Are there any other people that you believe contributed to your ability or desire to innovate (either people who took an interest in you or people you sought out to support you)?

Please tell me the story about them.

(ask relevant probing questions, follow any leads here)

Regarding people who've contributed to your ability to innovate, was there anyone specific when you were younger than 5? (Please tell me the story)

In elementary school? (Please tell me the story)

Middle School? (Please tell me the story)

High School? (Please tell me the story)

College? (Please tell me the story)

Post-College young adult? (Please tell me the story)

What role, if any, have your parents played in you becoming an ecological innovator? Are there any specific routines or frames of mind in your household that you feel have influenced who you are as an innovator?

Were there any specific ways your parents, mentors, caregivers, or teachers supported innovation exploration, or experimentation in your life? How so?
(Please tell me the story)

Are they any camps, clubs or institutions that contributed to your ability or desire to innovate?
(Please tell me the story)
(ask relevant probing questions, follow any leads here)

Were there any significant life experiences that motivated you or inspired you to make your innovation? (Please tell me the story)

Were there any local, regional, or global current events that influenced you in relationship to the process of you making this innovation? (Please tell me the story)

How about for becoming an innovator? (Please tell me the story)

If you were to tell your life story as it leads to you making this ecological innovation, what key events, characters, and experiences play a part?
(Please tell me the story)
(ask any relevant questions or follow any leads here)

When talking about making sure kids get their needs met, people talk about open free play time and formal activities. Please tell me about your free play time growing up. How much time do you remember having? What about formal scheduled enrichment activities. What were/ are your activities? How much time did/do you spend with each?

Do you think that there is or is not any connection between any of those activities and your innovative thinking/process? There are no right answers here. Remember, you are informing me.

Please think back to when you were younger than 5. Do you remember any interests you had then that may have served as precursors to this innovation? (Please tell me the story)

In elementary school? (Please tell me the story)

Middle School? (Please tell me the story)

High School? (Please tell me the story)

College? (Please tell me the story)

Post-College young adult? (Please tell me the story)

When you were in elementary school?

When you were younger than 5, were there any things that you did with other children or adults that helped you become an ecological innovator? (Please tell me the story)

In elementary school? (Please tell me the story)

Middle School? (Please tell me the story)

High School? (Please tell me the story)

College? (Please tell me the story)

Post-College young adult? (Please tell me the story)

When you were younger than 5, do you remember any specific adults, in the home or outside of the home that invested in you in such a way that may have supported you in becoming an ecological innovator? If so, what did they do? How do you remember that affecting you at the time? (Please tell me the story)

In elementary school? (Please tell me the story)

Middle School? (Please tell me the story)

High School? (Please tell me the story)

College? (Please tell me the story)

Post-College young adult? (Please tell me the story)

Makerspace Questions

(Look at Questionnaire, see if they attend makerspace, if so then use this next section of questions, if not, SKIP):

So, you attend a makerspace. Please tell me about that.

While the interviewee is responding, I will be looking for answers to the following questions. If I don't hear the answers, I may ask them as follow-up questions.

Do you feel that being a part of or going to the makerspace has contributed in any way to your ecological innovation? If so, please explain. If not, why not?

Does participation in the makerspace influence your ability to innovate?

If so, please describe how.

Is there any specific tool or technique that you learned at the makerspace that has contributed to your innovation? Are there certain habits of thinking that you learned at the makerspace that have influenced your innovation?

Did you take any specific classes or participate in any clubs that contributed to this innovation or your ability to innovate?

If so, please describe.

Have you ever been to a maker-faire or similar event?

If so, please tell me about that?

Do you think participating in that event influenced you as an innovator at all?

Are you part of any on-line maker communities? If so, can you please tell me about that. Do you think participating in your online maker community influenced your innovation or innovation process or thinking at all?

On Innovation:

Do you remember the first time you made something from scratch?

While the interviewee is responding, I will be looking for answers to the following questions. If I don't hear the answers, I may ask them as follow-up questions.

Can you tell me about that process?

Do you have an innovation hero that inspire you? Please tell me about that.

Did you go to innovation events or museums as a kid?

Did you have any mail-order innovation kits or magazines?

How many prototypes did you go through, or if you're in process of creating your ecological innovation, what stage of the process are you in?

Have you innovated anything before? If so, please tell me about that?

Did anyone help you, and if so, who and in what ways did they help you?

Challenges:

What challenges have you experienced through the process of making your eco-innovation?

How do you get through the challenges?

Do you have a story about getting through an innovation challenge? If so, please tell me.

Suggestion for Supports:

What suggestions do you have for people to support eco-innovation?

While the interviewee is responding, I will be looking for answers to the following questions. If I don't hear the answers, I may ask them as follow-up questions.

What suggestions do you have for parents to support eco-innovation in their kids?

What suggestions do you have for teachers to support eco-innovation in their students?

What suggestions do you have for school leaders to support eco-innovation in their schools?

What suggestions do you have for communities/society to support eco-innovation in general?

What suggestions do you have for your friends in terms of encouraging them to try addressing an ecological problem?

Snowball Sampling:

As I’m trying to interview as many ecological innovators as possible, do you know other eco-innovators who might be willing to be interviewed as well? Any leads from any of your online maker communities or your clubs, classes, or makerspace?

