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Conceptual Change Theory's Potential to Support Collaborative Environmental Problem Solving: Analogous Values and Convergent Properties

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Conceptual Change Theory's Potential to Support Collaborative Environmental Problem

Solving: Analogous Values and Convergent Properties

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Abstract

Contemporary understanding of our nervous system supports the contention that environment is inexorably linked to learning; that all experiences are learning experiences and all learning is experiential (Gooding & Metz, 2011; Hayward, 2012; Wilson, 1999). Public education systems in the US grew to accommodate cultural developments and were not designed to implement experiential education (Bishop & Scott, 1998; Dewey, 1915; Hayward, 2012). Ecologists and sociologists agree that global population growth and development are pushing our society to a precipice where traditional methods of production, valuation, and resource management become inadequate (IPCC, 2014; Proctor, Smith, & Wallace, 2013; Steffen & McNeill, 2007; Tietenberg & Lewis, 2012). Respected analysts from multiple disciplines have consistently expressed a need to update our system to one in which public good and sustainable development are guiding principles (Morton, 2012; Proctor, Smith, & Wallace, 2013; Steffen & McNeill, 2007; White, 1967). A populace that is informed and able to engage in collaborative environmental problem solving will foster this transition (Daniels & Walker, 2001; Hayward, 2012).

The objective of this study is to provide a synthesis of theoretical and experimental support for the claim that students who practice cooperative science learning through the Conceptual Change Model (CCM) may be better prepared to address environmental issues as collaborative citizens. Learning activities based on the CCM of knowledge acquisition developed by Schmidt, Saigo, and Stepans (2001) are analogous to effective collaborative environmental problem solving processes put forth by Daniels and Walker in *Working through environmental conflict: The collaborative learning approach* (2001). Some theorists recommend that methods

be augmented with cultural knowledge to extend connection to place (Sinatra, 2005; Zhou, 2012). Based on the results of this academic investigation, I conclude the use of CCM to be potentially effective in encouraging development of skills common to environmental problem solving. I propose a commitment to creating lifelong learners adept at integrative collaboration be adopted as a universal goal of public education. Meaningful experiential learning can incorporate critical thinking and cooperative problem solving while accommodating individual cognitive ecologies.

Acknowledgements

"Human beings are born intelligent. We are by nature question-asking, answer-making, problem-solving animals, and we are extremely good at it, above all when we are little. But under certain conditions, which may exist anywhere and certainly exist almost all of the time in almost all schools, we stop using our greatest intellectual powers, stop wanting to use them, even stop believing that we have them."

-John Holt, 1982

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Introduction

Personal Statement

When I was a public school student, I would never have predicted that I would be a teacher. It wasn't that I disliked school. I earned good grades and enjoyed socializing with my friends. My strongest subjects were consistently science and math. I now believe that my problem was that I was not sufficiently engaged by learning activities. This often manifested in an adversarial relationship with my instructor. I found myself labeled a nuisance or troublemaker by teacher after teacher. This caused tensions at home as well. As I matured, I learned to control impulses but still felt uninterested at times and, still got myself into trouble. Luckily, I had the opportunity to spend time outside through sports, Boy Scouts of America, family outings, and free time with friends. I have never recognized a division between classroom and experiential learning and I do not doubt the ever present impact of nurture on our nature.

I have always experienced a sense of serenity in natural places that I rarely enjoy indoors. My outdoor experiences were some of the most valuable lessons of my life. Beginning early in childhood, I was encouraged to use outdoor spaces for play. My family spent countless weekends in and around a small trailer in the Catskill mountains where I was able to explore the landscape. At home, our suburban town offered ample opportunity to roam formal playgrounds and adjacent forested areas.

Parents of the neighborhood were eager to release us to the wild. My best friend and I would build forts and rally allies, engaging in tribal warfare with rival sects of the neighborhood. The locations of secret shrub passages, easy stream crossings, and choice hiding spots became vital information. Rocks, branches, leaves, and snow were seasonal building materials and art

supplies. These experiences shaped my worldview by demonstrating that nature was not an enemy, it was a source of creativity, a playmate. This comfort outdoors grew into confidence through my involvement with the Boy Scouts.

I am one of the few, the proud, the nerdy whom attained every rank in the Boy Scouts, from tiny Tiger Cub through majestic Eagle Scout. While earning the rank of Eagle is arduous and I count it as an accomplishment, I consider the prestige to be secondary to the intellectual capital that I acquired. Under the tutelage of wise adult leaders (and a few not so wise), my confidence and leadership abilities flourished. My relationship to the outdoors deepened as I learned basic survival skills attuned to ecological conditions. I derived profound satisfaction from extracting subsistence and wisdom from the earth. It was not long before I attempted to connect observations from outdoor experiences with the classroom science that I found fascinating. My relationship to nature matured from playmate to guide.

Thus began my passionate pursuit to understand everything around me. It is thrilling for me to be able to describe underlying processes driving observable phenomena. This thrill pointed the way to my vocation during an experience at a National High Adventure scout camp in the Florida Keys. As an Island Mate (a title second only to Ice Cream Jerk in drawing ridicule from my sister), I was charged with leading crews of 8 on a 5 day excursion to an undeveloped barrier island. Given a high degree of deference in programming, my style as a wilderness guide began to emerge.

When I reflect now on lessons facilitated on Big Munson Island by 19 year old me, I discover that connection to place enhanced every endeavor. I wasn't trying to teach. I was only trying to use the island to do fun and interesting things. It was not until years later, post baccalaureate, that I would be motivated by this experience to become a classroom teacher.

As a public high school science teacher, I would teach students that ecology is a selfish science. "We study the interactions between organisms and the earth so we can best make use of our resources into the future." This utilitarian position is usually well received. However, I realized that my own understanding of man's relationship to nature presumed the existence of intangible benefits of biodiversity. I used the selfish definition of ecology to widen the appeal of environmental science and conservation but, I was doing little to address the way students felt about their environment. The missing piece was the connection that I *feel* to the world that sustains me.

My experience and studies indicate to me that the affective domain is intrinsically part of any learning experience. Towards the end of my classroom time, I attempted to bring in some of my outdoor education experience. I found place based principles to be effective and compatible with classroom curricula. I thought to myself, "Self, I bet that if I use outdoor education tricks, students will be more engaged, and learning will be more effective." In pursuit of validating this nebulous hypothesis, I set out on a two year odyssey to support my contention. This document is one product of that investigation.

My quest to understand how people relate to their surroundings while they learn involves the matter of whether we are a product of our genes or our environment. After much cogitation on the matter, I believe that there is no answer to the age old question of nature vs. nurture. We, and all living things, are an ever changing product of an initial set of genetic prescriptions that are subject to environmental alteration. Our paths begin with a certain breadth afforded by our genetics and are subsequently narrowed, expanded, or redirected by environmental conditions. Our decisions and decisions made by others on our behalf can impose entirely new paths or keep us trained on a desired outcome. The emerging field of epigenetics is the pursuit of

understanding how gene activity can be modified by environment. This resonates with me as I know that every living thing must be adaptable to various situations and mankind's golden ticket was our flexibility.

Homo sapiens has adapted, either socially or biologically, to explore all the ecosystems on earth (that we know about). As sentient beings, we are able to use complex observations to make long term decisions. In the next section, I will discuss human physiology related to the brain and this ability. We've used our evolutionary gifts to multiply, diversify, and monopolize. We have the skills and knowledge to shepherd our own history. Regardless of how you believe we developed our big brain, it is my contention that it should be used in pursuit of sustaining an "unconditional coexistence" (Morton, 2012) with all entities on earth. This position is sometimes regarded as unreasonable. However, I posit that it is in mankind's best interest.

