Sustained Relevance Through Elegance: Redesigning Higher Education from Within

by

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ABSTRACT

Universities and colleges in the United States (U.S.) are in a period of rapid transformation. Driven by the need for an educated workforce, higher education institutions are responding to rapid innovation, globalization, economic realities, and sociodemographic shifts. Simultaneously, extensive educational online networks connect millions of people worldwide enable learning and knowledge sharing beyond what society has experienced to date. In light of technological advancements, the preservation and presentation of certain ideals that undergird academia and the communication and application of knowledge are undergoing dramatic change. Within higher education, this is both a challenge and an opportunity to re-envision the commitment to educate the public. This research discusses potential forms of this redesign and how it can build upon and depart from previous iterations of higher education. How colleges and universities will adapt to become more relevant, engaging, and accessible is a pressing question that must be addressed.

Using case studies focused on creating sustainability education materials, this dissertation develops knowledge related to three interconnected areas of study that will contribute to redesigning higher education through participatory action research methodology. First, higher education has a civic responsibility to provide new ways of thinking, being, and doing globally and providing more access to education to broader society, especially through public research institutions. Second, with a vast array of available learning materials, higher education should invest in elegantly-designed experiences consisting of well-reasoned, meticulously-curated, and high-quality content that is aesthetically appealing, engaging, and accessible to a broad audience. Third, as

universities transition from the gatekeepers of knowledge to the connectors of knowledge, they also need to ensure that a coherent mission is articulated and invested in by stakeholders to create an intentionally beneficial transformational effort. The transformation of higher education toward a more inclusive learning environment through new ways of thinking and elegantly-designed learning experiences will serve to improve our learning institutions. As part of the necessary core for an educated democracy, higher education institutions must strive to create a more equitable, inclusive, and diverse society.

DEDICATION

To my wonderful parents Nina and Michael Hale, for everything always.

And to my most precious gift, my son Max — you make the world a better place. I am beyond thankful to be your mom, to learn alongside you, and to spend my time with you.

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INTRODUCTION

Currently, higher education institutions are grappling with an urgent need for an educated workforce that can bolster an economy driven by innovation and globalization, while also responding to shifting sociodemographic and geopolitical forces (Duderstadt, 2006, 2009; National Research Council, 2012). Constructed as a social institution by its very design, higher education in the U.S. has a responsibility to the publics with which it engages (Coleman, 2009). These publics, as Warner (2002) describes, are both a social totality and an attentive audience, with whom higher education engages both directly and indirectly. As an establishment that serves as both an intellectual and civically-minded transformational catalyst, there is great opportunity to re-conceptualize and expand the evolving social contract that higher education has with society (Crow & Dabars, 2015; Glion, 2008). However, for this to happen higher education needs to recognize and confront its own sociodemographic factors, institutional and community values, economic realities, and design challenges to deliver on this commitment, which is to educate the public and foster obtainable pathways for vertical economic and social mobility (Weber, L. E., & van der Zwaan, B. , 2020; Yankelovich, 2009). For this reason, the topic of transforming higher education in the U.S. is deserving of significant attention given that it is a major foundation upon which our intellectual endowment and democracy depends (Duderstadt, 2009; Englund, 2002).

In this dissertation, I examine how coherent frameworks, elegantly-designed instructional experiences, and the altruistic motivator of making the world a better place through the lens of sustainability illuminates the way in which higher education can be

transformed. This dissertation is a product of my explorations. As a researcher, educator, and content creator, I am fascinated by the transformation of higher education, of which I am a product in both my role as a doctoral student and as a scholar. With an altruistic mindset for the future of education and my educational experiences as a backdrop, I have focused my energy over the last ten years at the university with a clear intention: I aim to use my knowledge, skills, and abilities to create engagement, foster learning, and facilitate conversation linked to current issues and complex concepts grounded in reason through elegantly-designed experiences.

Throughout this work, I intentionally use the word *transform* as I am interested in the complete redesign of higher education institutions — including creative reconceptualizations and new avenues for leveraging knowledge from within, along with the ability to share these particular knowledge collections in fascinating new ways with the publics in which universities intend to serve (Coleman, 2009; Christenson & Horn, 2011; Warner, 2002). In addition, I also use the concept of *elegantly-designed experiences* both explicitly and implicitly as a formative principle that underpins all my work. *Elegantly-designed experiences* take into account the learning, instruction, aesthetic, current and future use, learning outcomes, trustworthiness of content, and technological design factors of each instructional experience. When these components work together, an attractive and effective offering is created. As a result, it coalesces into a seamless transaction between the learner and the learning environment — including front and end back end interfaces (Parrish, 2009; Shea-Schultz & Fogarty, 2002).

Meant to be experienced as a reasoned whole, this dissertation is a culmination of research that emanate from the Sustainability Science Education project begun in 2011 at

the Biodesign Institute's Pathfinder Center at Arizona State University (ASU). This introduction chapter, which is divided into three main parts, describes my intellectual foundation that ties together the research studies in each of three subsequent chapters. First, I attempt to encapsulate the existing ideas and concepts linked to higher education's ever-evolving role in society. I then discuss the redesign of higher education and what changes must be made to keep higher education relevant in the current milieu, and how to effect those changes. In the second section, I unpack how *elegantly-designed experiences* are pivotal for designers and digital consumers of knowledge, especially in service of furthering innovative broad-reaching topics such as sustainability—which higher education is poised to articulate with authority. With a vast array of available learning materials found across the web and on all of our digital devices, *elegantly-designed experiences* are the most well-reasoned, curated, and high-quality educational assets with prudent content that is aesthetically appealing (Brown & Katz, 2011; Robins & Holmes, 2008; University Professional and Continuing Education Association, 2019). This type of content will drive traffic and use in an ever-increasing market space where users make quick visual judgment calls in what they want to engage with, typically taking under 50 milliseconds (Bargas-Avila et al., 2012; Lindgaard et al., 2006). In large part, these quick choices are due to global access to information, and the constant increase and expansion of information one can consume (Wolfe & Andrews, 2014). In the third section of the introduction, motivated by the notion of elegantly design experiences, I discuss how sustainability is an innovative topic that fits seamlessly into the new paradigm of knowledge sharing that higher education is moving toward. I specifically use the field of sustainability because it is a novel lens that comprehends the vast array of challenges,

solutions, and successes enmeshed in our human experience, including equity and social justice concerns, environmental pollution, and global production systems. With an underlay of elegantly-designed experiences, transdisciplinary learning content grounded in sustainability concerns is essential because, as Wolfe and Andrews (2014) articulate, the "mission of universities will be changing from gatekeepers of knowledge to curators, creators, connectors, certifiers and codifiers of knowledge" (p. 210).

The Changing Role of Higher Education

Higher education institutions are fascinating ecosystems to explore our society's current pulse, review our collective histories, and draft grand visions of tomorrow. Higher education institutions are altering and being altered by society through culture, rules, innovations, technologies, and the general pace of change (Weber & van der Zwaan, 2020). Duderstadt (2009) describes, "For thousands of years, [higher education] is not only served as a custodian and conveyor of knowledge, wisdom, and values, but it has transformed the very society it serves, even as social forces have transformed it in turn" (p. 6).

Often slow to change, and traditionally taking a meticulous linear path, higher education is at a critical point where our knowledge-intensive society requires that universities keep pace with societal change and offer visionary content that prepares learners for futures that do not currently exist (Crow, 2018; Weber & Duderstadt, 2008). Scholars Frank Rhodes (2001), James Duderstadt (2006, 2009), Michael Crow and William Dabars (2015) describe universities as filling a number of societal needs: drivers of economic growth, creators of "the new" through research endeavors, stewards of cultural heritage, docents and curators of professions, and a source of trustworthy

preparation that comes from knowledge, skills, and dispositions acquired during an array of implicit and explicit university offerings. Rhodes (2001) aptly portrays universities as occupying a particular interstitial space:

> The university promotes neither political action nor government policy, but it provides the knowledge and data on which both are developed. It manufacturers no products, but it creates the science and technology on which those products depend. It produces no mass circulation newspapers, magazines, or other television programs, but it trains their publishers, writers, and producers. It informs public understanding, cultivates public taste, and contributes to the nation's well-being as it nurtures and trains each new generation of architects, artists, authors, business leaders, engineers, farmers, lawyers, physicians, poets, scientists, social workers, and teachers—as well as a steady succession of advocates, dreamers, doers, dropouts, parents, politicians, preachers, prophets, social reformers, visionaries, and volunteers—who leaven, nudge, and shape the course of public life (p. 11).

To make good on Rhodes's (2001) archetypes and to bolster the unique learning spaces that the academy would like to leverage, competition among universities to convert their offerings to align with these ideals requires acquiring staff, faculty, students, and resources. This poses a particular challenge for higher education and specifically public research institutions (Christenson & Horn, 2011; Duderstadt, 2009). Duderstadt (2009) asks that "during this time of great change, of shifting paradigms," we consider as a society the appropriate public agenda for the "evolving nature of the American university" (p. 13). In light of this, what does it look like for the U.S. system of higher

education—namely pubic institutions that were established almost 400 years ago to undergo a redesign from within?

At the crossroads of a call for both preservation and progress, new university models are being forged. A need for the preservation of certain standards such as a truly broad liberal arts education, personal and intellectual growth, service to the community, and engaged scholarship is echoed by those who work in the education field and Americans who have participated in further study beyond a bachelor's degree (Coleman, 2009; Pew Research Center [PEW], 2016). According to the PEW study, "Americans who have engaged in additional schooling beyond a bachelor's degree are especially likely to say that the main purpose of college should be personal and intellectual growth, rather than the acquisition of specific skills and knowledge. Some 47% of those with a postgraduate or professional degree think the main purpose of college should be personal and intellectual growth" (p. 78). At the same time, there is a pressing proposition to evolve the learner base, construct diverse offerings, enhance the connection to workplace skills, and be ever mindful of cost. These factors push a new model of learning that is rapidly evolving across selected intuitions across the U.S. (Crow & Dabars, 2015; Duderstadt, 2009; Ehrenberg, 2012).

Higher education is critical as knowledge is the new currency for preservation, progress, and prosperity of our global society. As Duderstadt (2009) puts it, "…in a sense, knowledge is the medium of the university" (p. 14). Unlike natural resources that were the drivers of earlier social, natural, and economic transformations—knowledge is inexhaustible. Unfortunately, though, this knowledge is not readily available to everyone (Neuman, 2017). As a result, access is a critical part of the redesign of higher education.

Duderstadt (2009) emphasizes the importance of knowledge as necessary for transforming society:

> [Knowledge] can be absorbed and applied only by the educated mind. Hence, schools in general and universities in particular will play increasingly important roles as our society enters this new age. The increasingly sophisticated labor market of knowledge-driven economy is driving new needs for advanced education and training. Even today roughly two-thirds of America's high school graduates will pursue some form of college education, and this will likely increase as college degrees become the entry credential to high performance workplace in the years ahead. There is an increasingly strong correlation between the level of one's education and personal prosperity and quality of life (p. 14).

The strong correlation that Duderstadt (2009) alludes to is supported by the cost of *not* attending college (PEW, 2014). According to PEW's (2014) economic analysis, college graduates (25-32-year-olds) who work fulltime earn roughly $17,500 more annually than those employees who only have a high school diploma. Interestingly, the pay gap was considerably smaller in previous generations.

Reading across several recent studies including the 2006 U.S. Department of Education's *A Test Of Leadership Charting The Future of U.S. Higher Education* (also known as the Spellings Commission), Duderstadt's 2006 *AGB Task Force on State of the University Presidency*, the 2007 National Academies *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* report, and the National Research Council's 2012 *Research Universities and the Future of America* report, it is evident that American education is being challenged to find new and inspired

ways to stimulate and sustain its knowledge creation efforts. Namely, these reports indicate that higher education must closely examine its administration, access, credibility, and development patterns and plans to be more inclusive and supportive of the publics in which it aims to serve.

The transformation of higher education will also require that institutions seek to provide knowledge services beyond the forms of traditional degree pathways and look toward new forms of accreditation in new ways such as micro-credentials or professional development badges. The Spellings Commission (2006) stated that "to meet the challenges of the 21st century, higher education must change from a system primarily based on reputation to one based on performance" (p. 21). The Spellings Commission examined this transition specifically through the lenses of access, affordability, accountability, and quality of U.S. colleges and universities. While our nation's major source of both new and continual knowledge has historically been universities, continuing in this role depends on a strengthening of our higher education system now and into the future.

Not without its complexities and challenges, this redesign is taking place as "intellectual capital, [better articulated as] brainpower, is replacing financial and physical capital as the key to our [countries] strength, prosperity, and well-being (Duderstadt, 2009, p. 13). When America's traditional universities were established, starting with Harvard in 1639 (Best Colleges, 2018), formal knowledge was scarce and could only be acquired through the professorate, apprenticeship, ongoing research, and books. In past eras, teaching and research were designed to be tightly coupled to meet the needs of the university's research and teaching goals as well as the learner's degree requirements.

Currently, this reciprocal relationship is evolving quickly. As Christenson and Horn (2011) explain, “Today, the Internet is democratizing people’s access to knowledge and enabling learning to take place far more conveniently in a variety of contexts, locations, and times” (p. 41). Extensive networks connect millions of people across the globe and enable learning and knowledge sharing beyond what society has experienced to date. This evolution of sophisticated connectivity from internet access to platforms for sharing ideas is reshaping knowledge creation and dissemination. It is also providing access to new ways of thinking, seeing, and doing and ushering in a new era of knowledge that can be cross-referenced with insight from around the world. At a time with such great transformation, and the need for higher education to convert, are the forces of change beyond the adaptive capacity of the present-day university? Furthermore, what might this redesign look like; would it be similar to previous interpretations or fundamentally different in some unique way?

Elegantly-Designed Experiences; Leveraging Design to Foster Transformation

In the already saturated education space, offerings must be thoughtfully designed to entice, capture, and engage savvy digital consumers. In fact, higher education must go one step further toward *elegantly-designed experiences*; consisting of well-reasoned, curated, and high-quality educational assets with prudent content that is aesthetically appealing. Elegantly-designed experiences in the education space are well-thought-out in a proactive and strategic way while engaging deeply with design qualities that are simple, smart, and well-conceived. The energy put forth to create these experiences is valued because of their scalable, reachable, and game-changing potential.

Instead of just using the word *design* to encapsulate what I am articulating, I am drawing on the experiences of others in similar spaces such as instructional design (Parrish, 2005, 2008), cognitive engineering (Norman, 2004, 2013), and design thinking strategists (Brown & Katz, 2011). To broaden and enliven the concept of *design*, I incorporate a few key words to the concept—*elegant* and *experience*. By enlarging the term *design*, and tying it to these other terms, I intend to invoke a grander vision specifically for higher education.

The word *elegant* is calling for more than something that is just pleasing or smart in its physical appearance; it signifies something ingenious and simple, attractive to the user in more than one way. When I use this term, I cannot help but think of Steve Jobs's love of his childhood home designed by Joseph Eichler, who imitated Frank Lloyd Wright's vision and created modern tract homes in the 1950s postwar for working-class families. In a *Smithsonian Magazine* article written by Walter Isaacson (2012), Jobs is quoted as saying, "It takes a lot of hard work, to make something simple, to truly understand the underlying challenges and come up with elegant solutions" (para. 3). The article also explains that Jobs was insistent that Apple products look good on both the inside and outside and blend form and function in harmony. Apple's first marketing brochure headline declared in 1977 that, "Simplicity is the ultimate sophistication," and it is this philosophy that underpins elegant design.