Please tell me why you suggested that person. (Ask for contact info!)

Thank you!

APPENDIX B:

ECOLOGICAL INNOVATOR QUESTIONNAIRE

Thank you for your time and willingness to share your story about how you became an ecological innovator. Please fill out this questionnaire first, then we will proceed to the video interview. *You and your auxiliary participants' identities and identifying information will be kept confidential.*

Name: ___________________________________ Today's Date: ___________________

Age: _____________ D.O.B.: ____________ Age you started innovation: ____________

School/Type of School: ____

Grade/Class: ___________ Teacher: ____

Makerspace Membership:___________________________ Years/Months attending:____

Name/Purpose of your Ecological Innovation:____________________________________

____

Contributing Teachers/Mentors to your Ecological Innovation (at any stage). You may list as many or as few as is appropriate. If you need more than 4 spots, please indicate with an asterisk (*) and write in the blank space provided at the end of this survey.

1.___________________________________ 2. __________________________________

3.___________________________________ 4. __________________________________

Please write a brief note about each person and the role that person played in your life and the innovation process. I will ask you more during the interview.

Person 1.____

Person 2.____

Person 3.____

Person 4.____

I may wish to contact these people to learn more from them about the process of developing you as an ecological innovator. Please indicate if I have your permission to contact each person, and if you have the contact info or are able to share it. If you have it on you, please let them know that I may be contacting them and please share their contact info below.

Thank you!

I give you permission to contact Person 1. *Yes / No*.

I *(have/do not have)* access to their contact information. I (*can/cannot)* get it for you.

Person 1 Name:_______________________ email: ________________________________

phone: ________________________ Place of work: _______________________________

I give you permission to contact Person 2. *Yes / No*.

I *(have/do not have)* access to their contact information. I (*can/cannot)* get it for you.

Person 2 Name:_______________________ email: ________________________________

phone: ________________________ Place of work: _______________________________

I give you permission to contact Person 3. *Yes / No*.

I *(have/do not have)* access to their contact information. I (*can/cannot)* get it for you.

Person 3 Name:_______________________ email: ________________________________

phone: ________________________ Place of work: _______________________________

I give you permission to contact Person 4. *Yes/No*.

I *(have/do not have)* access to their contact information. I (*can/cannot)* get it for you.

Person 4 Name:_______________________ email: ________________________________

phone: ________________________ Place of work: _______________________________

APPENDIX C:

INFORMED CONSENT FORM–ADULT

Dissertation Research: People Who Are Saving the World: The Influencing Factors and Conditions upon the Lives of Young People who become Ecological Innovators

Introduction:
I, Pascha Griffiths, the lead researcher, designer, funder, and facilitator of this study, am conducting this research as part of the requirements of Lesley University's Educational Leadership Doctoral Program. The purpose of this research is to explore the factors and conditions present in the lives of ecological innovators that led up to their experience of making an ecological innovation. This study aims to investigate 1-6 unique eco-innovator cases.

Volunteering for the Study:
You are invited to participate in this research case study either as a primary or auxiliary participant. To clarify, a primary participant is an ecological innovator as defined by this study, and an auxiliary participant is a person who holds an important and informative perspective on the primary participant's life such as a family member, teacher, mentor, friend, lab partner, or other related person. Volunteering for this study involves participating in 1-3 individual or group interviews that will range from 45-90 minutes. For the primary participants, it may also involve allowing Pascha Griffiths to follow you around like a documentarian/biographer for part of a day on one or more occasion as you are comfortable and is appropriate to the study and your circumstances.

Compensation:
Participants in this study will receive gift cards in the amount of $25 per video/audio interview from either Amazon or Target (your choice). If you prefer, your compensation can be in the form of a donation made by the principal investigator to a mutually agreed upon ecological/environmental charity of your choosing. Additionally, all participants will be entered into a drawing at the rate of one entry/interview (both group and individual interviews count) for one additional $100 Amazon or Target gift card that will be held at the end of data collection.

Outcomes:
There is potential for this study to influence educators and parents who aim to prepare youth for creatively solving and responding to environmental problems. The findings of this study may inform teaching practices and curriculum development for educators in schools, after-schools, summer camps, and makerspaces. It may also inform school leaders and policy makers in their support of programming and funding that could influence ecological/environmental education and innovation. This study may also yield information that serves to advance the supports for ecological innovation in schools, educational organizations, and society at large. In addition to the defense of this dissertation, information from this study may be used for a more formal presentation such as an article, book, or theatrical presentation.

Benefits:
The benefit of participating in this research is the opportunity to provide information useful in understanding the developmental factors and conditions that go into the lives of ecological innovators. Additionally, you may benefit from reflecting upon and retelling your experiences. Although these benefits may occur, we cannot guarantee that you will personally experience benefits from participating in this study.

Data Collection Process and Participant Involvement:
Participants in this study will participate in one or all of the following conducted by principal investigator, Pascha Griffiths:
Pre-interview questionnaire
One-on-one interview with freedom to sketch/write on a whiteboard during interview (video or audio recorded)
Group interview (video or audio recorded)
Follow up Interview
Additional Data Collected by Principal Investigator May Include:
Observational notes
Using shared artifacts such as articles, letters of recommendation, assignments, report cards, evaluations, etc.