As a student, employee, outdoorsman, leader, and teacher, my observations have consistently indicated that engagement, relevance, and connection to established cognitive concepts are what make effective learning occur. My goal is to use place based strategies to create learning experiences linking real world observations to content in a way that inspires wonder. I see a future where collaborative skills, creative problem solving, and commitment to common long term goals are vital characteristics of an American. I recognize that the values that I have employed in developing these goals are not shared universally. The justification for my position is derived from my experience. I remind myself that my values and experiences determine my worldview as they do for any other person.

Background

Contemporary understanding of our nervous system supports the contention that environment is inexorably linked to learning. Legendary scientist and philosopher, E.O. Wilson claims that it is this activation of not just the intellectual mind but the emotional mind that leads to empathy and deconstruction of barriers to meaningful learning (1999). If we work under the assumption that all truthful knowledge is good, we may further expound the influences affecting human experiential learning.

The following is an original proposition using anecdotal analogies. I feel that this informal account relates to later discussion. Within the boundaries of experiential knowledge, we may consider positive learning experiences (PLEx) and negative learning experiences (NLEx). Let positive learning experiences be those that provide meaningful learning to the individual. This is dependent on learning style and can be defined as the successful and unbiased relation of accurate information about the way one's environment functions. This implies that the content be incorporated into the person's intellectual framework to be relied upon later and, that the learning experience was neutral in presentation.

Let a negative learning experience be one that provides inaccurate information, misrepresents information, or attempts to manipulate the learner's cognitive ecology to support an agenda. Negative learning experiences are not usually known to be negative by the learner and can create misconceptions or psychological reticence to engage in a topic. These categories should be applied on small scales; where one event could provide opportunity for both types to occur.

For example, if I was learning to fix a foreign made lawn mower with my grandfather, I may have absorbed some valuable mechanical concepts (PLEx) while also being misinformed about the people in the mower's country of origin due to papa's own biases (NLEx). PLEx

would advance my engineering knowledge, dexterity, ability to complete complex, step-wise operations, self confidence, etc. as I watched, listened to small tips, and contributed when possible. NLEx here would occur to the tune of "this is what happens when you don't buy American" or "they make it this way so it breaks and you buy a new one" or "Jap engines are a bitch, everything is tight because their hands are so small." I may develop misconceptions from this experience that impact my future ability to collaborate. For instance, I may now have a negative preconception of Japanese people and be less likely to cooperate with individuals that my mind connects with grandpa's opinions.

This issue is compounded by the relationship to the instructor. I am more likely to adopt papa's racist notions because I love and respect him. I also compare this experience, consciously or otherwise, with other similar experiences, like helping my father with work. Cataloging similarities and differences between the experiences informs the way I will approach this type of work; likely a combination of dad's and papa's techniques.

Studies indicate that our values are influenced as the network of our mind restructures connections to integrate new observations. Schwartz argues that our emergent "value orientation" (Clement & Cheng, 2011) is a relative hierarchy of self-direction, stimulation, hedonism, achievement, power, security, conformity, tradition, benevolence, and universalism (Schwartz, 2014). My value orientation (Clement & Cheng, 2011) may change slightly to favor the self-direction, achievement, and security values as a result of the PLEx above. The NLEx aspect of this lesson may influence my power, conformity, benevolence, and universalism values in a way that detracts from my readiness to learn collaboratively (Schwartz, 2014; Daniels & Walker, 2001). These experiences inform how we enter a learning environment and may provide

the foundation of our interpretational abilities and behavior during collaboration (Daniels & Walker, 2001; Schmidt, Saigo, & Stepans, 2006).

Neurological Response to Environment

To help understand how people learn, it is useful to consider the biology of the human nervous system. A nerve cell (neuron) is like a tiny wire that communicates with many other nerve cells. The wires can initiate their own signals and transfer impulses in both directions to other neurons (Wilson, 1999). Bundles of these cells make up structures called nerves that carry signals (Wilson, 1999).

Afferent and efferent nerves are in place to get information to and from the brain (Shmaefsky, 2007). Nerve impulses travelling towards the brain are known as **afferent** while those that travel away from the brain are called **efferent** (Shmaefsky, 2007). Afferent nerves carry signals inward to the spinal cord from sensory organs located all over the body (Shmaefsky, 2007). The spinal cord leads directly into the brain where information is processed (Shmaefsky, 2007). The brain's response to stimuli is transmitted down the spinal cord through efferent nerves in the form of motor impulses (Shmaefsky, 2007). The brain processes incoming (afferent) signals and initiates a response through outgoing (efferent) pathways (Shmaefsky, 2007).

The brain itself is also made of neurons that are interconnected in a vast web that is then intricately folded to fit in your skull (Wilson, 1999). Neuroscience indicates that tissues of the brain are spatially organized by their function (Wilson, 1999). E.O. Wilson provides a springboard for unification of informal and formal learning in *Consilience* (1999).

In his model, the area of the brain responding to the stimuli is determined by nature of the environment (Wilson, 1999). The human brain can be imagined as an "evolutionary onion" wherein the neurological structures are layers and their importance to survival is directly related to their closeness to the core (Hubbell, 2014; Wilson, 1999). The three main sections are the brainstem, limbic system, and cerebral cortex (Wilson, 1999). See figure 1 below.

The innermost layers monitor and control very basic physiological and biochemical processes like breathing, circulation, and balance (Wilson, 1999). This **brainstem** is is similar in all vertebrates (Wilson, 1999).

The limbic system is situated atop and around the brainstem in precise position to relay between this basic brain and the higher brain (Wilson, 1999). The **limbic system** integrates emotions and memories (Wilson, 1999).

The outermost layer is referred to as the cerebral cortex, or cerebrum, and is most recognizable as a furrowed, folded dome of tissue (Wilson, 1999). Inside the wrinkled jelly of the forebrain is a dense network of tens of billions of nerve cells with 1,000 to 10,000 connections apiece (Hubbell, 2014). Constant flows of electrical and chemical signals careen through the biological wires of the cerebrum in complex patterns (Wilson, 1999). Sustained activation of neural pathways in this part of the brain is what we experience as consciousness (Wilson, 1999). Neural activity in the **cerebral cortex** allows complex decision making to occur (Wilson, 1999).

This "onion" model describes the organic machinery we use to interpret the world. "The key functions of the three successive divisions -hind plus midbrain, limbic system, and cerebral cortex- can be neatly summarized in this sequence: *heartbeat*, *heartstrings*, *heartless*" (Wilson, 1999).

Figure 1: "Evolutionary Onion" Layers of the Human Brain

"Heartless"

"Heartstrings"

"Heartbeat"

psychologytoday.com

Now, beyond self, consider the second component of life: environment. All organisms respond to their environment but, humans have applied their cerebral cortices to mastering their surroundings. It is the cooperative functioning of sensory organs and the brain that enables us to analyze our environment (Wilson, 1999). In most humans, the brain is fitted with an array of sensory organs that relate information about surroundings in real time (Wilson, 1999). If we combine these concepts, the nature of experience emerges.

For the sake of simplicity, let us explore the human condition beginning at birth. We exit the womb and our senses are immediately and persistently bombarded. Our prenatal peace shattered by a cold, glaring immensity. Fortunately, we are biologically equipped to make sense of the world around us.

We immediately begin to compile an intellectual encyclopedia about our universe (Wilson, 1999). Memories and attached emotions imprint on the psyche (Wilson, 1999). This

process will continue interminably during our conscious life (Wilson, 1999). We can track the physiological pathways to gain some insight.

Studies in physiology of the brain have inspired a layered model of brain activity (Wilson, 1999). The core is the brain stem that monitors and controls basic life functions (Wilson, 1999). Layer two is the limbic system; a collection of neural masses important in new memory formation and the integration of emotion (Wilson, 1999). The neocortex or cerebrum is the outer shell where our higher thinking emerges (Wilson, 1999). Situations are processed through these layers from the brainstem through the limbic system and out to the neocortex (Wilson, 1999).

Data received by the sense organs are integrated into the nervous system as electrical impulses (Wilson, 1999). These impulses travel down pathways of afferent neurons to the spinal cord and into the inner brain (Wilson, 1999).