Secondly, I incorporate the term *experience* into this concept. The term *experience* modifies the *elegant* and design because experiences happen and are experienced through us by observation and participation. Parrish's (2009) definition of experience, grounded in instructional design, highlights that "experience describes the

transaction that takes place between individual learners and the instructional environment" (p. 512). Parrish's (2009) definition is an excellent foundation to begin broadening the notion of student experiences in the educational spaces from a relationship between the learner and the instructional space. It should also include the full instructional team that created and developed the learning offering, the future use of an instructional asset, the mechanics, and all the passive and active moments in between. Subjectivity, immediacy, seamlessness, fluid mechanics, and aesthetics are critical qualities of experience that play a significant role in educational occurrences; when these aspects are part of the central focus of design, then the design will also fulfill emotional and sociocultural needs (Parrish, 2009; Wilson, 2005).

Mishra and Koehler (2003) explore the concept of being "design-wise" within the field of educational technology. Throughout their research, they state that designing education through technological driven mediums becomes a conversation, "a mutually constituted negotiation between the developing artifact and evolving conceptions of the designers" (p. 19). Design drives user engagement with products and concepts. It can render complex ideas legible and platforms easy to navigate, or it can add a layer of complexity that may make the experience (and learning) difficult and irrelevant.

The broadening of the term *design* is shared by scholars such as Parrish (2005, 2008, 2009), Wiesenberg and Stacey (2005), Shea-Schultz and Fogarty (2002), and Norman (2004, 2014) among others. This holistic and all-encompassing design concept is actively being worked on by researchers engaged in similar thinking and enlightened and boundary-crossing design firms such as IDEO. Tim Brown, IDEO CEO, and Barry Katz, IDEO Fellow and CAA professor (2011), provide illuminating words that resonate with

my vision: “rather than enlist designers to make an already developed idea more attractive, the most progressive organizations are challenging us [IDEO, a global design company] to create ideas at the outset of the development process. The former role is tactical; it builds on what exists and usually moves it one step further. The latter is strategic; it pulls “design” out of the studio and unleashes its disruptive, game-changing potential” (p. 381). This encapsulates what I am calling for with the concept of *elegantly-designed experiences*.

The complete instructional experience includes project design such as selecting the best delivery mode (e.g., face-to-face, blended, online). This is part of the fully elegantly-designed experience aimed at attracting and satiating learners’ appetite for aesthetically enticing materials while providing increased flexibly to be able to access educational content. Invoking the principle of elegantly-designed experiences is one way to make good on the adaptive capacity of the present-day university and the imminent transformation of higher education. The second is developing and curating boundary-crossing learning topics. While design draws one in and keeps them engaged, aesthetics and seamless technology are only part of the story. Other important elements include content that impacts thinking, increases engagement with the real world, and provides tangible pathways for personal and professional development. It keeps us coming back for more and connects to the intellectual endowment that is learning through one’s life.

The complete instructional experience is interlaced in this vision of elegantly-designed experiences. For example, this includes careful time spent on project design as well as a thoughtful review of visual appeal, visual narrative, attractiveness, or aesthetics. Invoking this principle of elegantly-designed experiences is one way to make good on the

present-day university's adaptive capacity toward the eminent transformation of higher education. The second way is by developing and curating boundary-crossing learning topics.

Transdisciplinary Topics: Sustainability

As Nixon (2004) puts it, "The purpose of any university is not only to bring society back to the questions it needs to ask of itself but to insist that those questions are formulated and addressed …" (p. 247). In line with Nixon's work on higher education's responsibility to create a "good society" and Englund's (2002) work on higher education's obligation to engender democracy and citizenship, in what ways and to what extent can higher education institutions become open and inclusive spaces for encounters between different people, cultures, and different views of *how society works?* Simultaneously, how can higher education institutions also model *the good society* which promoting a visionary safe space to explore these constructs? In short, what kind of knowledge, values, and attitudes should higher education promote in the 21st century?

Thinking about what content, ideas, and constructs should be promoted by higher education requires a glance at who (which publics and actors) would promote or prompt certain ideals. Particular dispositions (character qualities) are intrinsic to those engaged in the academy, including but not limited to dispositions toward truthfulness, respect, and authenticity (Barrick et al., 2013; Englund, 2002; Nixon, 2004). From students and connected publics, to staff and faculty, particular ways of seeing and moving through the world are shaped in large part by higher education's qualities and those character qualities it promotes. But it is more than dispositions, goals of the academy, and motivation to change the world; it is also the social imaginary that higher education is shaping and

being shaped by. Taylor (2004), one of the foremost practitioners exploring this concept, describes *social imaginary* as:

> The ways people imagine their social existence, how they fit together with others, how things go on between them and their fellows, the expectations that are normally met, and the deeper normative notions and images that underlie these expectations. Our social imaginary at any given time is complex. It incorporates a sense of the normal expectations we have of each other, the kind of common understanding that enables us to carry out the collective practices that make up our social life. This incorporates some sense of how we all fit together in carrying out the common practice. Such understanding is both factual and normative; that is, we have a sense of how things usually go, but this is interwoven with an idea of how they ought to go, of what missteps would invalidate the practice (p.23-24).

The shared social beliefs of a given group of people, either top down or bottom up, are part of a public dialog that fosters the social imaginary which Taylor (2004) advances in his work. With the imminent transformation of higher education and particular dispositions intrinsic to those engaged with the field of education, transdisciplinary learning content such as the broad boundary-crossing topic of sustainability is one such novel area for study—which higher education is poised to articulate with authority. Of course, other areas of study that are also multidisciplinary, interdisciplinary, or transdisciplinary (used synonymously throughout this work) similar to the field of sustainability should also be infused and deployed; such as the field of ArtScience (Root-

Bernstein, 2011), or Responsible Innovation (Richter et al., 2019) to name two plausible and complementary examples.

New approaches and ways of thinking are needed to transform our education system and our society (Orr, 2004). To become an educated citizen, one needs to understand complex problems facing our world and be prepared to design and enact creative solutions now, and in the future (Duderstadt, 2009; Weber & Duderstadt, 2008). Higher education is also preparing learners for jobs and professions that have yet to be imagined (Crow, 2018). Leaners must also be more aware of how their individual and collective actions impact the world, from natural to social systems. To accomplish these goals, offering content specific to sustainability is an essential endeavor that higher education can pursue.

The altruistic motivator of making the world a better place through the lens of sustainability illuminate the way in which higher education can be transformed and is aiming to transform society. Sustainability acknowledges the interconnectedness of the vast array of challenges, solutions, and successes enmeshed in our human experience. Likewise, the goals and means of sustainability are in line with the dispositions of those engaged in the academy and of the social imaginary that is deeply rooted.

Sustainability is an ideal, a goal, and an endeavor. It is an ideal worth pursing as sustainability promotes the goals of creating fair, equitable, and positive changes for our communities, societies, and the world as a whole. It "aspires to link knowledge to social actions that advance visions of natural and social well-being" (Miller, 2013). Duderstadt (2009) emphasizes, "As both a reflection and leader of society at large, the university has a unique responsibility to develop effective models of multicultural, pluralistic

communities for our nation. We must strive to achieve new levels of understanding, tolerance, and mutual fulfillment for peoples of diverse racial and cultural backgrounds both on our campuses and beyond" (p.18). These described responsibilities of the university are necessary for comprehensively understanding the host of issue before humanity and are intrinsically linked to sustainability. As a goal, sustainability aims to improve human well-being, promote equality, and reduce hunger and poverty (UN Sustainable Development Goals, 2020). It requires that society at large is ever mindful of the simultaneous need to minimize ecological damage and resource depletion. Sustainability calls upon humanity to pay particular attention to the Earth's natural limits when making decisions that impact people today and in the future. As an endeavor, sustainability activities tend to be vivid (e.g., people protesting), analytical (e.g., scientists in a lab), and action-oriented (e.g., a food drive). Change is born from these types of efforts. However, can society take a more responsible, thoughtful approach toward solving sustainability challenges through education? If sustainability is focused on the future, society needs tools, new ways of thinking, and ways to approach challenges. In turn, higher education can provide these new ways of thinking, being, and doing in the world and provide access, especially through public research institutions, to educate society as a civic responsibility (Crow & Dabars, 2015; Duderstadt, 2009; Ehrenberg, 2012). Sustainability knowledge spanning all areas of the field, which are elegantly-designed to draw learners in, is one such transformational perspective that higher education is posed to deploy with authority and promote through all of its learning avenues.

Of course, sustainability aims, efforts, and executed plans are not without their flaws. The widely known depiction of 'sustainability' employs three interconnected pillars and suggest harmony if all are in balance. This problematic three-pillar Venn diagram (social, economic, and environmental circles), which is ubiquitous with sustainability, aims to create logical relationships between inputs and outputs within each circle and signify that all three are in balance, then sustainability has been achieved. This diagram fosters false relationships and oversimplifies complicated relationships. Purvis, Mao, and Robinson (2018) conducted a detailed review of this diagram's origins and have yet to find a theoretically rigorous description of the three pillars. These scholars believe, "the absence of such a theoretically solid conception frustrates approaches towards a theoretically rigorous operationalization of *sustainability*" (Purvis, Mao, & Robinson, 2018). Beyond visioning issues linked to inputs and outputs, sustainability problems and identified solutions tend to take on neo-colonial perspectives and often involve European (intellectual or social) solutions. One such example can be explored through the lens of sustainability and agricultural practices. The use of genetically engineered crops, fertilizers, herbicides, mechanized farming, and irrigation practices is often cited as the gold standard of farming solutions. Other methods that aim to invoke traditional ecological knowledge are often discounted (Glasson et al., 2010). Beyond some of the blind spots associated with sustainability, there are also terminology issues that make traversing through the content confusing such as the competing language of 'sustainability' and 'sustainable development' (Purvis, Mao, & Robinson, 2018). Other known issues are linked to intrinsic questions of sustainability for whom and for what,

which bolster the argument presented by Brown (2016) and others that sustainability is, in fact, an empty signifier.

Even with the described complexities associated with sustainability, the overarching goal of making the world place mindful of and through human action makes sustainability one such lens worthy of deploying widely. With the changing role and impact of higher education, the need to create elegantly-designed learning experiences, and using sustainability as an interdisciplinary topic to curate instructional experiences that impact thinking, this dissertation follows a three-article format, presented in Chapters two through four, followed by implications discussed in Chapter 5. Each subsequent chapter is described below.

Chapter 2 explores the conceptual framework for a general audience on sustainability. The Sustainability Education Framework for Teachers (SEFT) seeks to build capacity for educators—who are seen as a general audience of learners—to be able to understand: (i) the broad, complex nature of sustainability, (ii) the problem-oriented, solution driven nature of sustainability, and (iii) how sustainability connects to them as both citizens and educators (Warren et al., 2014a). While this section develops a concept focused on educators, these lenses have proven to be understandable and malleable enough for other users from other sectors such as engineering education (Dalal, 2019) to textbook publishers (MGIEP, 2017). The four lenses—futures, systems, strategic, and values thinking—require considering critical inquiries related to societal values, equity, and visions of the future; unpacking the status quo; and exploring and articulating pathways and plans towards a sustainable tomorrow.

Chapter 3 examines Sustainability Science for Teachers (SCN 400), a required course in the Mary Lou Fulton Teachers College at Arizona State University. This semester-long hybrid course is designed to enable future teachers to engage in sustainability principles while developing their understanding of science from the human perspective in which an issues-based curriculum underpins social and biospheric responsibility (Hale et al., 2017). While SCN 400 spans fifteens weeks of content as part of a semester-long course, this particular research centers on the course's *water* unit. The water unit is explored as a case study which demonstrates the melding of sustainability and geoscience to engage educators in a more nuanced understanding of science education. A description of the course curriculum is presented, and its design process is explained. This is followed by a cross-sectional analysis of student outcomes. Data from preservice elementary classroom teachers (the enrolled population of learners in the course), as well as course alumni, were collected over a 4-year period. A mixed methods evaluation of teachers' perceptions and artifacts indicated that the unit on water facilitated the development of new understanding and new ways of thinking. Opportunities and challenges for fusing geosciences, sustainability concepts, and preservice teacher education in a novel and impactful fashion are discussed.

Chapter 4 investigates the redesign of higher education. Higher education institutions are being called to discover more effective and efficient ways of preparing learners of all types and at all stages. Redesigning higher education involves a complex set of actors, actions, and artifacts to convert established ways of providing educational experiences to a multiplicity of new ways to serve those desiring to learn (Hale et al., 2020). What lessons can higher education change agents, leaders, and engaged publics —

those fostering and leading transformation learn from those working to transform higher education to be more than it is currently? Through a case study approach and a narrative analysis, ten categories were identified through a close review of collected data from ten participants. Recommendations from the findings included clarifying the purpose and using transparent terminology for both implementers and learners as well as figuring out ways to help learners navigate learning pathways.

Chapter 5 concludes with a brief synthesis of the overarching story from Chapters one through four. It speculates on the implications of the inclusive transformation of higher education and considers how this line of inquiry continues into my present portfolio of research and future plans. I briefly describe a 2020 grant from the U.S Embassy in Kosovo titled, *Creating a Kosovo Educator Course; Integrating Education for Sustainability into the Classroom*. This online professional development course is an example of extending the reach of higher education offerings to new audiences through elegantly-designed instructional experiences that incorporate the topics of sustainability, the Four Ways of Thinking, and digital storytelling to engage the learner. The project requires cultural context restructuring and translation support through partnership, and it represents the power of higher education to transform society.

COVID-19: A Rapid Response by Higher Education

Before moving forward, it should be noted that the COVID-19 pandemic has further revealed the urgency of understanding these challenges and opportunities to higher education. While many sectors will rebound in a similar form and function to what they were before the pandemic—others will perish altogether. Higher education has already fundamentally changed very quickly out of necessity. Some universities have

suspended admissions while others, such as the San Francisco Art Institute, have plans to close permanently, citing COVID-19 as the final breaking point in the college's financial situation (Whitford, 2020). In contrast, some higher education institutions have quickly reimagined their courses to entirely online or blended offerings that can easily convert back and forth as the crisis dictates. The need for higher education to transform to include additional flexibility in modality, including when, where, and how students access educational content, has never been more critical. The full scope of changes is currently unfolding, and it is necessary to continue exploring the implications relevant to this work and future areas of study.

Beyond the rapid response to alternative teaching and learning, higher education institutions have also been instrumental in the scientific response to COVID-19. Universities in the State of Arizona have quickly responded to community and state needs through research, development of technological solutions such as testing, and strategic responses to community spread management that has been vital to crisis response workers, the re-opening of educational institutions, and the state's economy. Arizona Governor, Doug Ducey, announced in late September 2020 that $14 million for research and development (R&D) would go to Arizona's universities for additional testing research; $6 million of the R&D dollars would specifically support Arizona State University to develop an at-home test and expand testing across the state (Galka, 2020).

Both the quick pivoting educational and scientific R&D responses response did not happen randomly; long term investments and strategic planning laid the foundation for these types of desperately needed community responses. Looking at the Arizona Board of Regents Technology and Research Initiative Fund (TRIF) report for the fiscal

year 2020 describes the types of long-term research investments established in partnership with the universities and the communities they aim to serve. For example, TRIF funded research, and scientists in the Biodesign Institute at ASU quickly pivoted automated diagnostic technology to create the successful saliva-based COVID-19 test, which is now widely in Arizona at the university and in the state (Arizona Board of Regents, 2020). Similarly, Arizona State University partnered with Arizona Public Service (APS), the largest electric utility in Arizona, to ensure essential employees could be frequently and safely tested to maintain a healthy workforce. ASU is actively working with APS to improve the testing process and maintain worker safety and health.