Risks:
There are no known risks associated with participation in this project. Participating in this research study is completely voluntary. You have the right to refuse to be in this study. If you decide to be in this study and change your mind, you have the right to drop out at any time. You may skip questions. Whatever you decide, you will not lose any benefits to which you are otherwise entitled. You are encouraged to ask questions about this study at any time before or during this research.

Participant Confidentiality, Privacy, Anonymity, and Data Protection:
During the process of this study, all precautions will be taken to maintain confidentiality and participant anonymity. I will be the only one collecting and analyzing the data from the study. During the study, video and audio recordings will be securely stored in a locked file. Digital renderings will be password protected. Once the study is completed, the video and audio recordings will be destroyed. Transcript data, completely separated from any identifying information, may be retained and securely maintained for future studies and works noted above. To ensure anonymity, all notes and related materials collected will be decoupled from any identifying information and securely stored for a potential future follow-up study. Please note, in the event that you should reveal something which Federal or State laws require the researcher to report, then the researcher will be obliged to do so, even where such reports appear to violate confidentiality – applicable Federal and State laws take precedence.

Institutional Contact Information:
The researcher's contact information, as well as the researcher's Senior Advisor's and Lesley University's IRB contact information appear below. The benefit of participating in this research is the opportunity to provide information useful in understanding the developmental factors and conditions that go into the lives of ecological innovators. There are no known risks associated with participation in this project. *There is a Standing Committee for Human Subjects in Research at Lesley University to which complaints or problems concerning any research project may, and should, be reported if they arise. Contact the Committee Chairpersons at* **irb@lesley.edu**
By replying to this email and inserting an "X" next the appropriate statements, you are giving electronic consent to participate in this research study. You will have a chance to sign this in person at our first meeting. If you are handed this in person, your signature below is your consent for you or your child to participate in this study.

Thank you for your considering participating in this research study! I truly appreciate it!
For Potential Participants Who are 18 Years or older:

please circle one

____Yes, I agree to participate in this study as a primary/auxiliary participant and I am 18 years or older.

____ No, I do not agree to participate in this study and I am 18 years or older.

Participant's Signature (18 or older):
I am 18 years of age or older. The nature and purpose of this research have been satisfactorily explained to me and I agree to become a participant in the study as described above. I understand that I am free to discontinue participation at any time if I so choose, and that the investigator will gladly answer any questions that arise during the course of research.

______________ ___________________________________ __________________
Date Participant's Signature Print Name

Please Put an X in all that you are willing to participate in:

____Pre-interview questionnaire
____Video or audio recorded 1-on-1 interview which may include explanatory sketches created during the process
____Video or audio recorded group interview conducted
____Observational notes
____Collection of artifacts such as articles, letters of recommendation, assignments, report cards, evaluations, etc.
____Explanatory pencil/pen sketches may be published in this study

Investigator's Signature:

_____________ _________________________________ _________________
Date Investigator's Signature Print Name

Once again, I truly thank you for your considering participating in this research study!

Sincerely,
[signed]

Pascha Marlin Griffiths

Pascha Marlin Griffiths	Dr. Susan Rauchwerk	
Ph.D. Candidate	Senior Advisor	
Lesley University	Lesley University	
xxxxxx@lesley.edu	**xxxxxx@lesley.edu**	**irb@lesley.edu**
xxx-xxx-xxxx		

APPENDIX D:

INFORMED CONSENT FORM–MINOR

Dissertation Research: People Who Are Saving the World: The Influencing Factors and Conditions upon the Lives of Young People who become Ecological Innovators

Introduction:
I, Pascha Griffiths, the lead researcher, designer, funder, and facilitator of this study, am conducting this research as part of the requirements of Lesley University's Educational Leadership Doctoral Program. The purpose of this research is to explore the factors and conditions present in the lives of ecological innovators that led up to their experience of making an ecological innovation. This study aims to investigate 1-6 unique eco-innovator cases.

Volunteering for the Study:
You (and/or your child) are invited to participate in this research case study either as a primary or auxiliary participant. To clarify, a primary participant is an ecological innovator as defined by this study, and an auxiliary participant is a person who holds an important and informative perspective on the primary participant's life such as a family member, teacher, mentor, friend, lab partner, or other related person. Volunteering for this study involves participating in 1-3 individual or group interviews that will range from 45-90 minutes. For the primary participants, it may also involve allowing Pascha Griffiths to follow you around like a documentarian/biographer for part of a day on one or more occasion as you are comfortable and is appropriate to the study and your circumstances.

Compensation:
Participants in this study will receive gift cards in the amount of $25 per video/audio interview from either Amazon or Target (your choice). If you prefer, your compensation can be in the form of a donation made by the principal investigator to a mutually agreed upon ecological/environmental charity of your choosing. Additionally, all participants will be entered into a drawing at the rate of one entry/interview (both group and individual interviews count) for one additional $100 Amazon or Target gift card that will be held at the end of data collection.