Responsible for vital functions, the brain stem responds to the situation which is represented as a combination of nerve impulses generated by sensory input (Wilson, 1999). For example, temperature regulation, a basic life function, is controlled by the core structures of the brain (Wilson, 1999). If receptors in the skin transmit a message that surroundings are too warm, an efferent impulse is initiated that will result in sweat being excreted by glands in the skin to help cool the body. We must remember that it is the total of our sensory input that the brain receives including those monitoring internal conditions (Wilson, 1999). If no external or internal disharmony is causing a threat to homeostasis, no change in hindbrain activity is necessary (Wilson, 1999). In an environment of physical safety where no immediate threat to biological function is perceived through the senses, the response may filter through the next layer of the brain (Wilson, 1999).

The limbic system influences experience by recalling emotions and memories tied to sensory input (Wilson, 1999). This can be recognized as the beginning of learning. When sensory input is received, it activates specific patterns of electrical activity in the brain (Wilson, 1999). Patterns that are the same or similar to those that have been activated before, represent familiar situations (Wilson, 1999). The brain is using a profile of instantaneous sensory input to compare the current environment with previous experience (Wilson, 1999).

Feelings and memories arise to set the stage for human response (Wilson, 1999). For instance, the smells of fresh soil and flowers, warmth of sunshine on the skin, and sounds of insects could activate memories of gardening with a grandparent and thus produce a relaxed, content affect. Alternatively, one's experiences with multiple summer funerals could result in feelings of sadness and loss from the same sensory stimuli. External conditions are being cross referenced with previous experience to create a "mood" that is most likely to prepare the individual to respond (Wilson, 1999).

The last phase of human response to environment makes use of our bulbous forebrain (Wilson, 1999). "The human cerebral cortex is a sheet about one thousand square inches in area, packed with millions of cell bodies per square inch, folded and wadded precisely like an origami into many winding ridges and fissures, neatly stuffed into the quart-sized cranial cavity" (Wilson, 1999). If you unfolded your forebrain, it would cover a third to half of your skin. This part of the brain is used for critical thinking (Wilson, 1999). I propose critical thinking be loosely defined as the ability to interpret information and apply observations and experience to decision making.

The human nervous system grants us this ability. Our huge brain consumes up to 20% of the energy that we use daily (Shmaefsky, 2007). For this hungry organ to be evolutionarily

viable, it has to provide a significant edge to survival. Wilson claims that we use our neocortex

to make complex decisions based on previous experience and incoming sensory information

(1999). He sums up the combined effect of all neural activities on our mind's eye:

> [T]ogether they create scenarios that flow realistically back and forth through
> time. The scenarios are a virtual reality. They can either closely match pieces
> of the external world or depart indefinitely far from it. The recreate the past
> and cast up alternative futures that serve as choices for future thought and
> bodily action. (Wilson, 1999)

Free will is our response to myriad potential outcomes as judged through a lens of memories and

associated emotions. Our neurology banks these memories as sensory accounts of phenomena

within the context of our environment (Wilson, 1999).

Contemporary thinking indicates that the brain's biology is not designed to differentiate

between formal and informal instruction. The brain's approach to learning is based on constant

sensory input and connection to previous experience (Wilson, 1999). When surroundings cause

the sense organs to transmit a familiar combination of electrical input to the brain, emotions that

were present at times of similar surroundings are stimulated (Wilson, 1999).

Once the brain has assessed the scene by comparing the current information it's being

provided with experience, it establishes a mood (Wilson, 1999). Memories then enter the

conscious mind and are used to determine and take action (Wilson, 1999). We use our higher

thinking skills to make decisions based on the situation we are in, how it compares to previous

experience, and likelihood of achieving a desired outcome (Wilson, 1999).

The brain's response becomes conditioned as pathways are strengthened through

reinforcement (Wilson, 1999). The more a neurological pathway is activated, the stronger it

becomes (Wilson, 1999). The activity becomes a habit (Wilson, 1999). Based on this model of

human learning, it is my contention that all experiences are learning experiences and all learning is experiential.

Statement of Problem & Significance

Overwhelming scientific evidence indicates that we are likely to experience ecological changes in the near future due to climate change and, that the sooner we address these issues, the less severe they will be:

> Today, and even with adaptation, warming by the end of the 21st century will lead to high to very high risk of severe, widespread and irreversible impacts globally (high confidence). Mitigation involves some level of co-benefits and of risks due to adverse side effects, but these risks do not involve the same possibility of severe, widespread and irreversible impacts as risks from climate change, increasing the benefits from near-term mitigation efforts. (IPCC, 2014)

Ecologists and sociologists agree that global population growth and development necessitate a shift towards collaborative environmental problem solving (Daniels & Walker, 2001; Morton, 2012; Steffan & McNeill, 2007). Massive, intergovernmental literature reviews suggest that our global resources are finite and we have begun to stress the cycling ability of the planet (IPCC, 2015). There is significant support for the idea that many impacts can be traced to human activities (IPCC, 2015; Steffan & McNeill, 2007).

To deal with the challenges of expanding the planet's carrying capacity, Steffan & McNeill recommend systems "in which the recognition that human activities are indeed affecting the structure and functioning of the Earth System as a whole (as opposed to local- and regional-scale environmental issues) filter[s] through to decision-making" (2007). Mariacristina De Nardi alerts us of the worsening wealth inequality connected to resource use decisions (2004).

Experiential education has the potential to support development of critical thinking and collaborative skills in our public schools. According to the association of experiential education

(EE), "EE is a philosophy that informs many methodologies in which educators purposefully engage with learners in direct experience and focused reflection in order to increase knowledge, develop skills, clarify values, and develop people's capacity to contribute to their communities." Practice in these areas can help inculcate the skills necessary to approach resource conundrums of the future.

Public education systems in the US were not designed to implement experiential education (Dewey, 1915). Institutions and regulations grew organically with the population. Prior to the second half of the 19th century, relatively few resources were committed to public education in the US (ESEA, 1965; Hayward, 2012). Most US Americans led subsistence lifestyles wherein family dominated, functioning ecology was inherently valued, and the local community recognized their interdependence (Dewey, 1915; Hayward, 2012; White, 1967). Dewey and others identify the advent of industrialization made possible by energy from fossil fuel combustion as responsible for shifting the objective of public education in the US to industrial career training (Dewey, 1915; Hayward, 2012; White, 1967).

For over a century, theorists have lamented rigidly structured learning environments and conditioning to follow directives without question (Dewey, 1915; Hayward, 2012; White, 1967). Many would describe school faculty in the way of antagonistic authoritarians to students whose mission was to obey and acquire knowledge deemed necessary (Barrow, 2006; Dewey, 1915; Holt, 1982). Instruction was mostly designed as preparation for work in an industrial setting where laborers are paid to perform a fairly simple, repetitive task with little connection between their work and its contribution to the community (Dewey, 1915). One's education presumed one's vocation, with little regard for individualism (Barrow, 2006; Dewey, 1915). The goal was to encourage large scale economic growth through industrial culture.

After World War II, educational emphasis shifted to executive training. The allure of generating financial gains for oneself obscured the importance of collaboration. Ultra competitive business tactics drove development at a breakneck speed (De Nardi, 2004; Keister & Moller, 2001). Distribution of the wealth created became increasingly more unequal (De Nardi, 2004; Keister & Moller, 2001).

Keister, Moller, and De Nardi point out that the vast majority of wealth created in our economic system remains in the hands of the already wealthy (De Nardi, 2004; Keister & Moller, 2001). Studies in economics describe little opportunity for middle class individuals in the US to move significantly upward while thousands drop below the poverty line annually (De Nardi, 2004; Keister & Moller, 2001).