These activities and relationships highlight the rich affordances of a strategic investment into higher education and illustrate how a transformative redesign can continue to and further develop supportive structures that uplift the publics in which higher education institutes serve. COVID-19 has amplified this dissertation's importance and speaks to the relevance of the ideas put forth in the chapters that follow. The types of skillsets, mindsets, and infrastructural investments (scientific, educational, virtual, etc.) higher education institutes invest in now will serve our communities well into the future. Higher education institutes are poised to craft bold, strategic, and inclusive visions of tomorrow.

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CHAPTER 2
SUSTAINABILITY EDUCATION FRAMEWORK FOR TEACHERS: DEVELOPING SUSTAINABILITY LITERACY THROUGH FUTURES, VALUES, SYSTEMS AND STRATEGIC THINKING

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Abstract

The Sustainability Education Framework for Teachers (SEFT) intends to build a capacity for educators to be able to understand: (i) the broad, complex nature of sustainability, (ii) the problem-oriented, solution driven nature of sustainability, and (iii) how sustainability connects to them as both citizens and classroom teachers. SEFT embraces Four Ways of Thinking—futures, values, systems, and strategic which are conceptualized as being bi-directional and interconnected. The framework aids in linking sustainability topics that are seemingly disparate to the novice teacher population by building upon knowledge, skills, and attitudes necessary for problem-solving with respect to complex sustainability challenges. Imagined as a conceptual framework, it offers organizing principles for examining and considering sustainability problem/solution constellations in a coherent fashion. The framework provides the opportunity for self-reflection and independent enquiry by considering and learning through real world foci.

Likewise, SEFT offers a logical framework for working in interpersonal, intragroup, and

intergroup situations. The four lenses require considering critical inquiries related to societal values, equity, and visions of the future; unpacking the status quo; and exploring and articulating pathways towards a sustainable tomorrow.

Introduction

Educating the next generation on pathways toward a more sustainable way of life is of paramount importance. To accomplish this goal, teachers are a vital population with whom to work, and sustainability topics must be woven into teacher education and preparation programs (Nolet, 2009). Engendering a more informed teacher requires translating major sustainability challenges and solutions in a meaningful way together with articulating a deep concern for meeting people's needs, intergenerational equity, caring for the world's poor, and safeguarding the Earth's regenerative capacities (Our Common Future, 1986). Scholars have broadened this understanding to encompass environmental concerns more specifically through science and to denote the ecological relationships that exist between human-nonhuman and flora-fauna-land interactions (Kates et al., 2001; Orr, 1992). To confront these problems, evaluate solutions, and deal with growing inequities, education must be a central component to improving the human condition. A key focus must be on preparing the next generation to make informed decisions, challenge the status quo, and identify problems, as well as solutions.

Attending to populations with the potential of having the most catalytic effect is essential to the goals of sustainability. Teachers, their roles in schools, and society at large can work toward significant change for the better. Accordingly, to prepare teachers to take on this challenge, education and training are essential components that must be addressed, evaluated, and improved to meet this need (Nolet, 2009). Our Common

Future, the Report of the World Commission on Environment and Development (1987) states that, "the world's teachers have a crucial role to play" in helping to bring about "the changes in attitudes, in social values, and in aspirations related to and required for the longevity of our planet (p. 8). Furthermore, Our Common Future highlights that these changes will play out in the public sector through deliberate education and public engagement. Teacher preparation programs must answer this call and work toward a grander vision of preparing educators both as citizens and future leaders to enter a changing world and civic space where problems and solutions related to sustainability are seen as essential (United Nations Education, Scientific, and Cultural Organization, 2004).

For purposes of this paper, we shift from the current discourse on sustainability definitions and overarching sustainability competencies to a more teacher-focused and profession-specific vision for sustainability literacy. We highlight and explain the Sustainability Education Framework for Teachers (SEFT) in an effort to rapidly accelerate, inculcate, and prepare teachers with the goals of sustainability through a fundamental shift and transformation in the way they act, think, and engage with the world around them. The framework aids in linking sustainability topics that may seem disconnected to the novice teacher population. It does so by building upon knowledge, skills, and attitudes necessary for problem-solving with respect to complex sustainability challenges. The goal of the framework is to build a capacity for teachers to be able to approach: (i) the broad, complex nature of sustainability, (ii) the problem-oriented, solution driven nature of sustainability, and (iii) how sustainability connects to them as both citizens and classroom teachers. The remainder of this paper outlines the Sustainability Education Framework for Teachers and addresses examples of how it can

act as an organizing and motivating structure for exploring and operationalizing sustainability literacy as one of several core literacies for teachers. Each element of the framework is defined and includes related abilities and possible teaching strategies. An informative and detailed video accompanies each lens and is meant to act as valuable visual material to further enhance the conversation on sustainability literacy and the framework itself while sharing information in a variety of formats (e.g., textual, visual, auditory with closed captions including descriptions of the visual images).

Sustainability competencies and literacy

Overarching and general sustainability competencies have been researched, articulated, and evaluated by the field in recent years (see Wiek, Withycombe-Keeler & Redman, 2011). As described by Wiek et al. (2011), general sustainability competencies take the form of bullet point lists which aim to describe unifying themes, concepts, ideas, capacities, abilities, beliefs, behaviors, and knowledge sets that are required to move towards a greater vision of sustainability. The term competency refers to a wide set of skills, abilities, and behaviors that in theory should be measurable and observable. Currently the field is grappling with which sustainability competencies are the most valuable, justifications as to why certain competencies are essential, and ways to measure each competency. In this paper, we shift the conversation away from sustainability competencies to focus on sustainability literacy for teachers. This articulation provides a transition to a more teacher-centric and profession-specific vision of sustainability (Bertschy, Kunzli, Lehmann, 2013; Church & Skelton, 2010; Cortese, 2003; Nolet, 2009; Sipos et al., 2008; Wiek et al., 2011).

The concept of literacy fits well when considering and working with teachers. While there is a subtle difference between competency and literacy, and the terms are often used interchangeably, we believe that professional programs for teachers should consider sustainability literacy among other literacies such as math literacy/numeracy and language literacy. These key literacies and overarching profession-specific skills such as classroom management add up and embody the necessary abilities teachers must encompass for their field. Literacies suggest a collection of skills that, once achieved and formed, can manifest a particular level of competence that can be measured in the future. We use the term literacy as, "a collection of skills that allow for effective participation and influence in diverse areas of social life" (Stibbe & Luna, 2009).

Nolet (2009) defines sustainability literacy as various abilities and subsequent actions such as problem-solving and informed decision-making. Likewise, the concept of sustainability literacy is described by Tilbury (2011) as more than conveying new knowledge and, ― also means learning to: ask critical questions envision more positive futures clarify one's own values; think systemically; respond through applied learning opportunities; and to explore the dialectic between tradition and innovation (p. 13). Once teachers gain sustainability literacy, they become empowered to (a) approach society with a critical lens; (b) teach sustainability topics and ways of thinking to their students; (c) make informed decisions; (d) contribute to re-thinking intrapersonal, interpersonal, intragroup, and intergroup conceptions of society and the environment (Bertschy et al., 2013; Nolet, 2009; Stibbe & Luna, 2009). Along with other key literacies, teachers should be able to infuse sustainability literacy into their daily instruction and across the curriculum (Santone et al., 2014).

Sustainability Education Framework for Teachers (SEFT)

While scholars have worked in the area of sustainability literacy and with sustainability competencies in general, a clear coherent framework for both preservice and inservice teachers has yet to be clearly defined. We propose the SEFT, which aims to support the development of sustainability literacy that builds upon existing work (Bertschy et al., 2013; Nolet, 2009; Stibbe & Luna, 2009; Tilbury, 2011; Wiek et al., 2011) and answers the call for more specific engagement by educators. SEFT aids in linking sustainability topics to existing curricula that may seem unrelated to the novice sustainability teacher population by constructing knowledge and dispositions necessary for problem-solving complex sustainability challenges. While distinct sustainability content areas such as water, food, energy, poverty, population, ecosystem services, production, and disposal may appear disconnected, our framework seeks to operationalize the interconnections between and among sustainability-related topics. This framework provides a landscape in which teachers can situate sustainability content knowledge, pedagogy, and craft meaningful evaluations.

SEFT embraces Four Ways of Thinking—futures, values, systems, and strategic––which are more than just a list of steps or sets of knowledge that must be acquired. Instead, they are a conceptual framework for analyzing and considering sustainability problems and solutions through a networked approach. These specific Four Ways of Thinking were identified after extensive conversations with sustainability and education experts, reviewing the existing literature, and considering how to prepare teachers meaningfully to take on the role of educating for sustainability. While these Four Ways of Thinking are discussed across the literature in general, they are typically considered in

isolation, articulated in a dispersed fashion, and/or examined with complex terminology (Wiek et al., 2011; Stibbe & Luna, 2009; Bollmann-Zuberbuhler et al., 2014). Highlighting and clarifying these Four Ways of Thinking provides an opportunity to strengthen a more robust inquiry of sustainability topics, content, pedagogy, and evaluation. While each of these ways of thinking are presented in a specific order in this paper, they should be considered in parallel as they are conceptualized as being bi-directional and interconnected. Likewise, the logical entry point in the framework presented is dependent upon the problem and/or solution being questioned or observed. Intentionally, this framework is not represented with an accompanying Venn diagram because that type of visual representation may limit creative uses of the framework, create a false sense of overlap, and/or suggest a specific procedure for a given context that was not intended. In addition, SEFT is not meant to be prescriptive. The ways of thinking can be implemented in conjunction with one another or used individually after careful consideration of the topic has taken place.

SEFT provides the opportunity for self-reflection and independent enquiry by considering and learning through real life issues (Stibbe & Luna, 2009). The framework offers a logical method for working in interpersonal, intragroup, and intergroup situations. The four lenses may be used in a variety of ways. They require considering critical inquiries related to societal values, equity, and visions of the future; unpacking the status quo; and exploring and articulating pathways towards a sustainable tomorrow. The strength of the framework is that it requires considering other people, places, times, and spaces beyond the universe of just one person. It is about structuring knowledge(s) and mapping out a plan to address a particular situation through a problem/solution

constellation that exists at a variety of temporal scales (Wiek et al., 2011).Through the framework, we are proposing that teachers as both citizens and educators must be able to understand, evaluate how, and take action on the following notions:

- Observed symptoms are the result of cascading effects linked to interconnected systems (Meadows, 2008);
- Values connected to over-consumption and inequitable distribution of resources is creating conflict (Ostrom, 1990);
- Human-caused environmental damage to the biosphere and local ecosystems is threatening the viability of future human generations (Rockstrom et al., 2009); and
- Solutions to sustainability challenges must consider trade-offs and be constructed strategically to maximize benefits and ameliorate negative unintended consequences (Costanza, 2011; Gibson, 2006).

Making use of the framework and working through these sets of problem/solution constellations leads to achieving sustainability literacy. Each of the Four Ways of Thinking are described in the following section.

The Four Ways of Thinking: Building sustainability literacy

Futures Thinking.

Futures thinking is also known as anticipatory thinking, foresight, or trans-generational thinking. Sustainability requires future thinking. It includes, "the ability to collectively analyze, evaluate, and craft rich 'pictures' of the future related to sustainability issues and sustainability problem-solving frameworks" (Wiek, et al., 2011, p. 208-209). Futures thinking integrates the ability to think systematically about the

future and future generations. In seeking sustainable solutions, stakeholders, policy makers, innovators, and citizens need consider how past decisions led us to the crises we face today. We need to anticipate and imagine how today's solutions could introduce negative cascading effects and become tomorrow's problems. Likewise, we need to work through plausible scenarios of the future that can lead to safer, happier, and healthier futures, and work to achieve these futures today. Futures thinking works to answer the question, where are we headed? Futures thinking allows for anticipatory approaches to understanding, mitigating, and/or adaptively preparing for future changes, problems, and solutions (Gibson, 2006). Evaluating how unexpected events, such as hurricanes or newly enacted policies, could change our future plans is a necessary element of this type of thinking. Futures thinking challenges us to become more flexible the further into the future we envision. The longer the amount of time between the present and the future, the more uncertain a particular future may be. Thinking about the future requires understanding and being comfortable with uncertainty. Sustainability necessitates learning from the past, exploring the present, thinking about the future, and developing solutions that are adaptable and resilient. Futures thinking includes the ability to:

- Discuss how people in the past affected our options today, and how we now affect the options of people in the future (Our Common Future, 1986)
- Anticipate the potential future consequences of inaction in the present, often referred to as the 'no-action' scenario
- Envision desired futures and contrast them with the present status quo as a means to build strategies or backcasting (J. Robinson et al., 2011)

- Recognize emerging trends and their potential future trajectories (D. Robinson et al., 2011)
- Imagine a diversity of futures based on change in one or more dynamics or variables (Selin, 2007)
- Recognize different theories of how futures emerge (Kuhlman, 2001)
- Consider that futures are aspirational, and create futures instead of accepting futures (Newman & Jennings, 2008)
- Cope with the potential unintended consequences of interventions, ideas, and/or solutions we fabricate through adaptive management (Norton, 2005)
- Conceptualize different aspects of futures:
    - Utopian (ideal) or dystopian (repressive)
    - Possible futures (plausibility)
    - Probable futures (likeliness)
    - Value-laden futures (desirability, sustainability)

Educators should consider the broad range of plausible futures so that we can educate society to envision and create a more sustainable tomorrow. Futures thinking in the classroom by beginning to engage students with multiple possible outcomes of decisions and actions. Students can journal about the variety consequences associated with the choices they make, and teachers can push students to engage beyond the obvious first choice answers. Another idea is to make use of scenarios in the classroom. Scenarios are a tool that teachers can implement to help students think about how the future might unfold. Scenarios can take many forms beyond a written format such as visual, auditory,

embodied, kinesthetic and/or verbal. Students can work in groups developing alternative ends to stories they are currently reading or discuss and map out a range of possible outcomes. Thinking about the future also requires an understanding of the past. Knowing where decisions and outcomes originated from can support projections into the future. Teachers can guide students as they conduct a macrohistory, seeking patterns of change, or consider historical trends. Futures thinking asks teachers to explicitly address multiple futures and prepare students to ask questions, think critically about the past, challenge the status quo, and envision tomorrow on a variety of time scales.

Values Thinking.

Values thinking is also known as value-focused thinking, orientation thinking/knowledge, and/or ethical thinking. Because sustainability is a field that is problem-oriented and solution driven, potential solutions require values thinking. This includes, ―the ability to collectively map, specify, apply, reconcile, and negotiate sustainability values, principles, goals, and targets (Wiek et al., 2011, p. 9). To use values thinking involves concepts of justice, equity, social–ecological integrity, and ethics. It also means understanding how these concepts vary across and within cultures, and how integrating these concepts contributes to solving sustainability problems. According to Veugelers (2000), "Developing skills to analyze values and to communicate them is necessary to show students that values are constructs and that people can make choices for certain values" (p. 9).