Outcomes:
There is potential for this study to influence educators and parents who aim to prepare youth for creatively solving and responding to environmental problems. The findings of this study may inform teaching practices and curriculum development for educators in schools, after-schools, summer camps, and makerspaces. It may also inform school leaders and policy makers in their support of programming and funding that could influence ecological/environmental education and innovation. This study may also yield information that serves to advance the supports for ecological innovation in schools, educational organizations, and society at large. In addition to the defense of this dissertation, information from this study may be used for a more formal presentation such as an article, book, or theatrical presentation.

Benefits:
The benefit of participating in this research is the opportunity to provide information useful in understanding the developmental factors and conditions that go into the lives of ecological innovators. Additionally, you may benefit from reflecting upon and retelling your experiences. Although these benefits may occur, we cannot guarantee that you will personally experience benefits from participating in this study.

Data Collection Process and Participant Involvement:
Participants in this study will participate in one or all of the following conducted by principal investigator, Pascha Griffiths:

- Pre-interview questionnaire
- One-on-one interview with freedom to sketch/write on a whiteboard during interview (video or audio recorded)
- Group interview (video or audio recorded)
- Follow up Interview

Additional Data Collected by Principal Investigator May Include:

- Observational notes
- Using shared artifacts such as articles, letters of recommendation, assignments, report cards, evaluations, etc.

Risks:
There are no known risks associated with participation in this project. Participating in this research study is completely voluntary. You have the right to refuse to be in this study. If you decide to be in this study and change your mind, you have the right to drop out at any time. You may skip questions Whatever you decide, you will not lose any benefits to which you are otherwise entitled. You are encouraged to ask questions about this study at any time before or during this research.

Participant Confidentiality, Privacy, Anonymity, and Data Protection:
During the process of this study, all precautions will be taken to maintain confidentiality and participant anonymity. I will be the only one collecting and analyzing the data from the study. During the study, video and audio recordings will be securely stored in a locked file. Digital renderings will be password protected. Once the study is completed, the video and audio recordings will be destroyed. Transcript data, completely separated from any identifying information, may be retained and securely maintained for future studies and works noted above. To ensure anonymity, all notes and related materials collected will be decoupled from any identifying information and securely stored for a potential future follow-up study. Please note, in the event that you should reveal something which Federal or State laws require the researcher to report, then the researcher will be obliged to do so, even where such reports appear to violate confidentiality – applicable Federal and State laws take precedence.

Institutional Contact Information:
The researcher's contact information, as well as the researcher's Senior Advisor's and Lesley University's IRB contact information appear below. The benefit of participating in

this research is the opportunity to provide information useful in understanding the developmental factors and conditions that go into the lives of ecological innovators. There are no known risks associated with participation in this project. *There is a Standing Committee for Human Subjects in Research at Lesley University to which complaints or problems concerning any research project may, and should, be reported if they arise. Contact the Committee Chairpersons at* irb@lesley.edu
By replying to this email and inserting an "X" next the appropriate statements, you are giving electronic consent to participate in this research study. You will have a chance to sign this in person at our first meeting. If you are handed this in person, your signature below is your consent for you or your child to participate in this study.

Thank you for your considering participating in this research study! I truly appreciate it!

For Parent/Guardian of Minor Children (17 years or younger):

_____ Yes, I agree to allow my minor child (17 or younger) to participate in this study as a **primary participant** and I am 18 years or older.

_____ No, I do not agree to allow my minor child to participate in this study.

For Potential Participants who are 17 years or younger whose parent/guardian checked "Yes" above:

_____ Yes, I agree to participate in this study as a **primary participant** and I am 17 years or younger.

_____ No, I do not agree to participate in this study and I am 17 years or younger.

Investigator's Signature:

_____________ __________________________________ _________________
Date Investigator's Signature Print Name

Parent/Guardian Signature for Minor Participant:
I am 18 years of age or older, and the responsible parent/guardian of a participant in this research. The nature and purpose of this research have been satisfactorily explained to me and my child, and I agree to allow my child to become a participant in the study as described above. I understand that my child is free to discontinue participation at any time, by his or her choosing, or

my own. The investigator will gladly answer any questions that arise during the course of research.

_____________ __________________________________ __________________

Date	Signature of Parent/Guardian or Legally Authorized Representative	Print Name

Minor Participant's Signature:
I am younger than 18 years of age, so if my parent/guardian has already allowed permission, then I have the option of choosing to participate or not. The nature and purpose of this research have been satisfactorily explained to me and I agree to become a participant in the study as described above. I understand that I am free to discontinue participation at any time if I so choose, and that the investigator will gladly answer any questions that arise during the course of research.

_____________ __________________________________ __________________

Date	Participant's Signature	Print Name

Please Put an X in all that you are willing to participate in:

____Pre-interview questionnaire

____Video or audio recorded 1-on-1 interview which may include explanatory sketches created during the process

____Video or audio recorded group interview conducted

____Observational notes

____Collection of artifacts such as articles, letters of recommendation, assignments, report cards, evaluations, etc.

____Explanatory pencil/pen sketches may be published in this study

Once again, I truly thank you for your considering participating in this research study!