These economists refer to widespread inequity and strife as demonstrative of the potentially anti-social mechanisms of capitalism (De Nardi, 2004; Keister & Moller, 2001). I would argue that what we are witnessing is a symptom of inadequate regulation; an ever-present growing pain of a capitalist society. In 1902, champion "Trust Buster" and President, Theodore Roosevelt testified, "The great corporations are the creatures of the State, and the State not only has the right to control them, but it is duty bound to control them wherever the need of such control is shown." Many suggest that incorporating the public in resource extraction and associated environmental decisions will be necessary to make meaningful changes (Daniels & Walker, 2001; Proctor, Smith, & Wallace, 2013; Steffen & McNeill, 2007; Zhou, 2012)

Respected thought leaders have consistently expressed a need to update our system to one in which public good and sustainable development are paramount (Bishop & Scott, 1998; Dewey, 1915; Morton, 2012; Proctor, Smith, & Wallace, 2013; Steffen & McNeill, 2007; White, 1967). The fundamental objectives of public education in the US can be made congruent with

expectations of the future and stimulate development of valuable collaborative skills (Morton, 2012; Sinatra, 2005; Steffan & McNeill 2007; Zhou, 2012). CCM activities may have the potential to support this goal.

It is my position that it is more productive to help a student pursue topics that interest them personally than to insist that what is being presented is important to them. Prominent theorists have criticized our reliance on standardization for instruction and assessment as incongruent with learning theory (Dewey, 1915; Hayward, 2012). If a student has well developed analytical skills, they should be able to apply them to any situation and, the need for rote memorization that addles many students falls away (Dewey, 1915; Hayward, 2012). Teaching in this way can help create a generation of fishermen instead of merely fish consumers. Additionally, prominent educators and theorists have recognized the importance of communication and collaboration between students in accommodation of individual cognitive ecologies (Bishop & Scott, 1998; Festinger, 1962; Gooding and Metz, 2011; Hayward, 2012).

To better prepare our nation for the future, a major goal of public education should be to create lifelong learners who are skilled collaborative problem solvers. It is my opinion that this may be most effectively accomplished through educating for collaboration in public schools. When people collaborate meaningfully, they uncover the motivation for each others' positions and can work together towards a mutually beneficial solution (Lewicki, 2011). Behaviors practiced during school can be continuously valuable outside of formal education and are reinforced through repetition (Dewey, 1915; Wilson, 1999).

Purpose of Research

The purpose of this research is to explore the potential of a specific experiential strategy of instruction to reinforce behaviors that are valuable to collaborative problem solving. An investigation is conducted in order to describe and correlate vital characteristics of the conceptual change model of science learning, as described by Schmidt, Saigo, & Stepans in *Conceptual Change Model: The CCM Handbook* (2006) with those of effective collaborative environmental problem solving as set forth by Daniels & Walker in their seminal text *Working Through Environmental Conflict: The Collaborative Learning Approach* (2001). This comparison aims to uncover analogous features and support implementation of conceptual change based activities in public school classrooms as preparation for adult collaborative problem solving. The proposed steps of each process are considered side by side. Vital characteristics of the stages are correlated to explore the link between conceptual change learning principles and environmental problem solving.

Question

The guiding question behind this inquiry is as follows:

What does the academic literature say about the correlation between the conceptual change model of science learning, as described by Schmidt, Saigo, & Stepans in *Conceptual Change Model: The CCM Handbook* (2006) and collaborative environmental problem solving as set forth by Daniels & Walker in *Working Through Environmental Conflict: The Collaborative Learning Approach* (2001)?

<center>**Section 2**</center>

<center>**Literature Review**</center>

Introduction

  Reliable projections made by experts indicate that a profound shift in collective environmental decision making priorities is in order (IPCC, 2014; Morton, 2012; Steffan & McNeill 2007). Educators and ecologists have expressed a need for people to become interested in and concerned about their environment (Bishop & Scott, 1998; Hayward, 2012; Morton, 2012; Proctor, Smith, & Wallace, 2013). Carefully designed collaborative problem solving exercises facilitate sustainable environmental policy decisions with a high chance of stakeholder satisfaction (Daniels & Walker, 2001; Hayward, 2012, Steffen & McNeill, 2007).

  Historical economic analyses reveal that a reliance on market processes to correct inequities can be ineffective (De Nardi, 2004; Keister & Moller, 2001) and that the discounting "externalities" for the sake of parsimony often results in unaccounted for ecological costs (Steffen & McNeill, 2007; Tietenberg, 2012; Wilson, 1999). We are faced with the challenge of integrating these costs into resource use decision making if we wish to support continued population growth (Steffan & McNeill, 2007; Tietenberg, 2012).

  Because collaborative environmental problem solving techniques rely on stakeholder deliberation, they have the potential to identify and mitigate a wider range of impacts (Daniels & Walker). Many natural resource management professionals agree that the people of the US would benefit from a shift in prevailing decision making tactics towards meaningful collaboration (Daniels & Walker, 2001; Morton, 2012; Steffan & McNeill, 2007).

While scientific consensus forecasts a need for cooperative, stakeholder centered negotiation tactics in order to address ecological issues (IPCC, 2014; Morton, 2012; Steffan & McNeill 2007), these methods remain challenging to implement (Daniels & Walker, 2001). Daniels and Walker tell us that successful navigation of complex environmental problems works best when citizens are scientifically literate and able to collaborate (2001). They also identify this key element as a Fundamental Paradox: "Finding ways to increase the technical expertise, while simultaneously increasing inclusivity of decision processes, is perhaps the fundamental challenge of effective policy formation" (Daniels & Walker, 2001). Collaborative environmental decision making methods attempt to deal with the "Fundamental Paradox" of policy design through stakeholder responsibility (Daniels & Walker, 2001).

Stakeholder investment and resultant satisfaction are integral parts of successful collaborative problem solving (Daniels & Walker, 2001). As such, process design demands that stakeholders are accurately identified and, not only represented, but meaningfully integrated into decision making (Daniels & Walker, 2001). Theorists and practitioners recommend procedures wherein common goals are discussed, plans made, unbiased science conducted, and action taken (Proctor, Clark, Smith & Wallace, 2013). As an interdisciplinarian, I noticed parallel processes in academic literature of collaborative environmental problem solving and experiential education. Upon cursory investigation, I found some academic support for the idea that experiential education can be an effective inroad to development of collaborative values (Hayward, 2012). Motivated by an intellectual drive to reconcile my observations, I decided to investigate.

After scanning relevant literature, I identified *Working Through Environmental Conflict: The Collaborative Learning Approach* (2001) by Steven Daniels and Gregg Walker as a seminal text in the field of adult collaborative problem solving. I had been using Daniels and Walker's

book in a graduate course and was interested in unpacking the contents. While the authors celebrate their method's connection to learning theory, I found no academic analyses of a correlation between adult collaborative problem solving and childhood education.

The importance of early education is often overlooked when considering the problems of the complex adult world but, we certainly draw on skills developed in youth to navigate situations in adulthood (Piaget, 1964; Wilson, 1999). I have had the pleasure of studying a multitude of instructional strategies, all of which have their strengths.

Since learning of the Conceptual Change Model, I flagged this instructional strategy as potentially very powerful. I feel that cooperative problem solving skills are invaluable for students to learn. My investigation here seeks to verify through a formal literature review, the value of learning projects as prescribed by Schmidt, Saigo, and Stepans in the *Conceptual Change Model: The CCM Handbook* (2006) in development of skills useful in adult collaborative environmental problem solving as recommended by Daniels and Walker (2001). I hypothesize that this investigation will support the claim that experiential, student generated inquiries have the potential to connect learners with their surroundings in ways that promote lifelong critical thinking, creativity, and collaboration (Hayward, 2012; Posner et al., 1982).

Methods

The objective of this study is to identify areas of overlap between the tenets of conceptual change learning and effective collaboration. Vital characteristics of the conceptual change model of learning developed by Schmidt, Saigo and Stepans in *Conceptual Change Model: The CCM Handbook* (2006) will be catalogued and cross referenced with those of effective adult collaboration as set forth by Steven Daniels & Gregg Walker in *Working Through*

Environmental Conflict: The Collaborative Learning Approach (2001). Additional academic

material will be consulted to aid analysis.