Due to the complex problems the world faces such as poverty, access to nutritious food and clean water, and our current energy crisis to name a few; solutions cannot arise from a single group or discipline. Rather, solutions need to borrow insights from many

fields and areas of expertise to understand nature and our interaction with it. Another essential element for values thinking is to consider how our current problems and possible solutions impact a variety of different people. Solutions must be fair to concerned stakeholders and should be transparent to be equitable. Just as the development of sustainable solutions should involve everyone affected, solutions should not just benefit a single person or group. Values thinking includes the ability to:

- Assess a problem and its context comprehensively
- Describe how justice, equity, and social-ecological integrity vary across and within cultures (Holifield, Porter, & Walker, 2010)
- Determine how integrating justice, equity, and social-ecological integrity impact solving problems (Holifield, Porter, & Walker, 2010)
- Specify, negotiate, and apply values, principles, and goals while recognizing multiple viewpoints from others (Kurtz, 2008; Rolston, 1994)
- Articulate and work through preconceived notions (Rawls, 1985)
- Ensure group consensus is not achieved by limiting stakeholder involvement (Fischer, 1993; Corburn, 2007; Bäckstrand, 2003)

To explore values thinking in the classroom, teachers can help students seek different points of view, as well as explore their own feelings and values on various issues. Teachers should demonstrate and exhibit a strong sense of fairness and social justice in the classroom as a model for performance beyond the classroom. This can be accomplished through discussions in which students have the opportunity to ask questions, clarify and analyze their values, and explore others' values in a safe space.

Students should work through techniques on active listening/participation and role-play to allow them to view issues from different points of view. Teachers can also engage students in values thinking through the use of debates and discussions in the classroom. In addition to role-playing and debates, students should be able to ask clarifying questions and explore how values operate in a range of contexts that might not be initially transparent. Teachers should be sensitive to students needs and make sure topics are appropriate for the grade level, culture, and the community in which they are located.

Systems Thinking.

Systems thinking is also known as interconnected thinking or holistic thinking. According to Wiek et al. (2011), systems thinking is the ability to collectively analyze complex systems across different domains (society, environment, and economy) and across different scales (local to global), thereby considering cascading effects, inertia, feedback loops, and the other systemic features related to sustainability issues and sustainability problem-solving frameworks (p. 7). Systems thinking does not claim complete knowledge. Rather, systems thinking is about assessing the degree of system complexity and analyzing system dynamics to make informed decisions that reduce the risk of negative outcomes.

Systems thinking requires that we capture, begin to understand, and recognize that a system is a configuration of parts connected and joined together by a web of relationships, flows, and/or networks, some of which might not be readily transparent. Systems thinking is non-linear. This means that in systems thinking, cause and effect are not necessarily linked or connected with simple step-by-step chains. While sociotechnical events may be separated by place, time, and distance, systems thinking can illuminate

how incremental changes can invoke large complex changes in other systems. Connections between human and natural systems are of particular interest, because they offer excellent examples of cascading effects, illustrating that what might seem to be a simple outcome of a given system can actually have a series of effects on other interconnected systems. With systems thinking, it is important to unpack the interconnected nature of all elements and to understand that reacting to a problem in one part of the system may have unintended consequences on other components or the process as a whole. Systems thinking includes the ability to:

- List system components, denote flows in particular directions, and map out systems as needed (Meadows, 2008)
- Assess degrees of system complexity (Casti & Karlqvist, 1986)
- Analyze systems with a holistic perspective (Wheeler, 2014).
- Conceptualize diverse interconnections between systems
- Recognize system dynamics, cascading effects, feedback loops, and system states (Meadows, 2008)
- Recognize patterns and underlying relationships among problems and possible solutions (Grunwald, 2004)
- Describe intentionality, systemic inertia, path dependencies, barriers, and alliances

To support systems thinking in the classroom, teachers can help students explore how things might change under different circumstances. Games and models are a great tool to demonstrate this relationship of change under different circumstances. Teachers

should encourage students to look at possible associations and connections beyond what is specifically being studied. This is so they can seek possible explanations of these relationships and realize how these systems often directly impact one another. Students should be actively looking at possible associations and connections beyond the information that is being presented. Teachers can have students review case studies or current news stories to identify transparent and hidden connections. Teachers might consider conducting an institutional analysis, which includes a robust review of existing practices, mechanisms, and procedures currently in place. For example, a classroom project might be unpacking and exploring how food gets to the local grocery store or how specific products relatable to students are produced. Students should actively share findings with their peers and discuss as a class both hidden and visible flows. Teachers should move between local and global examples as a way to highlight the interconnected nature of the world around us.

Strategic Thinking.

Strategic thinking means being able to develop a strategy or a plan to achieve a particular vision. Strategic thinking frames every decision by how it contributes to achieving that vision. Strategic thinking is, ―the ability to collectively design and implement, interventions, transitions, and transformative governance strategies toward sustainability (Wiek et al., 2011, p. 210). It involves considering possible solutions under a given certain set of assumptions, articulating potential alternative solutions, and challenging existing assumptions and alternatives, potentially leading to new solutions that may be more appropriate (Lawrence, 1999). Strategic thinking involves using analogies and qualitative similarities to create new ideas in addition to developing a

course of action dependent on new learning (Lawrence, 1999). This means finding creative ways to solve the critical problems of our time and understanding and working to reduce inequalities. Strategic thinking involves finding opportunities for creativity, innovation, and learning, as well as creating new institutional frameworks for collaboration and better governance. One common stumbling block to strategic thinking is the status quo. The current state tends to exert a lot of influence over future states and can result in path dependency where our current state sets a path for the future. Good strategic thinking takes path dependency into account and can even turn it into an asset or an advantage. Strategic Thinking includes the ability to:

- Recognize the "big picture" (e.g., overall themes, trends, goals) in light of specific, local problems and solutions
- Design interventions that address sustainability problems at multiple temporal scales (Loorbach, 2007)
- Anticipate and build contingency plans for potential unintended consequences by making good use of anticipatory governance (Guston, 2014)
- Create intervention strategies to avoid undesirable scenarios and realize sustainable visions (Kemp & Rotmans, 2005)
- Collaboratively design and work to implement interventions/solutions that address sustainability problems
- Comprehend the impact of local problems on the global scale, and vice-versa (Geels, 2010)
- Describe viability, feasibility, efficiency, and efficacy of systemic interventions

Educators can develop strategic thinking with their students by making use of inquiry-based and project-based instruction such as designing, testing, evaluating, and adapting policies, programs, and action plans with their students. This can range from outlining a plan to collect food for a local shelter to suggesting a new after-school program at their school. Strategic thinking can be clearly conveyed in a meaningful way to students when working with real-world problems and solutions. Therefore, it is important to recognize that strategic thinking must be practiced live with real-world situations to achieve the particular cognitive activity that is required for this way of thinking. This type of thinking engages students as productive citizens who have ideas that can be implemented meaningfully with care and well-crafted plans.

Providing opportunities for students to challenge the status quo, keep an eye on the big picture, and reflect on every step while evaluating their personal progress as well as the group's progress is key for strategic thinking. Because this way of thinking is focused on having a vision and working to make it a reality, games and puzzles can be of good use for students to work on strategic thinking. Teachers should encourage students to move beyond the idea of winning as the ultimate result. Rather, strategic thinking is about the process, evaluation, and anticipation of the need to develop and deploy contingency plans for potential unintended consequences of choices previously made. By doing so, teachers can discuss, review, and map out design intervention strategies with their students to avoid undesirable scenarios and to build the necessary knowledge and skills to be able to create meaningful change.

Illustrative videos

Provided as a rich visual resource to complement and promote these descriptions, abilities, and possible teaching strategies are four brief videos on each way of thinking. These videos are made freely available for wide dissemination and use. Articulating the framework in written, auditory, and visual formats is of particular interest for capturing practical use by both scholars and educators alike. The accompanying videos are meant to act as supplemental material to further enhance, explain, and ignite the conversation on sustainability literacy and the Four Ways of Thinking: futures, values, systems, and strategic thinking as presented by the Sustainability Education Framework for Teachers (see the following link for more accompanying information on SEFT). The videos provide easy to follow narratives and examples related to each way of thinking in addition to presenting graphic indicators that capture the essence of these ideas. From text to videos, concepts related to sustainability must be shared in a variety of capacities to achieve maximum effect with minimal barriers.

Implications

The need for integration with sustainability as part of teacher education and professional development is an essential component that is largely being overlooked (Carney, 2011). Although preservice teachers have expressed an openness and enthusiasm regarding infusing sustainability topics in their classrooms, they are often not addressed in existing teacher education coursework (Carney, 2011). As Nolet (2009) writes, “In the United States, educational leaders, particularly those concerned with the preparation of teachers, have yet to respond meaningfully to the issues of over-

consumption, human-caused environmental damage, and the global and human catastrophe we are creating" (p. 411).

To address this need, SEFT was developed to assist teachers with developing sustainability literacy so they are better prepared to produce globally-minded and knowledgeable citizens. This includes being able to address issues from an intergenerational perspective, embrace stewardship, challenge the status quo, identify the need social justice and fair distribution, respect limits, appreciate the importance of local place, understand the need for economic restructuring, see nature as a model and a teacher, and identify with global citizenship as part of their curriculum (Nolet, 2009). In addition, teachers need to be able to take a global perspective to encourage their students to see that issues, people, cultures, and places are interconnected and that complex systems operate on a variety of transparent and hidden levels. Likewise, teachers need to impart critical thinking skills, which are directly linked to decision-making capabilities (Church & Skelton, 2009).

Teachers must spend time grappling with the SEFT approach and deploying the process with their own thinking before they can make good use of it as an educator. Once teachers have a better understanding of SEFT, they can begin implementing the approach as described in their classrooms at their specific grade level. Through the framework, teachers will be able to become more nimble with the problem-oriented, solution driven nature of sustainability and how sustainability connects to the curricula they are already teaching in a seamless fashion. The Four Ways of Thinking described by SEFT offer a way to synthesize and evaluate the many facets of the complex and interdisciplinary field of sustainability in a significant yet unobtrusive fashion in the classroom. Utilizing the

framework creates an inquiry-based approach to problem-solving (Bybee, 2002) that leverages student curiosity and promotes search and discovery skills. Because this framework is meant to act as a landscape in which to situate new knowledge and ideas, teachers of all grade levels can make use of it with their students. SEFT can be implicitly incorporated in lesson plans or activities and/or teachers can use the framework to evaluate new materials for their students. SEFT offers four lenses that work together to support a better understanding of the world we live in today and the one we desire in the future.

Conclusion

SEFT provides a landscape in which new knowledge about sustainability can be situated. This conceptual framework articulates concrete abilities and teaching strategies for linking pedagogy and learning to the goals of sustainability literacy. SEFT can provide a rich insight into key elements that should be infused into education for sustainability. It can also serve as a guide for meaningful assessment and evaluation of sustainability units, lesson plans, and activities. The authors' approach provides a unique attempt at articulating, mobilizing, and implementing sustainability literacy for the educator audience in a succinct and coherent fashion. The framework embodies the knowledge, skills, and attitudes necessary for problem-solving with respect to complex sustainability challenges. It clearly outlines the aim of sustainability literacy in both written and visual format with the provided videos (SEFT). Our hope is that by leveraging and implementing the framework in the classroom, teachers will be able to introduce vital issues to the next generation of decision-makers, enabling them to face key sustainability challenges of the 21st century.

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CHAPTER 3
INTEGRATING GEOSCIENCE AND SUSTAINABILITY: EXAMINING SOCIO-TECHNO-ECOLOGICAL RELATIONSHIPS WITHIN CONTENT DESIGNED

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Abstract

Coupling the study of sustainability with geoscience may enable students to explore science in a more sophisticated way by examining the social–technological–ecological relationships that exist between human–nonhuman and flora–fauna–land interactions. Elementary educators are a population capable of making these issues come to life for today's youngest citizens, who will ultimately become tomorrow's changemakers. This study explores Sustainability Science for Teachers, a semester-long hybrid course designed to enable future teachers to engage in sustainability and science concepts while developing their understanding of science from the human perspective and in which an issues-based curriculum underpins social and biosphere responsibility. The course's Water unit is explored as a case study of the melding of sustainability and geoscience to engage teachers in a more nuanced understanding of science education. The unit's curriculum is presented, and its design process is explained, followed by a cross-sectional analysis of student outcomes. Data from preservice teachers enrolled in the course, as well as course alumni, were collected over a 4-year period. A mixed methods evaluation of teachers' opinions and products indicate that the Water unit facilitated the development of new understanding and new ways of thinking about

teaching their future students. Opportunities and challenges for fusing the geosciences, sustainability concepts, and preservice teacher education in a novel and impactful fashion are discussed.

Introduction

Sustainability science and geoscience are intertwined disciplines. Geoscience integrates vast expertise in Earth- system behavior at the interfaces of the geosphere, atmosphere, hydrosphere, cryosphere, and biosphere. From locating and identifying fossil fuel resources to calculating underground aquifer capacities, the field of geoscience works to better understand and render legible the Earth processes that shape and reshape the world we live in and manipulate for human gain. Sustainability science concerns itself with people, the planet, and production systems in an overlapping fashion. Aiming to be future oriented, sustainability is guided by the goal of "meet[ing] the needs and aspirations of the present without compromising the ability to meet those of the future" (Our Common Future, 1987, p.11). Sustainability science is concerned with improving human well-being and is ever mindful of the simultaneous need to minimize ecological damage and resource depletion, especially over longer timescales. It requires that we pay attention to Earth's natural limits as identified in geoscience when making decisions that affect people today and, in the future, (Our Common Future, 1987; Orr, 1992; Kates et al., 2001). When explicitly coupling geoscience and sustainability narratives, sustainability goals and concepts focus on the social–technological–ecological relationships that exist between human–nonhuman and flora–fauna–land interactions. For example, when studying water with these two domains, it is necessary to explore both the natural water cycle and the variety of human-managed water systems that are in place.

These reinforce each other and illuminate various concepts, values, ideas, and questions that are necessary for a complete picture of the world we live in and the one we plan for.

The geoscience and sustainability science fields are also complementary, because both fields focus on holistically examining and understanding large and complex environmental systems. While the field of geoscience examines the ways that Earth's physical components are integrated, sustainability science explicitly brings in social and political components regarding the future of resource development and distribution on scales from the local to the global. These two fields support a critical need to plan and develop more sustainable, just, and equitable futures that are based on sound scientific and environmental principles, as well as long-term planning that recognizes durable and resilient human and environmental relationships as a common social goal. Geoscience education is a central component of achieving this goal, and "the Earth science community. . .needs to tackle the question of how best to inject scientific insights into the debate about a sustainable future" (Schlosser and Pfirman, 2012, p. 587). One of the most important arenas in which geoscience concepts should be brought to bear in discussions of sustainability is to teach future classroom and informal educators how basic scientific and environmental concepts are joined with sustainability concepts regarding values, sociopolitical action, economics, and development (Hodson, 2003). As Gosselin et al. (2013) have argued, "Incorporating sustainability topics into coursework can be a stimulating and powerful mechanism for linking course content to real-world issues" (p. 221). Students become excited about content that they can connect to the headlines they are reading online, as well as to their community or personal experience. Simultaneously incorporating geoscience concepts with sustainability concepts is one way to make both

exciting and relevant for future educators and to create holistic approaches to educating students about environmental issues.

With these knowledge sets in mind, a key focus must be on preparing the next generation to make informed decisions, challenge the status quo, and identify solutions. Citizens need to be able to marshal new insights and understand overlapping spheres of knowledge to redesign society along socially just pathways and ensure biosphere processes are stable. As part of achieving this outcome, education is a central component of improving the human condition and mobilizing new knowledge into actionable items (Hodson, 2003). The field of education represents a critical mechanism to enact lasting and impactful change toward achieving the goals of environmentally and socially sustainable societies. As such, a key element is educating future classroom teachers in sustainability literacy (UNESCO, 2010) and the geoscience concepts that sustainable planning is based upon. According to Nolet (2013), "Teacher education institutions can play a critical role in the work of reorienting education systems at all levels to address sustainability" (p. 53). Working with classroom teachers to inculcate sustainability concepts will have a direct effect on students who will be future leaders, thinkers, and citizens—those who will mobilize new knowledge and ways of thinking to change the world for the better.