Sincerely,

[signed]

Pascha Marlin Griffiths

Pascha Marlin Griffiths	Dr. Susan Rauchwerk	
Ph.D. Candidate	Senior Advisor	
Lesley University	Lesley University	
xxxxxxxx@lesley.edu	xxxxxxxx@lesley.edu	irb@lesley.edu
xxx-xxx-xxxx		

APPENDIX E:

DATA COLLECTED

Table E1. *Timeline of Participant Recruitment, Interviews, and Data Analysis*

Date	Primary Participant (PP)		
	PP1 Chaeli	PP2 Elisha	PP3 Jaffer and Leah
4/13/18		Received IRB Approval for Study	
4/13/18		Commenced participant recruitment: Launched recruitment website and started recruiting via emails to professors, word of mouth, posted links to website on Facebook and Twitter	
5/20/18	Received application for study from the recruitment website		
6/20/10	Interviewed PP1 & mother (Chaeli & Lily)		
6/27/18	Interviewed PP1's science teacher (Mrs. Wu)		
7/2/18	Interviewed PP1's mother (Lily)		
8/9/18	Attended summer science/gardening program expo that PP1 attended & claimed was influential		
8/11/18	Interviewed PP1's grandfather/mentor (Grandpa)		
8/13/18		Attended talk PP2 gave on solar innovation	Met at PP2's solar innovation talk
8/17/18		Interviewed PP2; observed PP2 in meeting regarding solar innovation business	
8/20/18	Interviewed PP1's camp counselor/ mentor (Seth)		
8/27/18			Interviewed PP3 (Jaffer)
9/13/18			Interviewed PP3' (Leah)
10/2018		Continued work on transcriptions	
11/26/18		Imported interview transcripts into NVivo; started initial coding	
11/29/18			Interviewed PP3's host-mom/mentor (Malia)
11/29/18	Uploaded Data to NVivo		Found online/transcribed PP3's speech to members of Congress
12/2018		Gathered data from print, video, online sources	Gathered data from online sources
12/27-29/18	Wrote initial case & started 1st data analysis step	Uploaded data to NVivo; wrote initial case & started 1st data analysis step	Uploaded data to NVivo
1/4/19		Initial participant checks on 1st draft of case	
1/5-6/19		Interviewed PP2's science teacher (Dr. Sterne)	
1/7/19			Wrote initial case & started 1st data analysis step
1-2/2019		Started initial coding of quintain	
1/8/19	Follow-up phone interview with PP1's mother (Lily)		
1/15/19		Interviewed PP2's mother (Hannah)	
1/2019		Completed all transcriptions; continue work on case writing; uploaded data to NVivo as necessary	
1-2/2019	Sent vignette to participant for checking	Sent vignette to participant for checking	Sent vignette to participants for checking
1-4/2019		Imported all remaining data to NVivo; engaged in remaining steps of eight-step analysis process of individual and quintain case analysis; submitted drafts of individual cases with theme and quintain analyses to dissertation advisor.	

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Data Collection

Tools
Interview Protocol (Appendix A): With eco-innovators (primary participants) With auxiliary participants (e.g., parents, teachers, mentors, siblings, lab partners) Trint.com recording app Rev.com recording App Dictopro recorder Writing and drawing materials for participant to use during interviews Camera for taking pictures of participants' drawings
Auxiliary participant gathering survey (Appendix B) Supplemental materials Online materials, such as videos made by or about the innovator, blogs by the eco-innovator, articles about the eco-innovator Documents shared with the researcher (e.g., emails, reports, work samples)
Observational interview notes

Table E2. *Data Collected by Case*

Primary participant	Data collected
PP1 Chaeli	In-person interview at mother’s hospital bed with mother present and occasionally contributing (audio recorded)
	PP1’s photographs on phone as shared during interview
	Observations & observational notes from Interview 1
	Drawings from Interview 1
	Follow up in-person interview with PP1’s mother (audio recorded)
	Photographs of PP1 shared by mother during interview
	Phone interview with PP1’s grandfather/science mentor (notes taken and participant verified via email communication)
	Newsletter mailed in from PP1’s grandfather
	In-person interview with PP1’s science teacher (audio recording failed; teacher supplied written answers to interview questions after the interview)
	In-person interview with PP1’s camp counselor (audio recorded)
	Observational attendance and participation in celebration put on by summer gardening camp that PP1 attends
	Phone call with leader of summer science camp at which PP1 designed her eco-innovation
PP2 Elisha	In-person interview at ’PP2’s collaborating educational institution (audio recorded)
	In-person interview with PP2’s science teacher
	Phone interview with PP2’s mother
	Observations and observational notes from PP2’s Interview 1
	Images of innovation drawn as child emailed to researcher
	On-line newspaper articles featuring PP2
	Observation of PP2 during group presentation of environmental work
	Observation of PP2 during one-on-one presentation of environmental work
	Web-pages about PP2 and PP2’s environmental work
	Content written about PP2 in published memoir written by close family member
PP3 Jaffer & Leah	In-person interview at participant’s innovation lab (audio recorded)
	Observations and observational notes from PP3’s Interview 1
	Phone interview with PP3’s host-mother and mentor (audio recorded)
	Online video of PP3 presenting a speech to members of Congress
	Online document related to innovation project
	Online document describing summer innovation program

APPENDIX F:

NIH COURSE COMPLETION CERTIFICATE

Certificate of Completion

The National Institutes of Health (NIH) Office of Extramural Research certifies that **PASCHA GRIFFITHS** successfully completed the NIH Web-based training course "Protecting Human Research Participants".