Literature to be considered consists of books, academic journals, editorials, interviews,

practitioner/theory articles, and case studies. The study involves using University of Wyoming

library access to search, read, and analyze electronic journals and physical documents. All

resources will be critiqued for reliability before their conclusions are accepted. Experimental,

correlational, descriptive, and qualitative research may be considered for data collection, though

the investigation focuses on overall conclusions and emergent trends. This inquiry may be

described as a literature review of theory and practical studies.

Figure 2: The Literature Review Process of this Investigation.

Literature Review

Methods

Conceptual Change Model

Collaborative Problem Solving

Description

Vital Characteristics

Vital Characteristics

Description

Analysis

Conclusions
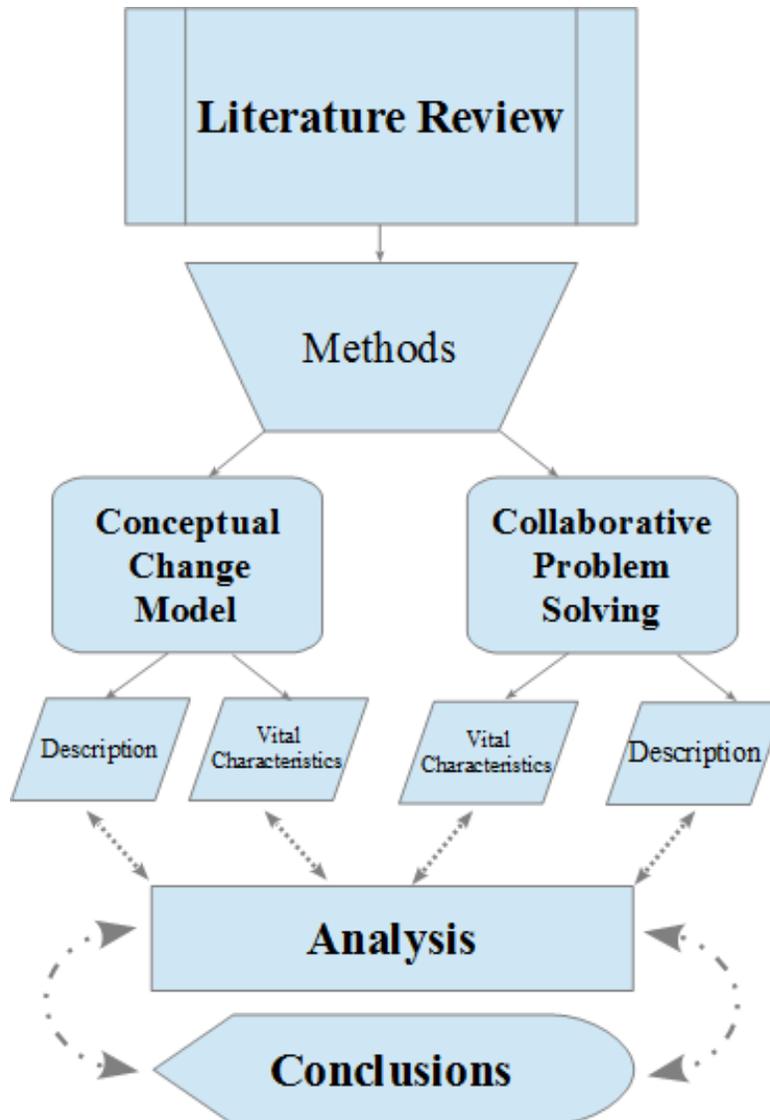
Integrative Vs. Distributive Bargaining

Towards our goal of fostering cooperative, inquiry-based learning skills, we can derive from the literature favorable pathways of learner interaction. Multiple strategies for negotiation are used when solving complex problems (Lewicki, 2011). Assertiveness is useful in conveying one's priorities and competing for resources but, if the ultimate objective is to create maximum value for all stakeholders, it is counterproductive (Lewicki, 2011).

In a collaborative situation, two prevailing attitudes dictate the course of negotiation. A party can view the situation in a competitive manner wherein there is finite benefit to be had.

This situation becomes **distributive**, and no additional value can be created through collaboration (Lewicki, 2011).

Pizza pie ordered by two friends lends a valid analogy. There is a set area of pizza to be split between two people and there is no way to create more pizza. Half the pizza pie goes to each friend. This approach works with simple problems and simple needs. Each friend is interested in all the parts of the pizza. However, if one friend is lactose intolerant, he may only eat the crust and sauce while the the other friend has a gluten allergy and may eat just the cheese. Distributive bargaining leaves each friend with half a pie worth of food they can't eat.

If the friends discuss their value orientations (Clement & Cheng, 2011), they may uncover new ways to approach problem solving. When the differentially digestive friends split the pizza by component (saucy crust to one and cheese to the other), they engage in **integrative** bargaining (Lewicki, 2011). The overall value of the system (pizza pie) is increased through collaboration.

Empathy allows negotiators to join the perspective of other parties and identify targets for compromise (Lewicki, 2011). Only when individuals have considered the motivations and values of their counterparty can integrative bargaining be accomplished. Margins of benefit to each stakeholder depend on many factors (Lewicki, 2011) and, these differentials must be uncovered in order to arrive at a mutually beneficial outcome (Lewicki, 2011). In short, *empathy creates value*.

Summary of the Conceptual Change Model

The conceptual change model of science education is based on the integration of new knowledge into a student's established notions of the world around them by creating

discrepancies (Posner, et al., 1982; Schmidt, Saigo, & Stepans, 2006). When a learner encounters a principle that does not fit well with their existing understanding of a concept, they are cognitively motivated to reconcile the new information with what they believe to be true (Festinger, 1962; Schmidt, Saigo, & Stepans, 2006).

Depending on how much dissonance occurs, the student can accommodate the novel principle by altering his mental framework or modifying the new material so that it can be assimilated into his prevailing conceptual scaffold (Posner, et al, 1982; Schmidt, Saigo, & Stepans, 2006).

Science instruction based on conceptual change requires that students recognize inconsistencies between their preconceptions and accurate observations, investigate these inconsistencies cooperatively using empirical methods, and actively apply their findings in order to cement their revised understanding (Cordova, et al., 2014; Hesse, 1989; Schmidt, Saigo, & Stepans, 2006). Teachers should support students throughout the resolution of their initial misconceptions (Filippatou & Kaldi, 2010; Schmidt, Saigo, & Stepans, 2006).

It is critical that students "share their ideas, predictions, and reasoning with their classmates" in "a safe venue for discussing ideas" (Schmidt, Saigo, Stepans, 2006). In the problem solving that is now relevant and important to the learner, a common goal is perceived. The process relies on this framework and is highly adaptable to content, environment, and learner characteristics (Schmidt, Saigo, & Stepans, 2006).

Figure 3: The Conceptual Change Model

1	Commit to a position or outcome	Students become aware of their own thinking by responding to a question or by attempting to solve a problem or challenge
2	Expose beliefs	Students share and discuss their ideas, predictions, and reasoning with their classmates before they begin to test their ideas with activities
3	Confront beliefs	Students confront their existing ideas through collaborative experiences that challenge their preconceptions; working with materials, collecting data, consulting resources
4	Accommodate the concept	Students accommodate a new view, concept, or skill by summarizing, discussing, debating, and incorporating new information
5	Extend the concept	Students apply and make connections between the new concept or skill and other situations and ideas
6	Go beyond	Students pose and pursue new questions, ideas, and problems of their own

(Schmidt, Saigo, & Stepans, 2006)

Figure 4: Looping back within the CCM

1 Commit to a Position or an Outcome

2 Expose Beliefs

3 Confront Beliefs

4 Accommodate The Concept

5 Extend the Concept

6 Go Beyond

Based upon questions students raise, misconceptions that are revealed, or lack of intended progress towards meeting lesson expectations, a new challenge may be posed.