The current study describes how we have drawn on the knowledge, processes, and logic from the geosciences to inform a course on sustainability science designed for preservice teachers. We describe Sustainability Science for Teachers (SSFT), a semester-long hybrid course that is a requirement in the undergraduate education program at a large public university. We explore the course's Water unit, one of the most well-

received units, as a case study of this educational approach. Details are presented regarding the curriculum and initial outcomes for this learning experience that intricately meld sustainability and geoscience concepts. A discussion follows regarding how the curricula for this course offer new ways to fuse the geosciences, sustainability concepts, and pedagogy in a novel and impactful fashion.

Rationale and Background

Challenges in Liberal Arts and Science Education

An integral part of liberal arts education in universities across the world is to animate science concepts for a lay audience of learners. An educated 21st century populous must challenge the traditional linear understanding of science and society exemplified at the 1933 Chicago World's Fair, where "Science discovers, genius invents, industry applies, and man adapts himself" (Chandler, 2010, p. 14). Rather than adhere to this reductionist role of the citizen in relation to scientific knowledge, we argue that citizens need a clear understanding of science and the societal implications of science and technology to gain intellectual independence (Gaon and Norris, 2001). Sustainability offers a lens through which to tackle this challenge, and geoscience topics such as the hydrosphere are a way to help university students understand the practical aspects and civic-related responsibilities of science, technology, engineering, and math (STEM) fields and their implications for the future of the planet (Shen, 1975; Liu, 2009).

Among colleges of education specifically, a challenge in preparing undergraduate preservice teachers is facilitating their ability to integrate the Next Generation Science Standards (NGSS Lead States, 2013) and Common Core Standards (National Governors Association Center for Best Practices and Council of Chief State School Officers, 2010)

into classroom teaching. These standards for education demand that teachers engage students in learning across content areas while exploring real-world, relevant problems. Tomorrow's teachers need to be equipped with the pedagogical skills and background content knowledge to explore the scientific and humanistic realities of current issues, such as the 2016 water crisis in Flint, Michigan. The Flint case study exemplifies the need for a rich exploration of socio-techno-ecological relationships that highlight infrastructure, politics, and geosciences to better expose how thinking across the curriculum can highlight consequences that disproportionately affect poor and minority populations. Over the last decade, educational scholars have begun to suggest that sustainability may be one way to approach such topics with elementary students and offer the necessary ways of thinking to make these important connections (Nolet, 2009, 2013, 2016; Stibbe and Luna, 2009).

Preparing Teachers to Teach Science

Scholars of science education have identified two major challenges that elementary educators face when integrating science into their curriculum. First, kindergarten through 8th grade (K–8) classroom teachers lack self-efficacy in teaching science topics, and preparation for teaching science is lacking, particularly when it comes to pedagogical approaches that animate science topics to bolster teachers' confidence in relation to both understanding and translating scientific concepts for students (Appleton, 1995; Westerback, 2006; Howitt, 2007). Consequently, the National Research Council (NRC) Committee on Science Learning stated that an increased effort on science literacy is important for educators in the K–8 space (NRC, 2000). Second, sustainability issues

are not formally addressed in most schools. Nolet (2009) reports that U.S. teachers are not prepared to meaningfully teach how current and future issues related to overconsumption of resources, human-caused environmental damage, and technological solutions affect the world we live and the one we plan. Meanwhile, the Intergovernmental Panel on Climate Change (2014) articulates a need for greater access to education that raises awareness about adaptation and resiliency strategies grounded in an understanding of scientific concepts and appropriate applications of technology (Brooks et al., 2005; Adger, 2006). Critically, as Paavola's (2008) international case study demonstrates, a lack of education about both environmental science and sustainability concepts is a constraint that contributes to systemic environmental vulnerability and insecurity.

The SSFT course was adopted to address these complex and interconnected issues by prompting preservice teachers to explore current issues related to geoscience, environmental science, biological science, physical science, history, social science, engineering, and technology to make sustainability science topics come to life. The course aims to facilitate teachers' ability to integrate these concepts in the K–8 curriculum by increasing both their confidence in understanding of environmental science concepts and their comfort in translating those for students in relation to sustainability concepts.

Sustainability Science for Teachers

Three main areas of literature are useful for conceptualizing sustainability for a teacher audience: environmental education (including geosciences), ecological literacy (Orr,1989), and sustainability literacy (Sachs, 1997, 2004; Nolet, 2009; Stibbe and Luna, 2009; Wiek et al., 2011). Major definitions associated with science and sustainability

(Our Common Future, 1987; Kates et al., 2001) are also valuable for integrating these three fields, which complementarily consider causality and complexity of scientific knowledge production, technological applications, and social concerns. For instance, sustainability seeks to question and unpack how topics of science, technology, and society are embedded in human relations with and decisions about Earth's natural and human-made systems (Solomon and Aikenhead, 1994). Similarly, emerging epistemologies associated with complexity (Bateson, 1991; Maturana, 1978) are a useful way to engage with complex thinking about various wicked sustainability problems and plausible solutions that are or could be responsibly implemented.

Sustainability Education Framework for Teachers

Warren et al. (2014a) have argued that sustainability literacy can be developed in teachers via the Sustainability Education Framework for Teachers (SEFT). This framework was developed specifically for the SSFT course to scaffold preservice teachers' ability to engage in critical thinking about sustainability topics, and it has implications for other courses and teaching models. At the core of SEFT are Four Ways of Thinking: futures, values, systems, and strategic. These are conceptualized as being bidirectional and inter-related (see the following link for supplemental content [Available in the online journal and at http:dx.doi.org/10.5408/16-177s1], including brief videos on SEFT).

Futures thinking includes "the ability to collectively analyze, evaluate, and craft rich 'pictures' of the future related to sustainability issues and sustainability problem-solving frameworks" (Wiek et al., 2011, p. 208–209), while values thinking means understanding concepts of justice, equity, social–ecological integrity, and ethics, along

with how these concepts vary across and within cultures and how they can be integrated to contribute to addressing sustainability problems. Systems thinking includes the ability to analyze complex systems, both across the major areas of sustainability, including society, the environment, and the economy, and across different scales, from local to global, all while "considering possible cascading effects, inertia, feed-back loops, and the other systemic features related to sustainability issues and sustainability problem-solving frameworks" (Wiek et al., 2011, p. 207). Finally, strategic thinking involves considering various pathways for addressing environmental problems, including identifying alternative solutions, and challenging existing cultural assumptions about wicked problems (Lawrence, 1999). This process may identify new solutions that may be more culturally and environmentally appropriate, especially when influenced by futures, values, and systems thinking.

SEFT's Four Ways of Thinking are inherently interlinked, and combining them to address sustainability issues, especially resource allocation, aids in linking sustainability topics that are seemingly disparate and too complex for the novice teacher population to understand and teach about without specialized formal study. Instead, using these different ways of conceptualizing scientific concepts builds knowledge, skills, and attitudes necessary for addressing social and environmental problems with respect to complex sustainability challenges. As a conceptual framework, SEFT offers organizing principles for examining and considering sustainability problem–solution sets, like those explored in the SSFT course. It offers a logical framework for working in interpersonal, intragroup, and intergroup situations. Reconceptualized from existing sustainability literacy (Stibbe and Luna, 2009), sustainability competency (Wiek et al., 2011), and

sustainability development literature (Sachs, 1997, 2004), the framework is streamlined for a teacher audience.

Course Overview

SSFT is a semester-long hybrid class that aims to develop preservice teachers' science content knowledge in the context of society's engagement with science and technology. See Archambault and Warren (2015) for a detailed overview of the course curriculum and structure. Additional information can also be found online via http://sse.asu.edu/courses/scn400/.

Connecting Sustainability and Geoscience. Over the semester, SSFT explores 13 weeklong units, or domains of sustainability knowledge: introduction to sustainability, population, poverty, food, water, fossil fuels, new energy, ecosystem services, biome stories, production, disposal, governance, and change. Many of the units draw inspiration from Earth systems and geoscience to teach sustainability concepts, especially in relation to natural cycles, resource limitations, and the effects of human–nature interactions on the environment. For instance, the Water unit explores the natural water cycle, as well as different ways that humans use and alter this cycle on different scales, from the community level to the national and international levels. As another example, the Ecosystem Services unit examines basic environmental and geosciences, focusing on how the carbon system functions, how fossil fuels are derived from geologic exploration, and how humans exploit basic ecosystem functions to further the success of the human species but often do not realize how much they are altering natural systems or affecting other species, humans, and organisms.

Across the units, preservice teachers learn about different aspects of core geosciences to understand what systems are in place and how human intervention has changed these systems, as well as an overview of the consequences of those changes. By combining geoscience, sustainability concepts, and new pedagogical resources and perspectives, the goal is for preservice teachers gain confidence in their grasp of basic geoscience and environmental science concepts, which may make them more effective at translating sustainability concepts to their future students.

Course Design Team and Instructors. An interdisciplinary design team of experts in sustainability, science education, pedagogy, and technology was brought together in 2011 to create the initial content for the SSFT course. The team included 20 individuals, composed of professors, postdoctoral fellows, graduate students, graphic designers, and administrative support. The team's specific disciplinary training ranged from scholars steeped in sustainability science and geoscience, with an emphasis on phosphorus recovery, water systems and governance, nanotechnology, genetics, food systems, justice, and urban landscapes, to those with training in educational technology, engineering, and the science of design. The team updates all course materials annually to reflect principled practices that satisfy both education and sustainability requirements. Instructors for the course vary by semester and come from a variety of disciplinary backgrounds, including sustainability science, science and technology studies, justice studies, and education.

Course Student Population. Approximately 125–200 preservice teachers enroll in SSFT each semester, divided into course sections of 20–35 teachers each. Although demographic data have not been formally collected since the course's inception,

demographics were collected in the most recent semester, spring 2016 (n= 99). At that time, the SSFT student population was predominantly female (92%), identified as white or Caucasian (77%), and was interested in teaching grades 3–5 (65%). Most preservice teachers were under the age of 25 (86%) and were considered digital natives who have grown up using computers, the Internet, and mobile technologies (Lei, 2009). These population descriptors are consistent with informal observations of the student population since SSFT's inception in 2011.

Initial Evidence of Course Impact. Foley et al. (2015) provided initial evidence demonstrating that SSFT is an effective way to cultivate sustainability literacy among preservice teachers. In the study, preservice teachers enrolled in the first SSFT cohort (fall 2012) were asked to create sustainability concept maps at the beginning and conclusion of the course. Upon comparing the maps within subjects, results indicated that most preservice teachers entered the course with limited understanding of sustainability. By the end of the course, preservice teachers' understandings became more complex and interconnected, with concept maps that had significantly more nodes and levels of hierarchy, reflecting a greater depth of understanding. The study suggests that SSFT is a promising intervention for developing sustainability literacy but was limited because it used a limited sample size and only examined proximal outcomes of current students, as opposed to exploring lasting impacts over time, actual classroom impacts, or both.

The current study extends Foley et al.'s (2015) work, examining outcomes from a larger sample of SSFT preservice teachers across multiple data sources, while also examining impacts to classroom practice (distal outcomes) among course alumni. The current study focuses specifically on how the SSFT curriculum draws on the knowledge,

processes, and logic from Earth systems to inform sustainability education for preservice teachers, using the Water unit as a case study.

Method

Design

A case study approach was used, because this supports the exploration and description of a rich and authentic course context (Yin, 2014). The Water unit was explored as a single case, addressing the following research questions:

1. How was the Water unit designed to reach the goals of developing new understandings of science, geo-science, and sustainability and new ways of teaching and thinking in preservice teacher-students?
2. How did the Water unit affect future teachers?

To address the first research question, we provide a narrative description of the structure, design, and content for the unit. To address the second research question, we evaluate evidence regarding preservice teachers' beliefs and products from the learning experience. We also explore course alumni reports about the lasting impacts of the learning experience. Regarding teachers' perspectives and practices, qualitative and quantitative data sources were analyzed together to consider the most robust evidence available (Creswell, 2015).

Case Selection

The Water unit was selected because it is an ideal example of connecting geoscience and sustainability within SSFT. In the unit, preservice teachers learn about hydrology systems, including human-produced systems and natural systems such as the water cycle, while considering the impacts of these systems on humans, the environment,

and the economy. Preservice teachers evaluate and explore how to engage these concepts with K–8 students through hands-on activities and a lesson evaluation assignment. The Water unit is an example of the extent to which the study of Earth systems truly complements SSFT's approach to sustainability education.

Data Sources and Analysis

To address the first research question, we garnered evidence from a number of course materials, including the syllabus, online course resources, the instructors' collaborative online wiki site, and lesson plans for the face-to-face (FtF) class meetings. The authors also brought knowledge of their personal experiences as instructors and designers for the course.

To address the second research question, qualitative and quantitative data were collected from three sources (Table I). The two surveys were developed by the course design team using an iterative process (Czaja and Blair, 2005). Quantitative data were analyzed for descriptive frequencies, and qualitative data were open coded, drawing on a constant comparative approach (Strauss and Corbin, 1998). In coding open-ended responses, we identified several themes of interest in participants' responses regarding why they believed water was an important topic (course exit survey) and why course alumni chose to teach this topic (alumni survey). We also identified exemplars that embodied compelling examples of the observed themes in the participants' own words (Tracy, 2013).

Table 1.
Case Study Data Sources

Data Source	Quant	Qual	Sample	*n*	Response Rate	Format
Course exit survey	Yes	Yes	Preservice teachers in the Spring 2016 Cohort	123	99%	• Web-based survey • 15 minutes to complete • Administered at last course meeting of spring 2016.
Alumni survey	Yes	Yes	Preservice teachers in the Spring 2012 - Spring 2013 Cohorts	99	31%	• Web-based survey • 15 minutes to complete • Administered in summer 2014.
Sustainability unit projects	Yes	No	Students in the Fall 2012 - Spring 2015 Cohorts	819	81%	• Students' digital artifacts (typically websites) showcasing an original sustainability unit they created for elementary students.

Trustworthiness and Limitations

This case study presents limited and contextually bound evidence, so it is difficult to generalize findings (Yin, 2009). Nonetheless, it takes place in an authentic setting and, as a case study, aims to provide a rich description of a unique case, which may provide nascent ideas for applications to similar contexts. The concerns and proposals explored in SSFT are intended to be global, but the course was created by a group of scholars and designers situated in a Western industrialized society. The data presented in this paper rely primarily on self-report from preservice teacher-students and course alumni, which

may not necessarily be reflective of participants' actions or observable experiences (Fowler, 2002). Future work may provide a more complete picture by investigating impacts via observational methods such as classroom observation and lesson plan artifact analysis.

In addition, as much as the course aims to address significant sustainability and geoscience content, as well as teaching strategies to incorporate this content into K–12 classrooms, there are constraints to what can be accomplished in a single semester. Although the course seeks to improve both content knowledge and pedagogical approaches to teaching, there is always potential to improve. One area for future advancement may include more directly addressing ways to help teachers be prepared to meet the needs of student populations that are directly and differently affected by sustainability challenges, specifically dealing with the equitable or inequitable distribution of impacts, in addition to brainstorming ways to tackle such challenges. Often this area is addressed through in-class activities and discussions that happen during the weekly FtF portion of the course. However, the main thrust and focus of the course remains centered on building future teachers' pedagogical content knowledge (Shulman, 1986) specific to sustainability science.