Date of completion: 07/27/2016.

Certification Number: 2117192.

APPENDIX G:

LESLEY UNIVERSITY IRB APPROVAL

Lesley UNIVERSITY

29 Everett Street
Cambridge, MA 02138
Tel 617 349 8234
Fax 617 349 8190
irb@lesley.edu

Institutional Review

DATE: 4/13/2018

To: Pascha Griffiths

From: Dr. Robyn Flaum Cruz & Dr. Ulas Kaplan, Co-Chairs, Lesley IRB

RE: **IRB Number: 17/18 - 042**

The application for the research project, "Kids who are Saving the World: The Influencing Factors and Conditions upon the Lives of Young People who become Ecological Innovators" provides a detailed description of the recruitment of participants, the method of the proposed research, the protection of participants' identities and the confidentiality of the data collected. The consent form is sufficient to ensure voluntary participation in the study and contains the appropriate contact information for the researcher and the IRB.

This application is approved for one calendar year from the date of approval.

You may conduct this project.

Date of approval of application: 4/13/18

Investigators shall immediately suspend an inquiry if they observe an adverse change in the health or behavior of a subject that may be attributable to the research. They shall promptly report the circumstances to the IRB. They shall not resume the use of human subjects without the approval of the IRB.

APPENDIX H:

RECRUITMENT FLYER

Seeking Eco-Innovators for Research Study

Definition of eco-innovator for this study:

A person who has made or is in the process of making an invention or innovative response to ameliorate or mitigate an ecological or environmental problem. Examples would be an innovation to clear the plastics in the ocean, a device to address the lack of potable water for people in a given geographical region, an innovation to mitigate the deleterious rise of carbon in the atmosphere, or a solution to ameliorate a threat to a given species due to human influenced environmental conditions.

I am a doctoral student of Educational Leadership at Lesley University. I am researching factors and conditions present in the lives of ecological innovators that led up to their experience of creating an ecological innovation.

I am seeking 2-6 ecological innovators willing to participate in a case study who started creating their first ecological innovation before they were 30 years old.

If you believe you fit the criteria and you are willing to consider participating in a case study, please scan this QR code to learn more about the study and sign up for a potential case-candidate screening.

If you are selected and choose to volunteer in the study, compensation will be $25 Amazon or Target gift card/interview + chance at $100 Amazon/Target gift card.

If you cannot scan this QR code, please take a picture of this URL and visit it to learn more and sign up for a pre-screen:

https://eco-innovator.weebly.com

If you know someone who fits the criteria, please share this with them. Thank you!

APPENDIX I:

EMAILS TO PARTICIPANTS

Dear Eco-Innovator (and Parent/Guardian if a Minor),

I was referred to you by ________________________ to ask you if you would be willing to consider participating in a research study on eco-innovation.

I am a doctoral student and an advisor to science teachers. Given my perspective, I am interested in examining the factors and conditions that contribute to a person becoming an ecological innovator.

You and/or your child are invited to participate in a research study that aims to find the set of developmental factors and conditions that go into the lives of ecological innovators. You and/or your child were selected based on the fact that you are either the primary subject and have created at least one ecological innovation, or you are a supplemental participant, able of providing insights into the factors and conditions that led the primary subject becoming an ecological innovator.

The research study utilizes a case study method. This means that I will be engaging with the primary and auxiliary participants somewhat like a biographer trying to discover the factors and conditions that led you/the primary subject to become an eco-innovator. As a case study attempts to get the full picture from multiple perspectives, your/your child's insights are considered relevant and valuable to understanding the contributing factors that went into the primary subject's life. As case studies go, I will also incorporate observations, documents, & artifacts such as newspaper articles or awards that you would be willing to show me. I hope this will be a fun and enriching time for all involved. Of course, any participant may refuse any question or end their participation in the study at any time without any need to explain and without any repercussion whatsoever.

The results from this research will be used as part of my doctoral dissertation and may be submitted to an education or ecological journal for publication. Additionally, while maintaining confidentiality, elements of this study may be used in the formation of a theatrical production about ecological innovation. As a dissertation, article, or production, there is potential for this study to influence the professional preparation of future science teachers, as well as serve the advancement of ecological innovation in schools and educational organizations.

To ensure accuracy of the data collected, interviews will be video recorded, unless you request an audio recording. If you decide to participate/allow your child to participate in this research study, simply reply to this email message with the consent form completed. The attached consent form outlines your voluntary participation with an option to allow me to publish an image of your explanatory white-board sketches created during the study, as long as the image maintains your anonymity.

I understand how demanding life can be, so it is with this in mind that I respectfully and humbly ask for you to share your story of how you or your primary participant became an ecological innovator. Your kind allowance of participation and collaboration will help me complete this study. Please read the attached consent form and consider participating and/or allowing your child to participate by responding to this email. Do not hesitate to call me (xxx-xxx-xxxx) if you have any questions. I look forward to hearing from you as soon as possible!