Students propose new questions or problems to explore as a result of the lesson; may be basis for a new lesson.

The lesson may be one of a nested set of lessons organized within a unit so the teacher may plan to save Extend and Go Beyond to be culminating experiences.

Students' inability to make meaningful connections of the concept, skill, or process to other situations or problems may indicate a need to have more experience to develop understanding

(Schmidt, Saigo, & Stepans, 2006)

Stages and **Vital characteristics the Conceptual Change Model**

Learners...

1. Experience a sense of cognitive dissonance to stimulate inquiry. **(Interesting, Important)**
2. Acknowledge and prepare to modify their preconceived notions.**(Introspective)**
3. Cooperatively investigate phenomena relevant to the concept. **(Interpersonal, Experiential)**
4. Develop a new conceptual structure that is logical and fits with other well-supported knowledge. **(Contextualized)**
5. Take responsibility for outcomes **(Continuingly Relevant)**
6. Constantly refine their understanding in order to rectify discrepancy. **(Iterative)**

Synthesized from Schmidt, Saigo, & Stepans, 2006

Summary of Collaborative Environmental Problem Solving

Steven Daniels and Gregg Walker describe collaborative environmental problem solving as "a means of designing and implementing a series of events to promote creative thought, constructive debate, and effective implementation of proposals that stakeholders generate" (2001). The most central idea of the process is that stakeholders empathize with each other in order to address preconceptions (Daniels & Walker, 2001).
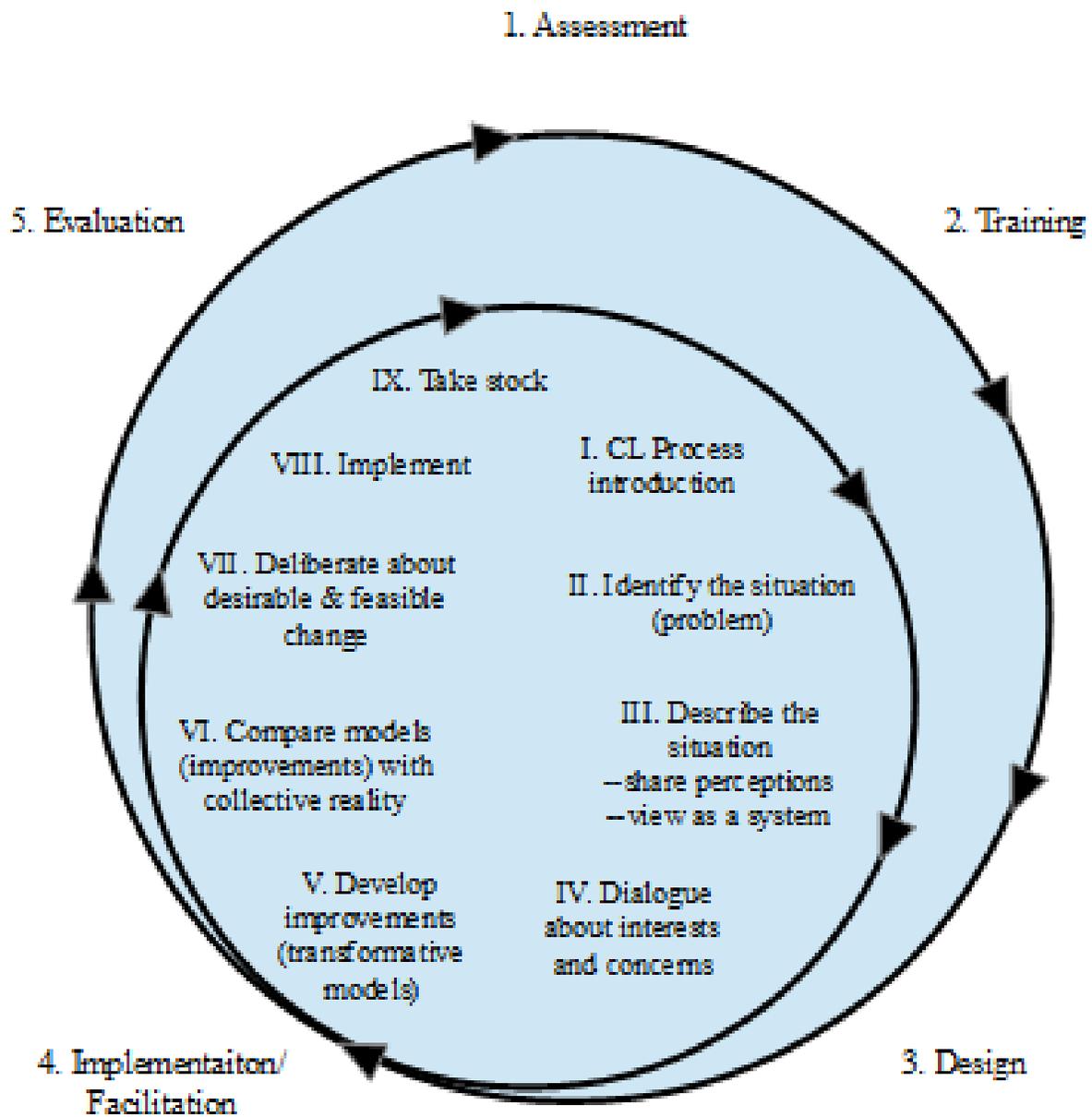
Once this is accomplished, participants can interact as intellectual peers and mutual respect is developed. Lewicki would remind us that this is where "bargaining" can become integrative and value can be created (2011). Even referring to the process as a "learning project," Daniels and Walker identify 10 total phases for participants. See figure 5 and "Stages and Vital Characteristics" below.

Each individual in a collaborative situation should be valued for their distinct experiential knowledge (Daniels & Walker, 2001). When this value fails to be recognized in the learning process, an individual is likely to feel unappreciated and alienated (Daniels & Walker, 2001). This sentiment is produced as one's value orientation (Clement & Cheng, 2011) responds to

social cues and, often arises in connection with external forces that activate existing misconceptions or biases (Cordova, et al, 2014; Daniels & Walker, 2001). If someone approaches the collaborative learning process with the preconception that it may be unsuccessful, this person is unlikely to contribute productively to the process (Daniels & Walker, 2001)..

For a collaborative learning project to be successful, stakeholders must uncover their own preconceptions and work with others (Daniels & Walker, 2001). "The purpose is to identify activities that would be most conducive to creativity and critical thought" (Daniels & Walker, 2001). A culture of cooperation and empathy are used to formulate a mutually acceptable and actionable plan (Daniels & Walker, 2001).

Figure 5: Collaborative Learning Project Phases & Process Stages

1. Assessment

5. Evaluation

2. Training

IX. Take stock

VIII. Implement

I. CL Process
introduction

VII. Deliberate about
desirable & feasible
change

II. Identify the situation
(problem)

III. Describe the
situation
—share perceptions
—view as a system

VI. Compare models
(improvements) with
collective reality

V. Develop
improvements
(transformative
models)

IV. Dialogue
about interests
and concerns

4. Implementaiton/
Facilitation

3. Design

(Daniels & Walker, 2001)

Stages and Vital Characteristics

Stakeholders...

1. Identify the situation as relevant to their lives and environment. **(Interesting, Important)**

2. "Describe the situation, share perceptions, view the issue as a system." **(Introspective)**

3. "Dialogue about interests and concerns [to] develop improvements." **(Interpersonal, Experiential)**

4. "Compare, deliberate, and implement transformative models." **(Contextualized)**

5. "Take stock", evaluate, and take responsibility for outcomes. **(Continuingly Relevant)**

6. Continue to revisit and refine approaches to problem solving. **(Iterative)**

From Daniels & Walker, 2001

Self Test

"Empowerment comes from creating a constructive environment that allows the knowledge and values held by individuals to be combined into a larger understanding of the situation."

-Schmidt, Saigo, & Stepans, 2006 or Daniels & Walker, 2001?