Finally, the authors have been involved in both the development and the instruction of the course. As a result, they have had intimate experience with it over time. While some may view this as a limitation to impartial evaluation, we view it as an advantage. Our truly immersive experience with the course, preservice teachers, and instructors over time allows us to provide a deeper, richer, and more accurate analysis of the context (Tracy, 2013).

Results

Description of the Water Unit Design

The Water unit is presented during the fifth week of the SSFT course sequence. The essential question asks, ‘‘How can we provide water to meet human needs sustainably?” Activities for both online and face-to-face portions of the unit are presented in Table II. Consistent with the other weeks in the course, before attending the in-person class, preservice teachers watch online digital storytelling videos (Robin, 2008), complete an online quiz, and write a personal reflection submitted online. Then, in the FtF class, preservice teachers engage more deeply with the concepts in collaborative groups, concluding with a K–8 lesson plan evaluation completed online. Throughout the unit, preservice teachers employ SEFT’s Four Ways of Thinking (Warren et al., 2014a), considering the water issues presented with a critical lens. Below, we describe the curricular components of the unit, organized by the two principal learning objectives for the course, which aim for preservice teachers to develop new understandings and new ways of teaching sustainability science.

Table 2.
Water Unit Activities

Goal	Process	Environment	Activity	Description
Developing New Ways of Thinking	1	Online	Digital Stories	Watch seven digital storytelling video segments
	2	Online	Formative Assessments	1. Complete 10 item electronic quiz 2. Write 2 paragraph personal reflection on the water topic
Developing New Ways of Teaching	3	Face-to-Face	Hands-on Activities	Participate in collaborative centers exploring water systems
	4	Online	Lesson Plan Evaluation	Write an evaluation of an authentic water lesson plan

Table 3.
Water Unit Video Clips

Video Clip	Title	Description
1	Introduction to H_20	The scientific study of hydrology including the hydrologic cycle is presented.
2	Water as a System	Water sustainability is explored, including a focus on the balance between the demand for water and the natural supply.
3	Wastewater, Labor, and Energy	Where does our water go when it leaves our house and how does it get clean?
4	Human Health and Water	According to the World Health Organization, poor water supply sanitation and hygiene causes water-related diseases such as enema, dehydration, and malnutrition.
5	Environmental Health and Water	The rapid increase of human population over the last century, from 2 billion people in 1910, to 7 billion people in 2010 has created pressure on many environments where humans have transformed the water landscape.
6	Local case study: Phoenix Arizona's Water Sources	Phoenix, Arizona's water supply comes from three primary sources: aquifers, the Salt and Verde Watersheds managed by The Salt River Project, and the Colorado River. The complexities of these systems are explored.
7	Global case study: Bali's Water Management	Balinese "water temples" and the management of irrigation systems as a sociocultural practice are presented. Are major water infrastructure investments the only way to manage society's need for water?

Developing New Understandings. A first goal of the course is to develop preservice teachers' content knowledge regarding sustainability science and their ability to critically evaluate sustainability problems and solutions. Because SSFT preservice

teachers as a population enter the course with limited sustainability knowledge (Foley et al., 2015), the unit was designed to first provide sufficient coverage of water issues followed by scaffolded student interaction with the material.

Digital Stories

The unit begins by presenting the topic of water through seven digital storytelling video vignettes spanning approximately 60 minutes (Table III). Preservice teachers watch at their convenience before attending class. The digital stories visualize authentic sustainability stories that consider global and local issues, following the cadence of a captivating documentary. The stories are produced by the SSFT course design team, and an in-depth discussion of the video design process is forthcoming (Shelton et al., 2017). To obtain a sense of the video content, the Water unit trailer is viewable at http://sse.asu.edu/courses/scn400/.

These digital stories present a narrative story, which prompts consideration of how sustainability issues are shaped by and for various technologies, landscapes, peoples, and places. For example, one of the Water unit vignettes tells the story of traditional water systems in Bali, describing how these once locally sustainable systems were remade by well-meaning international nongovernmental organizations and corporations to serve more people with water. But without understanding how local practices were rooted in an intimate knowledge of available water resources, the modern system broke down continually, resulting in less efficiency and an inability to cope with stochastic rain patterns and seasonal flooding conditions. The technology proved sound in one context but was applied in a way that was not suitable for the local setting, making water a less sustainable and usable good.

In another Water unit vignette, we explore the Central Arizona Project (CAP), a 300-mile canal system that brings water from the Colorado River to the Salt River Valley and the major urban center of Phoenix, Arizona. The video shows the historical aspects of water management in a desert climate, because the CAP supplies water not only to the city but also to a hydroelectric plant that provides electricity. Technological advances have allowed Phoenix to grow to a metropolitan area of 4.5 million residents, but based on future projections of rainfall and climate change, it is doubtful that Phoenix can sustain this level of growth without considering different methods for conserving water and a more detailed understanding of its water resources. This is a critical aspect of water management for the metropolis of Phoenix and many other desert cities. However, preservice teachers are generally unaware of where water for the city comes from, undermining their ability to teach about it and limiting the development of sustainability concepts surrounding water management in the American Southwest.

These described digital stories, along with others that visualize the human and natural water cycles and those that teach preservice teachers how to directly apply SEFT's Four Ways of Thinking to real-world situations, make up the video content for the Water unit and have the explicit goal of being ''explanatory stories'' that underscore how human values influence the application of science and technology and why these systems are not always sustainable, equitable, or legible to the general citizen or end user. Combining water system concepts with sustainability ideas aims to facilitate learning different notions, strategies, and examples in a short amount of time through interrelated ideas, which altogether provide a richer understanding of the topic—geoscience and

sustainability science are complementary topics that work to reinforce each other. It also gives an overview of the complex interplay between human and natural systems using both local and international examples.

Table 4.
Water Unit Written Reflection Prompts

Way of Thinking Addressed	Prompt
Systems Thinking	What makes up Phoenix's water system?
Futures Thinking	How has Phoenix used (or failed to use) Futures Thinking to develop policies governing the production and distribution of water?
Values Thinking	How does Values Thinking play a role in how, and for what purposes, water is used in Phoenix?
Strategic Thinking	What are some strategies to ensure that Phoenix starts using water more sustainably?

Formative Assessments

The digital stories are followed by a 10-question multiple-choice online quiz, serving as an accountability check. Preservice teachers value the quiz to stay on track and monitor their learning (Shelton et al., 2016). They also write a reflection designed to promote deeper thinking and a personal connection with the video content. In two written paragraphs, preservice teachers consider the sixth digital story about the CAP, a critical water supply for Phoenix, and address the prompts in Table IV. The prompts were designed to (1) ignite interest, through the exploration of the relevant, local issue of water security in their desert climate, and (2) develop deeper understandings about issues preservice teachers may not have previously considered. Because most preservice

teachers care deeply about making the world a better place, the prompts also aim to resonate with their interest in finding solutions and positive outcomes to big, complex, yet practical problems.

At the core of the Water unit is the value that understanding complex Earth systems offers a rich way to motivate the exploration of sustainability problems—be it through exploring visual narratives of water stories throughout the world or critically considering local water sourcing options and solutions. It also examines the natural system and the myriad ways that humans interact with, and affect, these biophysical systems, as well as different ways that the cultural values of water are understood and used by different societies. Next, the unit goes beyond developing preservice teachers' understanding of the content to empowering them with the pedagogical content knowledge (Shulman, 1986) needed to teach these concepts.

Developing New Ways of Teaching. How might the big, complex ideas that preservice teachers consider in the videos and online assignments be translated for K–8 students? The second half of the Water unit focuses on classroom applications of water sustainability. To empower future teachers to not just know the concepts but also be able to teach them, two activities were developed: a collaborative exercise designed to explore water systems and a written evaluation of a lesson plan. Each stage of this process reiterates geoscience concepts in relation to sustainability concepts, underscoring how foundational scientific concepts about Earth systems are an integral part of understanding how values drive knowledge production and how human-created technological systems, like canals and sewers, reflect values that are not rooted in sustainable practices.

Table 5.
Water Unit Lesson Plan Evaluation Prompts

Writing Prompts
1. How was Strategic Thinking exemplified in the lesson plan?
2. How did the information in the lesson plan reinforce the data, logic, and ideas in this week's online content?
3. Explain how you might modify the plan to connect the lesson to the daily lives of K-8 students to inspire action and change.

Collaborative Centers: Exploring Water Systems

During the 75-minute FtF class meeting, preservice teachers engage in a collaborative learning activity in which they create demonstrations of the water cycle and human-managed water systems using different presentation modalities, such as building a physical model with clay, markers, and paper; drawing a graphic display; or writing a narrative story to describe the system (see the full lesson plan in the supplemental file available in the online journal and at http:dx.doi.org/10.5408/16-177s1). The activities emphasize considering the interconnectedness of human and environmental systems and are intended to simulate a learning experience that might be adapted to the K–8 classroom. Geoscience concepts about natural systems are an integral entry point for understanding how human activity has changed water systems locally and globally. This approach informs how preservice teachers can use different SEFT ways of thinking to facilitate K–8 students' consideration of how to make more sustainable decisions in their lives, carrying concepts and ideas further as they learn more about the world.

Lesson Plan Evaluation

The unit culminates in an evaluation of an existing K–8 lesson plan on the topic of water that presents a hands-on learning activity in which elementary students learn about what happens to water once it goes down the drain in their home and how it becomes drinkable again, demonstrating an explicitly anthropocentric approach to water management by humans. The lesson plan was selected because it was an authentic online source and represented an adequate example of exploring water issues in the K–8 context. Table V illustrates the lesson evaluation prompts completed by preservice teachers. This assignment was designed to support preservice teachers in establishing connections between the water sustainability stories that they grappled with throughout the unit and how concepts can be made relevant to their future elementary curricula. It also aims to show them an example of interdisciplinarity in elementary lessons, in which concepts and standards from science, math, social studies, and English and language arts are integrated. This is important in establishing relevance for preservice teachers who are highly motivated by wanting to integrate the standards yet simultaneously find standards integration, especially across scientific content areas, to be a challenging task.

In summary, the Water unit was designed to both quell preservice teachers' fears about a lack of understanding of geoscience concepts and give them practical tools and perspectives for teaching diverse K–8 students about sustainability concepts. The unit is an example of providing specific content knowledge and practical teaching strategies, but the question remains: What do teachers take from the learning experience?

Table 6.
Evidence of Teachers' Interest in Teaching the Topic of Water

Data Source	Frequency selecting water / total participants (%)	Was water the most commonly selected of the 12 topic options?	Data Source
"Of the 12 sustainability topic weeks in the course, which topic do you most envision teaching in your future classroom?"	116 / 123 94%	Yes	Course Exit Survey
"Of the 12 sustainability topic weeks in the course, which topic have you addressed in your classroom?"	36 / 53 72%	Yes	Alumni Survey
Frequency of preservice teachers selecting water for their sustainability project topic	172 / 819 21%	Yes	Sustainability Unit Projects

Impact of the Water Unit

To assess how preservice teachers have been affected by the Water unit, the data sources listed in Table I were analyzed together.

Water Is a Popular Topic. Across all three data sources, participants consistently indicated that the Water unit was the SSFT topic they were most likely to teach in their own classrooms (Table VI). At the end of the course, the highest frequency of preservice teachers envisioned teaching the Water unit over other sustainability topics covered in the course. Furthermore, course alumni in their first year of teaching or student teaching listed water as the most common topic that they addressed in their classrooms. Finally,

preservice teachers most often selected water as the topic for the sustainability unit they create for their final projects.

Why Water Resonates with Teachers. Next, we explored the reasons for teachers' interest in teaching the Water unit. On both the exit survey and the alumni survey, after teachers selected their preferred course topics, they were asked to indicate the reason for their selection. Thematic analysis of responses indicated that water was a compelling topic because it lent itself to teachers' development of (1) action-oriented understandings and (2) new ways of teaching. Both are discussed next.

Developing Action-Oriented Understandings

Participants explained that the Water unit was compelling because the unit helped them develop newer, deeper understandings of environmental systems and human interactions and inspired a personal desire to improve sustainability problems. Table VII presents exemplar responses. The evidence suggests that relevant concepts relating to Earth systems, such as the human and natural water cycle, resonate with the preservice teacher audience because they expose teachers to new and relevant ideas while connecting with teachers' desire to make the world a better place. Preservice teachers are generally uninformed about science, current events, and sustainability issues or unsure how to incorporate them into standards (Appleton, 1995; Westerback, 2006; Howitt, 2007). However, they care deeply about making the world a better place (Fullan, 1993). They stand to gain from the applied study of real-world water problems when considering their connections to sustainability.

Developing New Ways of Teaching

Participants also indicated that the Water unit was compelling because it could be so easily applied in their future classrooms. Future teachers explained that they felt empowered to teach the topic of hydrology and sustainability because it (1) was interdisciplinary, (2) connected to the established curriculum they are already expected to teach, (3) incorporated engaging content relevant to the real world and preservice teachers' lives, and (4) aligned with national and state standards to which they are already required to teach. Table VIII presents exemplar responses embodying these four subthemes.

Participants indicated that the study of water was exciting because it lends itself to a host of pedagogical opportunities for K–8 students. First, they cited interdisciplinary opportunities, explaining that the Water unit was relevant to a variety of other sustainability topics, including access and equity locally and around the world, food production, and population limitations. They also believed water was a useful topic for facilitating student learning across content areas, including math, science, social studies, and English and language arts. Second, participants expressed that the Water unit corroborates well with topics, standards, and units being taught in elementary and middle school classrooms and aligns with the Next Generation Science Standards (NGSS Lead States, 2013) and Common Core Standards (National Governors Association Center for Best Practices and Council of Chief State School Officers, 2010). Likewise, the topic is relatable to both teachers and K–8 students. Water is a particularly relevant topic in the desert southwest and is more age-level appropriate in terms of complexity and sensitivity than other SSFT topics, such as poverty and population.

Discussion and Impact

Through an exploration of SSFT's Water unit, we highlighted the curricular design decisions and processes that make the development of this learning experience possible. Evidence from course alumni and preservice teacher-students suggest that SSFT's approach for connecting Earth systems to sustainability topics is particularly popular among preservice teachers and a meaningful learning experience that affects them as teachers and as citizens.