Sincerely,
Pascha Griffiths
Lesley University Doctoral Candidate xxxxx@lesley.edu

Email Letter to Auxiliary Participants

Dear Potential Auxiliary Participant in a Case Study about ________________'s Life as An Eco-Innovator,

I was referred to you by _________________________ to ask you if you would be willing to consider participating in a research study on eco-innovation. This is a case study focused on (Primary Participant) as (he/she/they) has/have created an ecological innovation which qualifies them as a primary subject for this research. You and/or your child are invited to participate in this research study which aims to find the set of developmental factors and conditions that go into the lives of ecological innovators. You and/or your child were recommended as auxiliary participants by ______________ as you hold a valuable informative perspective on ___________________'s life.

As the doctoral student researcher, I am also an Advisor to science teachers. As such, I am interested in examining the factors and conditions that contribute to a person becoming an ecological innovator.

The research study utilizes a case study method. This means that I will be engaging with the primary and auxiliary participants somewhat like a biographer trying to discover the factors and conditions that led the primary subject to become an eco-innovator. As a case study attempts to get the full picture from multiple perspectives, your/your child's insights are considered relevant and valuable to understanding the contributing factors that went into the primary subject's life. As case studies go, I will also incorporate observations and any relevant documents or artifacts such as newspaper articles or awards that you would be willing to show me. I hope this will be a fun and enriching time for all involved. Of course, any participant may refuse any question or end their participation in the study at any time without any need to explain and without any repercussion whatsoever.

The results from this research will be used as part of my doctoral dissertation and may be submitted to an education or ecological journal for publication. Additionally, while maintaining confidentiality, elements of this study may be used in the formation of a theatrical production about ecological innovation. As a dissertation, article, or production, there is potential for this study to influence the professional preparation of future science teachers, as well as serve the advancement of ecological innovation in schools and educational organizations.

To ensure accuracy of the data collected, interviews will be video recorded, unless you request an audio recording. If you decide to participate/allow your child to participate in this research study, simply reply to this email message with the consent form completed. The attached consent form outlines your voluntary participation with an option to allow me to publish an image of any whiteboard sketches you/your child may create during the study, as long as the image maintains all participants' anonymity.

I understand how demanding life can be, so it is with this in mind that I respectfully and humbly ask for you to share your perspective on the primary participant's life. Your kind allowance of participation and collaboration will help me complete this study. Please read the attached consent form and consider participating and/or allowing your child to participate by responding to this email. Do not hesitate to call me (xxx-xxx-xxxx) if you have any questions. I look forward to hearing from you as soon as possible!

Sincerely,
Pascha Griffiths
Lesley University Doctoral Candidate xxxxxx@lesley.edu

Email Recruitment/Referral Letter to Professors and Teachers

Dear Professor (Name)/Science Teacher (Name),

As an Advisor to science teachers and as an educational researcher/doctoral student, I am interested in examining the factors and conditions that contribute to a young person becoming an ecological innovator.

I am conducting a criterion-based case study, so I am contacting you to ask for referrals of any current or former students or colleagues who, before the age of 30, made (or attempted to make) some sort of ecological innovation to support some aspect of ecological sustainability, environmental stewardship, climate change mitigation, or any sort of attempted solution to mitigate or ameliorate anthropogenic consequences for any part or species in our global ecosystem. Their innovation may have been for an assignment, competition, conference, collaborative project, or self-guided exploration. You may nominate yourself as well as long as you fit the criteria.

If you know someone who might fit the criteria for this study, will you please forward this email to them with this following note, please copy and paste it and include it in the email exactly:

This email is being forwarded to you by (your professor/your child's teacher) because (you/your child) may fit the criteria for a research study I'm conducting for my doctoral dissertation at Lesley University. My name is Pascha Griffiths, and I have asked your professor/your child's teacher for suggestions of students who may fit the criteria of being an "eco-innovator." Before I explain more, please note that there is no obligation for you or your child to participate in this study. Participation in this study is completely voluntary, and you may choose to (withdraw/withdraw your child) from the study at any time without explanation and without any repercussion. You/your child may also choose to not answer some questions, and that is completely fine, as participation is 100% voluntary. (You/You and your child) are encouraged to ask questions before and during the study. After the interviews have been transcribed, all participants will be asked to review and approve the transcript for accuracy, privacy protection, anonymity, and confidentiality. If you are interesting, will you please kindly contact me via email at xxxxx@lesley.edu with the subject heading: Eco-Innovator Study

This study utilizes a case study method, so I will be engaging with the primary participants somewhat like a biographer trying to discover the factors and conditions that led the person to become an eco-innovator. As a case study attempts to get the full picture from multiple perspectives, I will also be interviewing auxiliary participants such as his or her parents, mentors, and case-relevant teachers, so if you are one of these people for this student, I may be returning to you to invite you to participate in the study as well. I hope this will be a fun and enriching time for all involved. Of course, any participant may refuse any question or end their participation in the study at any time without any need to explain and without any repercussion whatsoever.

The results from this research will be used as part of my doctoral dissertation and may be submitted to an education or ecological journal for publication. Additionally, while maintaining confidentiality, elements of this study may be used in the formation of a theatrical production about ecological innovation. As a dissertation, article, or production, there is potential for this study to influence the professional preparation of future science teachers as well as serve the advancement of ecological innovation in schools, educational organizations, and communities.