Comparison and Commonalities

A successful collaborative learning activity relies on tenets similar to those of the conceptual change model of learning theory. The way people understand and analyze the world is dependent on their conceptual ecology as determined by previous experiences and situational affect (Daniels & Walker, 2001; Wilson, 1999). Upon confrontation with a discrepancy between some new information and their existing understanding of a process, a person will have a psychological need to eliminate conflict (Festinger, 1962).

The learner can take one of several routes to reconcile the dissonance depending on their cognitive framework as influenced by their value orientation (Clement & Cheng, 2011; Festinger, 1962; Gooding & Metz, 2011; Posner, et al, 1982). The person may not be ready to incorporate the new information and may reject it (Gooding & Metz, 2011; Schmidt, Saigo, & Stepans, 2006). This is a situation where one's values and attitude are not conducive to collaborative learning (Daniels & Walker, 2001). Hedonism, self-direction, and security likely dominate the value inventory (Schwartz, 2014).

This person's understanding of relevant systems is sufficiently incompatible with new information and/or the learner is not psychologically willing to abandon prior conceptions (Gooding & Metz, 201; Schmidt, Saigo, & Stepans, 2006). Often, emotion and negative experience affect response to an intellectual challenge (Cordova, et al, 2014; Wilson, 1999). As an educator, I would like to think that a case of incompatibly must be rare and linked to an unproductive culture of learning or extensive framework of misconceptions. Alternatively to rejection, assimilation or accommodation may occur.

Assimilation is the incorporation of new content into one's existing cognitive framework and is resultant of one's open mindedness and readiness to collaborate (Cordova, et al, 2014; Gooding & Metz, 2011; Posner, et. al, 1982; Schmidt, Saigo, & Stepans, 2006). Schwartz's tradition, benevolence, conformity, and universalism values would be of no small import to these individuals (2014). When a learner is presented with new observations, they attempt to incorporate this data into their understanding of the world (Festinger, 1962; Schmidt, Saigo, & Stepans, 2006).

Similarities, patterns, and grouping dictate psychological sorting (Wilson, 1999), so new information is matched to similar observations and connected to the rest of the learner's known universe (Festinger, 1962; Schmidt, Saigo, & Stepans, 2006). Repetition reinforces neural pathways that recall memories and elicit emotion (Wilson, 1999). We use our experience to predict the impact of our decisions and act according to preferred results (Wilson, 1999). Assimilation can only occur if observations are readily compatible with the learner's cognitive ecology (Cordova, et al, 2014; Festinger, 1962; Schmidt, Saigo, & Stepans, 2006). In many cases, the mind must restructure to accommodate new truths (Posner, et. al, 1982; Schmidt, Saigo, & Stepans, 2006).

Accommodation requires that previous conceptions are modified or abandoned in favor of exploring novel explanations (Posner, et al, 1982; Schmidt, Saigo, & Stepans, 2006) and is facilitated by a receptive value orientation (Clement & Cheng, 2011). Learners and instructors must work deliberately to engage in a process of exploration (Schmidt, Saigo, & Stepans, 2006). Through the process of collaborative inquiry, participants can rewire their intellectual frameworks to incorporate novel ideas (Schmidt, Saigo, & Stepans, 2006; Wilson, 1999). Should accomodation need to occur, a conceptual change would need to as well (Schmidt, Saigo, & Stepans, 2006).

Conceptual change requires that several important conditions occur. Learners must constantly refine their understanding in order to rectify discrepancy (Schmidt, Saigo, & Stepans, 2006). A sense of cognitive dissonance must exist to stimulate inquiry (Festinger, 1962). Learners must be prepared to modify their preconceived notions (Schmidt, Saigo, & Stepans, 2006). They must then personally investigate phenomena that apply to the concept that they are meant to grasp (Schmidt, Saigo, & Stepans, 2006). The new conceptual structure that is developed must seem logical and fit with other well-supported knowledge (Schmidt, Saigo, & Stepans, 2006). This seems to mirror the successful collaborative learning process which Daniels & Walker describe (2001).

The model progresses from an introductory period where the problem is identified, perceptions are shared, and overall systemic framework is established based on the mutually acknowledged perspectives of stakeholders (Daniels & Walker, 2001). This is where the conceptual change model would have misconceptions identified and addressed (Schmidt, Saigo, & Stepans, 2006). The next stage has participants "develop transformative models, compare these models, and deliberate about desirable and feasible change" (Daniels & Walker, 2001;

Schmidt, Saigo, & Stepans, 2006). In the discussion and creation that accompany this stage, participants would have an opportunity to investigate the system and work with others who think differently to formulate a solution (Daniels & Walker, 2001).

After these goals are met, both processes call for implementation and evaluation (Daniels & Walker, 2001; Schmidt, Saigo, & Stepans, 2006). This provides stakeholders with real world results from their efforts so they can witness their carefully considered theoretical concepts in action (Daniels & Walker, 2001; Schmidt, Saigo, & Stepans, 2006). Participants are now invested and can observe the system operate in a way that they understand (Daniels & Walker, 2001: Schmidt, Saigo, & Stepans, 2006).

Problem solving continues as participants make observations, refine their systemic understanding, and work collaboratively to steward the situation (Daniels & Walker, 2001; Schmidt, Saigo, & Stepans, 2006). Due to these inherent parallels, conceptual change model learning activities can provide opportunities for young people to practice effective collaborative skills to carry with them into adulthood.

The Role of Facilitator

Responsibilities of the teacher in conceptual change learning and those of the facilitator in collaborative environmental problem solving are quite similar. Due to the inherently complex interactions between competing yet, interdependent stakeholders, the moderator is responsible for much of the success of the decision making process (Daniels & Walker, 2001). He or she must maintain neutrality and ensure that perspectives are shared and considered calmly and objectively (Daniels & Walker, 2001; Schmidt, Saigo, & Stepans, 2006).

Facilitation of effective conceptual change requires significant instructor anticipation and guidance (Gooding & Metz,, 2011; Hesse, 1989) just as a collaborative environmental problem solving mediator must be well trained and remain neutral in his/her demeanor and actions (Daniels & Walker, 2001). One of the most difficult aspects of collaboration is to effectively establish an opportunity for deliberation (Daniels & Walker, 2001). "If community leaders convene a process, it may not be adequate to merely decree that it is collaborative; rather, collaborative behaviors may have to be modeled by the conveners, encouraged by the process, and discouraged by group norms and behaviors" (2001).

The design of the collaborative process is of the utmost importance (Daniels & Walker, 2001). The data presented to stakeholders should be understandable and intuitive for the layperson to interpret (Daniels & Walker, 2001; Schmidt, Saigo, & Stepans, 2006). Polk and Holbert have shown that even an innocuous interjection of humor can influence decision making skills (2009). Facilitators must be constantly aware of their affect and presentation as they may have a significant effect on collaborators (Daniels & Walker, 2001; Petty, 1983). If designed properly, once the process has begun, it falls to the teacher/facilitator to provide resources and artfully guide participants without imbuing bias (Daniels & Walker, 2001; Schmidt, Saigo, & Stepans, 2006). Recommended questioning strategies from both *Conceptual Change Handbook* (2006) and *Working Through Environmental Conflict* (2001) bear remarkable similarities.

Local Cultural Knowledge links CCM to Place for Additional convergence

Some researchers suggest that a more inclusive model of conceptual change be developed to incorporate cultural wisdom into modern scientific theory and encourage personal connection to emerging knowledge (Zhou, 2012). The idea of "warm" conceptual change

embodies this movement (Sinatra, 2005). Conceptual change activities are warmer when they evoke emotion and tie the system being analyzed to cultural knowledge (Sinatra, 2005). The result is a more genuine and lasting impact from learning and, a deeper sense of connectivity to others and place (Sinatra, 2005). I would argue that "warm" conceptual change is more realistic, profound, and better practice for adult collaboration than more disconnected, "cold" conceptual change.