Table 7.
Action-Oriented Understandings that Teachers Developed through the Study of Water Sustainability

Participant response	Themes embodied in the response	Data Source
"Growing up we kind of see that the earth has so much water and you think its an endless supply, but you realize as you get older that its not. Classes like this allowed me to understand why."	1. Newer, deeper understandings	Course Exit Survey
"I never realized just how complicated the process of having clean water is. It opened my eyes to how much I take for granted the accessible water I have in my life."	1. Newer, deeper understandings	Course Exit Survey
"I did not know about regulations on municipal water versus bottled water, the process our water goes through again and again to make it accessible to all houses."	1. Newer, deeper understandings	Course Exit Survey
"I had never thought twice about using plastic water bottles. I didn't even know that they can be harmful to the environment."	1. Newer, deeper understandings 2. Desire to create action-oriented change	Course Exit Survey
"It was an eye opener as to how much water is wasted on a day to day basis. Furthermore, the fact that our water resources are being depleted without being replenished is very scary. My habits as well as my families at home have changed drastically. We have taken inventory of the areas that need change. We have purchased small cups for brushing our teeth. We tried turning the faucet off as we brushed and then only let water run as we rinsed, but we felt that wasn't enough. We feel that by making this small change we have made a big difference in preserving water. We also time out showers now to five minutes instead of a long shower that lasts longer than needed. Although these changes have been small ones, we feel that we are making a positive difference."	1. Newer, deeper understandings 2. Desire to create action-oriented change	Course Exit Survey

Table 8.
New Ways of Teaching that Teachers Developed through the Study of Water Sustainability

Participant response	Themes embodied in the responses	Data Source
"In teaching 6th grade science this year, much of my core curriculum I am able to connect back to the topics discussed in this course. I completed a water unit with them in which they looked at various countries worldwide and their access to clean drinking water. They considered the connections that clean water was on other aspects of people's lives."	1. Interdisciplinarity 2. Established curriculum	Alumni Survey
"Population and poverty are both ideas that are already taught in a social studies curriculum. These topics are interwoven with the topics of food and water. Students should see that population has a direct link to water , food and poverty."	1. Interdisciplinarity 2. Established curriculum	Course Exit Survey
"I would like to teach students about where their food and water comes from, as this is extremely relevant to each of their lives. Students should be aware of the challenges that we face related to food and water access, availability/security."	1. Interdisciplinarity 2. Real world relevance	Course Exit Survey

"I really enjoyed my unit lesson plan on The Great Pacific Garbage Patch that we did for the final project. In my lesson plan, I interwove sustainability in with other science concepts that the students have to learn in/by the 6th grade, such as the water cycle and food webs. I also incorporated math into my lesson plan by having the students dissect their own garbage and finding out the percentages of the types of garbage they found (plastics, glass, paper, etc.). Finally, I included a writing portion, where students will be able to create brochures to be given to restaurant managers to ask them to be more conscientious of the waste that they create. Students will be engaged, using the current standards, and combining the problem-solving skills of scientists in a real-world problem to come up with solutions. I imagine I will come up with many lesson units like these in the future. Not only are they engaging but also teach students how to problem solve by using real world context and engineering design challenges which use higher order thinking skills."	1. Interdisciplinarity 2. Established curriculum 3. Real world relevance 4. Standards	Course Exit Survey

Reflections: Designing the Unit

The design decisions for the Water unit were rooted in teaching best practices, vetted over repeated iterations of the course (Archambault et al., submitted). One of the biggest challenges the course designers faced was making decisions about the best content to convey the complex interplay of geoscience and sustainability while engaging and challenging preservice teachers. One example of this challenge has been in determining the video content that makes the cut for the digital stories. The design team acknowledges that the digital storytelling videos ultimately used in the course do not necessarily render the whole story of the water cycle. Rather, specific representative aspects are presented, because they are worth investigating and engaging with for

purposes of the course. As MacKian (2010) notes, ‘‘We choose what to observe, what to record, what to render visible, and there is no such thing as immaculate perception’’ (p. 360). Stories, whether textual or visual, are performances that require analysis, interpretation, and presentation—they are movements, shapes, and gestures of everyday experiences (Dewsbury, 2010). They are impressions of what was, is, or could be, and this type of experience is key when exploring sustainability science and geoscience concepts.

The videos not only inform about certain topics but also serve as points of initial inquiry, encouraging learners to ask themselves how certain systems they may take for granted, like water or energy, are parts of historical patterns and embedded value systems. It is critical that instructors address this issue, connecting the online materials to relevant discussion and action in the FtF environment. Unlike traditional notions of science concepts (Chandler, 2010), sustainability acknowledges that problems and stories are multifaceted and should be interpreted with a critical lens. The present analysis of SSFT's Water unit suggests that study of water, and geoscience in general, benefits from taking the sustainability perspective.

Reflections: Affecting Preservice Teachers

The present findings extend our understanding of the impact of SSFT beyond the initial work by Foley et al. (2015) by examining a number of data sources over the 4 years of the course. Water overwhelmingly affected preservice teachers, and this impact extended longitudinally in course alumni, who reported bringing water sustainability concepts into their classrooms.

The reasons for these impacts are multifaceted. SSFT employs an intervention targeting individuals as citizens and future teachers. One cannot separate these two aspects of identity. If one is affected as a citizen, learning new ideas and deepening one's understanding of complex sustainability and environmental science issues, it is likely that these ideas will carry over into the classroom in some way, whether overtly, through formal teaching, or covertly, in the ''hidden curriculum'' in the class. Similarly, if preservice teachers are emboldened to teach sustainability topics, by pursuing such topics in the classroom, they can likewise be affected personally, as citizens. In the face-to-face Water unit activities, engaging in a simulation of what it would be like to apply the content to a K–8 audience or thinking about a lesson plan evaluation develops preservice teachers' conceptual understanding even more deeply. Preservice teachers continue to develop their ideas about water and sustainability after the unit ends, throughout the SSFT course (as they engage in their classroom internships and the remaining units in the course), and beyond (as ideas, ways of thinking, and new ways of teaching evolve over time).

Conclusion

SSFT is a small-scale effort to answer the call to produce sustainability-minded and scientifically knowledgeable citizens prepared with the skills, attitudes, and literacies that are needed to engage with sustainability, technological, and societal issues content (Stibbe and Luna, 2009; Nolet, 2013, 2016). The course was designed to provide creative examples for preservice teachers to consider and use in their own teaching after graduation. The use of both online and face-to-face learning components aims to integrate digital storytelling video, reflection, and hands-on activities in an engaging and

modern way. The use of virtual spaces aims to engage preservice teachers, foster autonomy, and differentiate for individual needs. By exploring teachers' feedback regarding the Water unit, we see that this method is an effective way to enable teachers to take control of the informational content, including geosciences, environmental science, and sustainability concepts, with innovative pedagogical elements, such as modeling activities, that dovetail with current academic standards but have a focus on teaching ideas about values and sustainable environmental practices.

SSFT attempts to answer the call from the NRC Committee on Science Learning, stating that increased effort on science literacy is important in the K–8 space (NRC, 2007). The SSFT model may provide a useful example for other initiatives targeting teacher education regarding the geosciences and sustainability. Through SSFT, we created accessible and engaging content for elementary educators, animating geoscience content through sustainability science. Geosciences are a critical and foundational aspect of the sustainability concepts in the course. By teaching them in a way that is easily accessible and grounded in material examples, and by using activities that model the geosciences, as well as SEFT's Four Ways of Thinking, SSFT is able to engage with preservice teachers in a unique and inspiring way. Complex and often wicked problems, such as groundwater remediation, water management, and equitable distribution across present and future societies, require creative, adaptive educators who can propose and strategically implement novel solutions. They also require educators who can inspire hope and action among their students, the next generation of changemakers.

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CHAPTER 4
LESSONS FROM WITHIN: REDESIGNING HIGHER EDUCATION

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Introduction

As higher education continues to evolve from the gatekeepers of knowledge to a space of curators, creators, and connectors – universities are at a unique point in their history and trajectory (Wolfe & Andrews, 2014). Institutions are being called to discover more effective and efficient ways of preparing learners of all types and at all stages. Despite criticism, a general lack of funding, and false starts along the way (e.g., the concept of a massive open online course) – this transition involves a complex set of actors, actions, and artifacts. The question becomes, what lessons can we learn from those involved in transforming higher education to be more than it is currently?

Visionary scholars and leaders are calling for engaged change while leading efforts to reform and transform higher education (Crow & Dabars, 2015). Ramaley (2000) and the Kellogg Commission (2000) aim for higher education to better embrace their civic responsibility and conduct socially inspired research. While a wide variety of ideas and large-scale plans for execution exist, most do not closely unpack how individuals tasked with implementing these goals grapple with and overcome barriers.

What are the challenges associated with educational transformation?

Often unspoken and unacknowledged, attempting to innovate in an environment steeped in tradition can result in numerous challenges. From a purposefully selected review of several major universities in the United States undertaking such change in the

last five years (specifically, Arizona State University, University of Maryland, Southern New Hampshire University, Georgia State University, Massachusetts Institute of Technology, and Purdue), we have identified several elements that crosscut each universities efforts:

- a strong university leader who has projected a vision for the 21st-century learner;
- embracing and investing in digital tools to assist learners; and
- a large personnel base to design, build, and implement.

Case study

The following ten categories have been identified from a review of the academic literature, our participation in this space over the last ten years as researchers, and in-depth analysis of transcripts from a recent 2019 Pedagogy and Virtual Education (PAVE) meeting (n = 10) at our case study university in the desert southwest. PAVE is a self-generated working group that aims to share successes and struggles. PAVE members include senior developers, directors, researchers, and content experts who focus on non-degree education.

Using both a narrative analysis and constant comparative methodological approach, ten major categories were identified through a close review of the collected data. Two researchers met to explore their independently coded analysis to identify the overarching categories and discuss any discrepancies in coding. The third researcher independently cross-checked the effort.

What lessons can we learn from those involved in transforming higher education?

Listed below are the ten constructed categories with simple clarifying descriptions. We use the term implementer to describe an employee of the university and learner to describe someone who engages with learning at the university. These considerations include:

- clarify purpose for both implementers and learners;
- use transparent terminology for both implementers and learners;
- design coherent learning pathways and create an accessible learning environment;
- determine standards/quality metrics used by the institution to demonstrate trustworthiness of constructed assets that represent the earned result (e.g., certificate, badge, credential);
- describe learning futures that include a rich exploration of scale, models of learning, questions about the future of learning, and account for path dependency;
- ensure that the purpose, direction, and goals are not only clear but also include iterative evaluation;
- develop incentives/business model(s) to explore mechanisms for implementation, evaluation, revision, and recognition;
- offer resources and provide support for implementers;
- identify and research the intended learner population to ensure that specific needs for retention and completion are met; and
- create and implement learning assets through a careful examination of what is in/out of scope and in light of what already exists.

Discussion

We center on three key categories: clarifying purpose, using transparent terminology, and identifying relevant standards and measures. Originating from an aspiration to execute high-quality work in the digital education landscape, PAVE meeting participants identified a deep desire for a more cogent vision of transformation from their institution. They wanted to participate in the co-creation of such vision or to be able to directly shape its ultimate formation. A top-down decision-making approach, commonplace in higher education, often obscures what is actually taking place on the ground. One participant mentioned, "[Leadership] is not on the ground, creating this content. So, they are looking at us in our little boxes, watching us run around our little mazes going, oh, they must be doing that." This is illustrative of many university initiatives that may overlook the importance" of clarifying the rationale.

Similar to a desire for a coherent vision is the need for clear terminology. Understanding the definition of particular words, phrases, and acronyms such as Continuing and Professional Education (CPE), Career and Technical Education (CTE), and Professional Education (PD) present a hurdle. Likewise, relating and connecting often ambiguous terms to broad university initiatives can increase confusion. For instance, one member during the meeting mentioned, "Just below the [overarching initiative]. Do [we] separate at that point by academic for-credit and non-academic for-credit? What's the next level below the initiative?" As various large-scale initiatives evolve, another implication for practice is to take the time to ensure that the main message/goals are clear.

Another consideration is quality standards and metrics. Notably, participants were concerned that quality would be diminished within the non-degree space without quality-

control metrics such as formal accreditation oversight. Other members questioned how they could better design content or legitimize various types of content learning assets that could meet the needs of evolving learners within a digitally-transformed world. Institutions must consider their broader roles, including asking how their efforts could or should transcend the concept of offering traditional university courses.

Additional questions that are worthy of consideration are:

Q1. How can university leadership develop better systems for the co-creation of institutional transformation or modify midstream existing visions?

Q2. Could universities involve personnel earlier on and seek more robust feedback?

Q3. In what ways and to what extent should universities help designers navigate emerging trends and terms?

Final thoughts

For universities seeking to innovate beyond the traditional modes of education to meet the needs of learners at the pre-college, college, and post-college levels, sharing the experiences and challenges from those who have begun down this path is critical. Creating new methods and models for a wide array of diverse learners requires breaking out of traditional structures, which can be difficult on a variety of fronts. It is useful to explore universities who are trying new techniques and pushing boundaries. Likewise, it is also important to examine the inevitable growing pains that are part of the journey so they can be addressed and overcome as part of the process of pushing learning forward into the 21st century.

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CHAPTER 5

DISCUSSION

Change is inevitable. Higher education is altering and being altered by society through culture, rules, innovations, technologies, and the rapid pace of these changes. However, universities' essential role has not and should not change; higher education develops people (Weber & van der Zwaan, 2020). Envisioning collective futures that take into account a rapidly evolving world where people live longer, can easily connect with others worldwide, and where Google has the explicit mission to share the world's information, requires consideration of what a redesign of higher education should look like. We need to consider the types of knowledge, values, and attitudes higher education should intentionally promote into the 21st century. The studies presented throughout this dissertation represent a form of action-oriented research that begins to carve out an answer to these overarching research questions presented in Chapter 1.

Action-oriented research aims for transformative change through the process of selecting a deliberative action, making and deploying the intended change, and simultaneously conducting research with critical reflection for adoption (Rauch et al., 2014). This approach represents a process of inquiry in which an iterative and reciprocal relationship exists between the study and the action in a cyclical form (Rauch et al., 2014). Changes in higher education, even seemingly ideal ones, cannot be made in isolation. These modifications need to be part of a broader strategic plan in which changes are placed in context, evaluated, possibly modified, and appropriately shared with internal and external publics (Warner, 2002). Inquiry through action-orientated research is needed to demonstrate the type of connectedness between intention and action

that is necessary as higher education explores the most effective path(s) toward intentional redesign at various scales. This dissertation aimed to generate new ideas, develop elegantly-designed circular assets, and explore how these ideas, pedagogies, and assets performed systematically within a higher education setting. In service of those broader aims, this dissertation investigated affordances, barriers, and reactions to implementation as well as concepts of co-creation and participation, transdisciplinarity, and education for the 21st century. The methodological choices made in Chapters 3 and 4 — namely participatory action research and case study methodology with narrative analysis using a constant comparative methodology — underscore the need for various ways of collecting, assessing, and evaluating actions. Similarly, published research not collated here, but part of the larger described project on elegantly-designed experiences deploying cutting edge topics in higher education, represent the types of data one can collect and the inferences that can be made toward the adoption of transformative change (see Foley et al., 2017; Merritt et al., 2019; Shelton et al., 2016).

Chapters 2 and 3 provided two ways of working toward transformations in higher education and society while making deliberate use of sustainability's boundary-crossing topic. The first researched, created, and deployed four specific frameworks (futures, values, systems, and strategic thinking) for engaging with sustainability topics both visually and textually and the second created and deployed cutting edge hybrid curriculum for preservice teachers on the topic of sustainability science education. The field of sustainability, as described throughout, is an important topic that higher education institutions can mobilize by leveraging their knowledge assets (e.g., faculty, students, staff, campuses, research endeavors, knowledge creation) for the greater good of the

communities they serve. With compelling new ways of sharing content through elegantly-designed experiences (e.g., digital storytelling), universities are particularly poised to make this transdisciplinary topic both engaging and valuable as a catalyst for change.

Sustainability, conceptualized as a goal, endeavor, or solution, "aspires to link knowledge to social actions that advance visions of natural and social well-being" (Miller, 2013). However, because sustainability is such a large, amorphic topic (Brown, 2016), learners need coherent knowledge maps or starting points that reduce the complexity of the topic, to engage with sustainability thinking and work. Chapter 2 presents four lenses for engaging with the complexities related to sustainability. The four lenses — futures, systems, strategic, and values thinking — were shaped by conversations with colleagues at the university engaged in various research areas and through a deep dive into the academic literature. Higher education provides opportunities for this type of cross collaboration with multiple fields of study that may not otherwise communicate.