I respectfully and humbly ask for you to think of any people you may know who might fit the criterion as described: ***a person who, before the age of 30, made (or attempted to make) some sort of ecological innovation to support some aspect of ecological sustainability, environmental stewardship, climate change mitigation, or any sort of attempted solution to mitigate or ameliorate anthropogenic consequences for any part or species in our global ecosystem.*** Your kind collaboration will help me complete this study. Please think it over, ask your colleagues, and please respond to this email, even if it is a "no, sorry." If you don't know of a person who fits the criteria, but know someone who might know one, will you please connect me with that person? Thank you.

Do not hesitate to call me (xxx-xxx-xxxx) if you have any questions. I look forward to hearing from you as soon as possible!

Sincerely,
Pascha Griffiths
Lesley University Doctoral Candidate
xxxxxx@lesley.edu

APPENDIX J:

TECHNICAL ASPECTS OF THE PROCESS TO TURN INTERVIEW TRANSCRIPTS INTO CASES

Process of Transforming Primary and Auxiliary Interview Texts into Cases

Step 1. Using Microsoft Word, copy and paste the whole transcript to a new document.

Step 2. Go through the document and delete all irrelevant small talk and unrelated content, such as warm-up chatter about the weather.

Step 3. Look up any contextual information mentioned in the interview such as the "Yom Kippur War," or "Second Intifada" to understand and clarify these references for the reader. Verify or enhance text with related supplemental information such as web sites, articles, or publications.

Step 4. Start at the beginning of the interview. Go through section by section of text in order from the beginning to the end. A section, in this instance, would be a complete segment of the interviewee's response to a question. Focus on one section of interview at a time. Transform identified section of text from the interview transcript language to the third-person language of a case. Repeat until entire transcript is turned into third person.

Step 5. Read entire document for continuity.

Rearrange text to maintain story flow, and chronology.

Step 6. Read the document to identify themes.

Step 7. Create vignette by rearranging text into sections based on themes, chronology, and flow. When completed, this will serve as the foundational vignette for the case.

Step 8. Send draft of this vignette to interviewee for participant checking for accuracy, maintaining anonymity, editing, and approval.

Step 9. When Steps 1–8 have been completed for all interview vignettes, integrate the content from the auxiliary within primary participant's perspective into the original piece where it makes sense to do so. Repeat this step until all auxiliary participants' perspectives are included. This process leads to the development of the long-form case.

Step 10. Edit long-form case to short-form case by excising extraneous content and honing relevant content for clarity. This is the version that appears in this dissertation.

Example Transformation

First, I conducted and recorded the primary participant interview guided by questions that aimed to get the story from the participant, then transcribed that interview (the entire written transcript from the primary 'participant's interview was used as the foundation for the case).

Step 1: Using Microsoft Word, I copy and pasted the entire transcript into a new document.

Step 2. I read the entire document and deleted all irrelevant content, such as the warmup where I shared about myself and irrelevant tangents.

Step 4.

(a) I started at beginning of interview, highlighting chunk of texts in yellow, then focusing on that bit of text until the following process was completed:

(b) Take a section of text spoken by the participant and change the language so that it is written as a narrative. This involves changing tense from either first- or second-person to an embodied third-person narrator who occasionally breaks the fourth wall to provide researcher transparency. If the words spoken by the participant are excellent for quotation, then keep them and wrap quotations marks around it or, if the quotation is larger than 40 words, turn it into a block quote.

(c) When each bit of writing gets changed from the raw data of the interview to the narrative form of the case, highlight that bit of text in gray.

(d) Once all yellow in that section has been turned to gray, highlight the next chunk of text in yellow and repeat this process. Keep repeating until the entire document is turned into a gray highlighted document.

(e) Once 100% of the document is highlighted in gray, remove the highlighting.

(f) Read the document and put subheadings on areas or themes. If one theme shows up on different pages of the document, cut and paste those paragraphs to all be in the same location and under the same heading.

(g) Look for chronological order of the person's life and rearrange the data to give the story in as chronological as possible, barring the themes that have been grouped together. Keep doing this until the foundational case is based on the primary participant's interview flows and has grouped together the related themes.

(h) Repeat this same procedure for each auxiliary participant interview.

(i) Import the auxiliary participants' perspectives into the foundational case document.

APPENDIX K:

SNYDER'S (1995) STRATEGIES FOR NURTURING HOPE

Snyder's (1995) strategies for nurturing hope:

- learn self-talk about succeeding;
- think of difficulties encountered as reflecting wrong strategy, not lack of talent;
- think of goals and setbacks as challenges, not failures;
- recall past successes;
- hear stories of how other people have succeeded (e.g., from movies, tapes, books);
- cultivate friends to talk with about the goals;
- find role models to emulate (everyday heroes are closer than one may think);
- exercise physically (relearn that the body and mind are connected);
- eat properly (remember bodies need fuel);
- rest adequately (recharge for the next active goal-directed output);
- laugh at oneself (especially when stuck);
- re-goal (persistence in the face of absolute goal blockage deflates agency and pathways);
- reward oneself for small subgoal attainments on the way to larger, long-term goals; and
- educate oneself for specific skills, as well as learn how to learn.

  (pp. 358–359)