More than just describing the four lenses with characteristics and examples, Chapter 2 presents them through the pedagogical strategy of elegantly-designed experiences. Each way of thinking is shared textually, visually, and auditorily through approachable and open access videos (see Appendix A). The rich insights that are provided and the way they are presented illustrate an example of the types of reachable intellectual assets higher education can produce. One can think of these types of highly curated and designed assets as stackable building blocks that can be placed into a variety of courses and websites. As a result, each of the Four Ways of Thinking videos can be

shared with a wide range of learners both through traditional means such as coursework, along with non-traditional means such as accessing open-access resources via the internet.

Chapter 3 examines Sustainability Science for Teachers (SCN 400), a required course in the Mary Lou Fulton Teachers College at Arizona State University. This semester-long hybrid course is designed to enable future teachers to engage in sustainability principles while developing their understanding of science from the human perspective. The course presents an issues-based curriculum underpinned by social and biospheric responsibility (Hale et al., 2017). The included study emphasizes the course's water unit which demonstrates the melding of sustainability and geoscience to engage educators in a more nuanced understanding of science education. Beyond the presentation of the course curriculum, which is described, the data that was collected spans a 4-year period, unpacks the learner's perceptions, and explores student artifacts produced for the class. Through the analysis of data, the publication shares the story of how elegantly-designed experiences (including compelling content) can transform thinking, make transdisciplinary concepts easy to follow, and provide increased access through a blended learning format. This type of longitudinal data collection is valuable for higher education to take a systematic look at what is actually transpiring within the university's offerings over time.

Chapter 4 investigates the redesign of higher education and the lessons that can be gleaned from the change agents, leaders, and engaged publics — those fostering and leading higher education transformations. Exploring the innerworkings of higher education processes through a narrative analysis of those doing the work (mostly

administration and staff in this case) offers rich insights into how changes are being understood, produced, and administered. Unpacking and making sense of various experiences and challenges from those who have begun the intentional work of transforming higher education is critical. Creating new methods and models for a wide array of diverse learners requires breaking out of traditional structures, which can be difficult. It is useful for universities to share their new approaches and where they are pushing boundaries, including the challenges and the successes of these efforts. This publication serves as a reminder that what may appear obvious to some can be confusing to others, even those within the same division at a university. For significant change to be possible — especially changes that are vastly different from previous manifestations — a repeated clarified purpose, transparent terminology, and easy to access support structures are vital for implementers.

The creative and detailed approach applied in this dissertation addresses the vision and execution that many universities, certainly those that wish to be transformative, are aiming to take or in the midst of pursuing (Weber & van der Zwaan, 2020). The research and concepts presented in Chapters 2 and 3 may appear to be narrow and not generalizable to university wide efforts given that both studies focus on preservice teachers, specifically future teachers in grades K-8. However, a population of preservice teacher undergraduates at a public research university who have a deliberate career path aimed to prepare the next generation is actually an ideal population to explore the concepts of sustainability and elegantly-designed learning experiences aimed at transforming higher education.

Throughout this dissertation, key contributions to the evolving fields of redesigning higher education, educational pedological practices, and education for sustainability are highlighted. However, as with any research, there are limitations to the work presented. Further research would be required to explore how educational transformations proposed by this work could be applied in other fields of study or departments (e.g., architecture, engineering, history) within higher education. While preservice teachers found both the content and the presentation valuable as described in Chapter 3, other fields of study may not have similar reactions and may require buy-in, early ideation participation, and regular co-creation opportunities. Similarly, mobilizing elegantly-designed solutions has a financial cost that is not directly described in the included research. From graphic designers to content area experts, to project managers, creating transformative content that is engaging and compelling to students and can be utilized in various courses and educational settings, requires planning, resources, and time — all of which comes at a cost. For example, to produce the Four Ways of Thinking videos (see Appendix A) a project manager, content area experts, a graphic designer, and a multimedia specialist were contracted (Warren et. al., 2014b). Similarly, Chapter 4 explores an informally-constructed working group at a public research university and the challenges and successes of implementing a big vision of transformation to various programs and initiatives across a single university. While the insights are seemingly transferable to other universities, a multi-university study using a Delphi research methodology, for example, would confirm the trustworthiness and transferability of the findings described in Chapter 4.

There is a real-world need for the type of action-oriented research presented in this dissertation, including work that unpacks the types of knowledge higher education is working to create, leverage, and share. Being reflexively deliberate about the types of knowledge, values, and attitudes that institutions of higher education are intentionally promoting is essential for the educational endowment that higher education is bestowing upon the future and to ensure basic elements of our democracy. What may seem obvious or easy can actually be quite complicated within higher education settings where change often looks glacial. For example, as described in Chapter 4, researching how university employees understand new plans to ensure a horizontal and vertical execution is critical for seamless transitions and coherent changes that are not lost in translation from leaders to their staff.

Similarly, providing sustainability experiences for preservice teachers, as detailed in Chapter 3, is a novel approach within teacher education in the United States. It presents an opportunity that goes beyond the basic required curriculum that are typically offered by colleges of education. For example, the 2016 Flint Michigan case study explored in SCN 400 exemplifies the need for a rich exploration of socio-techno-ecological relationships that highlight infrastructure, politics, and geosciences to better expose how thinking across the curriculum can highlight consequences that disproportionately affect poor and minority populations (Stibbe & Luna, 2009). Tomorrow's teachers, and frankly all learners in higher education settings, need to be equipped with sufficient content knowledge presented in a clear, understandable, and relatable way through elegant design to be able to explore the scientific and humanistic realities of current issues.

Expanding Elegantly-Designed Learning Experiences

Transformation for the highest social good is imperative, and higher education is an essential public good. From climate action, a growing global population, to reduced inequalities, there is much work to be done that requires knowledge, skills, and passion to work toward a just world (UN Sustainable Development Goals, 2020; Weber & Duderstadt, 2012). Higher education should promote an educated democracy equipped with detailed expertise from particular fields of study, but perhaps more importantly, with transdisciplinary understandings and mental knowledge maps that allow for cross-fertilization of big and creative ideas (Coleman, 2009). It is through this very passion to shape a better future that higher education institutions should become more open and inclusive spaces for encounters between different peoples, cultures, and perspectives. Greater recognition of the myriad of challenges faced by underrepresented populations and a commitment to addressing related issues are essential elements of any transformation of higher education. Likewise, there should be many pathways into the university throughout one's life, and not all avenues need to lead to a formal undergraduate or graduate degree; some may want to engage with continuing education and lifelong learning opportunities. As social institutions by their very design, higher education has a responsibility to the publics with which it engages. It should map community needs and visions for a better future, and then work through local partnerships (e.g., government and nonprofit organizations) to forge deliberate educational offerings. This type of endeavor can work to meet the evolving social contract that higher education has with society toward an intentional common good (Crow & Dabars, 2015; Weber & van der Zwaan, 2020).

Teeming with vibrant ideas and an urgency to engender an impowered knowledgeable society, most institutions are responding to the challenges and opportunities presented by a changing world. A knowledgeable public is forged through higher education experiences. This knowledge transfer includes historical accountings, humanities experiences, STEM interactions, and social–technological–ecological understandings—all of which are shaped through essential critical thinking skills. Elegantly-designed experiences that foster coherent knowledge translation and invite knowledge creation are vital for all learners to engage with and make sense of, in an effort to solve the complex challenges our world faces and will continue to encounter in the decades to come.

As described throughout Duderstadt's (2009) writings, drivers of higher education's transformation include financial constraints, society's changing needs, technological innovations, and market forces (p. 321). Some of these drivers for change may at first appear to be problematic, but there are many examples of universities working toward creative solutions to these current challenges. Such examples include the University of Michigan and Arizona State University, institutions that have sought innovative funding strategies as state resources have been reduced significantly over the years (Faller, 2018; RU-TV Network, 2018). Higher education, by many measures, is evolving to serve new demographics with the explicit goals of inclusivity with whom they admit, educate, and matriculate (Christensen et al., 2011; Arizona State University, 2020). More recently, COVID-19 has required that higher education institutions confront and conceive creative, accessible, and digitally enhanced ways of delivering education to our country's vast population of learners (Kim, 2020).

The research presented in this dissertation contributes to my portfolio of efforts to realize the redesign of higher education. A 2019-2020 grant from the U.S Embassy in Kosovo titled, *Creating a Kosovo Educator Course; Integrating Education for Sustainability into the Classroom* is one example. This project reimagines a newly launched professional development course created as an offshoot from the SCN 400 course described in Chapter 3. The online professional development course is an example of extending the reach of higher education offerings to new audiences through elegantly-designed instructional experiences that incorporate the topics of sustainability, the Four Ways of Thinking, and digital storytelling to engage the learner. The project, one of the first university-developed online courses in Kosovo, leverages existing content and sequence but is reimagined for an audience of classroom teachers. Answering the need for more inclusive ways of engaging with Education for Sustainable Development (ESD), the elegantly-designed course provides educators, classroom teachers, and administrators from Kosovo practical ideas, materials, and cutting-edge ways of thinking about sustainability to bring to their young learners. The Republic of Kosovo, through the Ministry of Education, Science, and Technology Committee, approved a new curriculum framework in 2016 that aims to revise all course work through the lens of sustainability and sustainable development. However, few existing resources are accessible because most resources are in English, rather than Albanian, which is the common language. Likewise, given a lack of resources, those in Kosovo do not have widespread online learning use. This project seeks to create a culturally relevant course in the appropriate language and is provided in an online platform accessible for their learners. The course, co-produced as a collaborative effort by those at Arizona State University and the

University of Prishtina in Kosovo, represents the power of higher education to transform society and leverage valuable assets beyond the walls of one institution. Universities do not readily share course content or materials. Therefore, this example presents a break from the past of the isolated actor, and ushers in a nontraditional way of creating content and sharing expertise. University structures that fully embrace collaboration, creativity, and use multi-institution solutions will lead to concrete action that begins to solve some of the urgent issues our world faces.

Final Thoughts

Higher education institutes are one of the most fascinating ecosystems we have in which to explore the current values that shape society, review our collective histories, and draft grand visions of tomorrow. As Duderstadt (2009) described, higher education is both a curator and conveyor of knowledge and values; it transforms and is transformed by the very society it serves. Throughout this dissertation, I demonstrated my visions of intervention into the redesign of higher education institutions through three main crosscutting concepts:

1. Higher education institutions prepare members of society to become responsible and informed citizens, and should do so intentionally with the guiding principle of making the world a more equitable place by furthering innovative broad-reaching topics such as sustainability—which higher education is poised to articulate with authority. Higher education has a civic responsibility to provide new ways of thinking, being, and doing in the world and provide more access to education to broader society, especially through public research institutions

2. Second, with a vast array of available learning materials, higher education should invest in elegantly-designed experiences consisting of well-reasoned, meticulously-curated, and high-quality content that is aesthetically appealing, engaging, and accessible to a broad audience.
3. As universities transition from the gatekeepers of knowledge to the connectors of knowledge, ensuring that a coherent mission is articulated and invested in by stakeholders is vital to the success of any transformational effort, as it will provide a rationale for curricular paths and major educational shifts.

Each of these points considered on its own or as a collective whole can drive change and foster creative learning opportunities that can be accessed by a plethora of publics from degree-seeking students to lifelong learners. Prioritizing an educated society prepared to face the world's challenges is an avenue worth pursuing intentionally. This needs to be balanced and align with local realities, community needs, each university's core practices, and overarching mission. Essentially, targeting social change, innovation, and an educated community through elegantly-designed experiences can be a foundation in which more extensive changes are fostered. Higher education and its transformation toward a more inclusive learning environment are at the core of our educational endowment in the United States. Such efforts to improve higher learning institutions are vital as higher education provides the necessary core for an educated democracy, poised to construct a more equitable, inclusive, and diverse society guided by integrity. These are essential components to make good on the altruistic motivator of making the world a better place through education.

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APPENDIX A

FOUR WAYS OF THINKING WEBSITE LINKS

- Four ways of thinking YouTube playlist for general audience of learners: https://www.youtube.com/playlist?list=PLuw96SM3dPmcMB9umkMNUu4miTgmrvKQx
- Four ways of thinking YouTube playlist for educator audience: https://www.youtube.com/playlist?list=PLuw96SM3dPmcRht3hYtBLlggAF1TE2is5
- The open source article on the Four Ways of Thinking is presented in an elegantly-designed experience textually, visually, and auditorily with pithy and visually intriguing freely available closed-captioned YouTube videos: videos:http://www.susted.com/wordpress/content/sustainability-education-framework-for-teachers-developing-sustainability-literacy-through-futures-values-systems-and-strategic-thinking_2015_01/#:~:text=craft%20meaningful%20evaluations.-,SEFT%20embraces%20four%20ways%20of%20thinking%E2%80%93%E2%80%93futures%2C%20values%2C,knowledge%20that%20must%20be%20acquired

APPENDIX B

PREVIOUSLY PUBLISHED WORKS

Chapter 2, *Sustainability education framework for teachers: Developing sustainability literacy through futures, values, systems, and strategic thinking* was previously published in *Journal of Sustainability Education.* Approval from all co-authors was received on Monday September 14, 2020 via email for use in my cumulating experience dissertation document.

Warren, A., Archambault, L., & Foley, R. (2014a). Sustainability Education Framework for Teachers: Developing sustainability literacy through futures, values, systems, and strategic thinking. *Journal of Sustainability Education, 6*, 1-14. http://www.jsedimensions.org/wordpress/wp-content/uploads/2015/01/Warren-et-al.-JSE-May-2014-With-Hyperlinks-Rider-corrected.pdf

Chapter 3, *Integrating geoscience and sustainability: Examining socio-techno-ecological relationships within content designed to prepare teachers* was previously published in *Journal of Geoscience Education.* Approval from all co-authors was received on Monday September 14, 2020 via email for use in my cumulating experience dissertation document.

Hale, A. E., Shelton, C. C., Richter, J., & Archambault, L. M. (2017). Integrating geoscience and sustainability: Examining socio-techno-ecological relationships within content designed to prepare teachers. *Journal of Geoscience Education*, *65*(2), 101-112. https://doi.org/10.5408/16-177.1

Chapter 4, *Lessons from within: Redesigning higher education* was previously published in *Development and Learning in Organizations: An International Journal.* Approval

from all co-authors was received on Monday September 14, 2020 via email for use in my cumulating experience dissertation document.

Hale, A., Archambault, L., & Wenrick, L. (2020). Lessons from within: redesigning higher education. *Development and Learning in Organizations: An International Journal, 34*(2), 37-40. DOI 10.1108/DLO-09-2019-0203

BIOGRAPHICAL SKETCH

Dr. Annie Elizabeth Hale is based at the Biodesign Institute, Arizona State University, Tempe, Arizona, USA. She is a Director of Research and Development for the Biodesign Pathfinder Center at Arizona State University. Annie's work combines the fields of science and technology studies, sustainability, and design from a human-centered approach. Her research interests focus on the question: How do people construct and understand the world around them, and, in turn, how do those constructs change the way people engage with their world? She directs various educational programs that target sustainability and 21st-century learning that aim to inspire, engage, and empower a variety of publics, from educators to community leaders, through elegantly-designed experiences. Annie is a learning design expert weaving in best pedological practices for online, hybrid, flipped, and face-to-face learning experiences. With a background in design, Annie creates experiences that are simple, smart, and well-conceived.