Section 3

Discussion

Conclusions from Literature Review

      Learning activities based on the conceptual change model of knowledge acquisition are analogous to effective collaborative environmental problem solving processes. Daniels & Walker readily boast that their method's "value comes from its strong foundation in the best contemporary thinking about how people process information, how they deal with different viewpoints and goals, and how to best organize their thinking about complex situations" (2001). The conclusion of this investigation supports this claim. Additionally and anecdotally, I have found a simple guiding principle to form the basis for effective instruction that happens to flow nicely with the stages of our subject frameworks.

      A commonly known tactic to educators, I continually ask myself if the learning may make **sense** and have **meaning** to the students. With this in mind, a teacher (or facilitator) can reach all students (or stakeholders) regardless of existing skill level or cognitive schema. Intellectual growth through expansive creative thinking should be the goal, rather than proficiency towards benchmarks. The challenges, both external and metacognitive, that present themselves in the early stages of conceptual change model activities can engage all learners (Schmidt, Saigo, & Stepans, 2006). This makes them **interested** and the situation seems **important**; as if it were a real scenario affecting their personal lives (Schmidt, Saigo, & Stepans, 2006).

      Participants then **introspect** about the situation and the underlying preconceptions that they have (Daniels & Walker, 2001; Schmidt, Saigo, & Stepans, 2006). Value orientations

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(Clement & Cheng, 2011) emerge. Next, individual perspectives are shared and the system is investigated to determine potential for improvement on the current situation (Daniels & Walker, 2001; Schmidt, Saigo, & Stepans, 2006).

Interpersonal communication is key to conduct inquiries and relate **experiences**. Now that the situation is transparent, positions have been clarified to relative values, the group perceives a common goal, and empathy has begun to develop, a new state can be planned (Daniels & Walker, 2001; Schmidt, Saigo, & Stepans, 2006).

Since learners now view each other as potential contributors to a more productive system, they draw on a wider intellectual resource and are capable of creating value (Lewicki, 2011). Proposed actions derived under these cooperative, value-oriented conditions maximize human problem solving potential (Daniels & Walker, 2001; Lewicki, 2011; Schmidt, Saigo, & Stepans, 2006).

These models are **contextualized** in mutual understanding of the system and how it functions (Daniels & Walker, 2001; Schmidt, Saigo, & Stepans, 2006). Though the most substantive portion of collaboration in terms of problem solving has occurred at this point, both conceptual change and collaborative conflict management would insist that learning has not ceased (Daniels & Walker, 2001; Schmidt, Saigo, & Stepans, 2006).

Vitally, these issues are **continually relevant** to participants as they are responsible for the outcomes and may reflect on the new situation (Daniels & Walker, 2001; Schmidt, Saigo, & Stepans, 2006). The most realistic and promising characteristic shared by conceptual change and real world collaborative environmental problem solving may be their shared **iterative** nature. Each process is meant to determine the start point of its next revolution (Daniels & Walker, 2001; Schmidt, Saigo, & Stepans, 2006).

Table 1: Side by Side of Stages. Researcher Identified Vital Characteristics in **Bold**

Stage	**Conceptual Change Model**	**Collaborative Problem Solving**
1	Experience a sense of cognitive dissonance to stimulate inquiry. **(Interesting, Important)**	Identify the situation as relevant to their lives and environment. **(Interesting, Important)**
2	Acknowledge and prepare to modify their preconceived notions. **(Introspective)**	"Describe the situation, share perceptions, view the issue as a system." **(Introspective)**
3	Cooperatively investigate phenomena relevant to the concept. **(Interpersonal, Experiential)**	"Dialogue about interests and concerns [to] develop improvements." **(Interpersonal, Experiential)**
4	Develop a new conceptual structure that is logical and fits with other well-supported knowledge. **(Contextualized)**	"Compare, deliberate, and implement transformative models." **(Contextualized**)
5	Assess new conceptual structure and take responsibility for outcomes **(Continuingly Relevant)**	"Take stock", evaluate, and take responsibility for outcomes. **(Continuingly Relevant)**
6	Constantly refine their understanding in order to rectify discrepancy. **(Iterative)**	Continue to revisit and refine approaches to problem solving. **(Iterative)**

Synthesized from Daniels & Walker, 2001 & Schmidt, Saigo, & Stepans, 2006

Students who practice cooperative science learning through conceptual change may be better prepared to address environmental issues as collaborative citizens. As students engage in Conceptual Change Model learning, "they build positive learning dispositions and help each other come to a level of understanding that makes sense to each of them" (Schmidt, Saigo, & Stepans, 2006). Mediated group discussion, cooperative assessment, and structured inquiry are integral to the process (Schmidt, Saigo, & Stepans, 2006).

"In a nutshell, Collaborative Learning seeks improvement through creativity, and creativity derives from a rich understanding of the complexity of the situation at hand" (Daniels & Walker, 2001). This process relies on an analogous progression of mediated group discussion, cooperative assessment, and structured inquiry (Daniels & Walker, 2001). CCM is an organically grown experiential education theory based on the wisdom of Dewey, Piaget, and others. Collaborative environmental problem solving is a program melding disciplines of social and natural sciences. Emergent properties of these two methods indicate that they share compatible objectives and Conceptual Change learning has the potential to augment useful adult collaborative problem solving skills.

Our understanding of human brain activity bolsters the idea that practice makes perfect (Wilson, 1999). Every human on earth harbors their own unique cognitive ecology through which sensory information is processed and its meaning deciphered (Posner, 1982; Wilson, 1999). A person's intellect is constantly evolving to assimilate or accommodate new concepts (Posner, 1982; Wilson, 1999). A comprehensive worldview emerges as stimuli are processed and their significance shaded by experience in the form of memories and emotions elicited (Wilson, 1999). In this way, subjective experience affects biases and how people engage in problem solving.

Young students that have practiced collaborative skills prior to adolescence will be better prepared to engage in the next phase of their social development. As students enter adolescence, their intellectual framework becomes geared towards interpersonal relationships (Piaget, 1964). Biological forces can be blamed as recent pubescents are much more concerned with their peers than with content (Piaget, 1964). If students are not sufficiently prepared before this stage, they could be seriously handicapped in their ability to empathize and collaborate.

Environmental issues are especially difficult to address due to the unique profiles of individuals, stakeholder group characteristics, and the tendency of these problems to be "wicked" (Conklin, 2001; Daniels & Walker, 2001). As an educator, I want to create citizens that are ready to function productively as part of a global, sustainable society or, at least provide impetus in that direction. Our preparedness to collaborate is dependent on how we feel about the situation and our vested interest in the result (Daniels & Walker, 2001)..

While many students can learn through independent study alone, it is experience that persists and motivates (Dewey, 1915; Gooding & Metz, 2011; Piaget, 1962). Theory and strategic curriculum design provide a scaffold and canvas on which a learning experience is created (Gooding & Metz, 2011; Proctor, et. al, 2013). It falls to the instructor to gently persuade students to engage in self discovery. This is the appeal of the conceptual change model.

Exploration and immersive experience promote critical thinking and creativity. These learning experiences are further enhanced with group problem solving that provides opportunities to collaborate. Students who practice collaborative problem solving are more likely to empathize with others (Hayward, 2012; Kipp-Newbold, 2010; Scott, 2009). In my vision for the future of our nation, it is a combination of acute observation, critical analysis, and willingness to collaborate that makes a US citizen.

Recommendations

Conceptual change, while demonstrably conducive to collaborative learning, is by no means the sole model by which important skills can be practiced. When we analyze the critical features of meaningful collaboration, we can identify an emergent scheme that has much in common with other established instructional theories. Among these are design thinking, project based learning, and student driven inquiry.

Design thinking lessons have students approach an untenable issue that involves multiple underlying motivations toward solutions (Scheer, Noweski, & Meinel, 2012). Participants engage in iterative problem solving with each experiment designed and witnessed as a group (Scheer, Noweski, & Meinel, 2012). The process is focused on moving closer to an acceptable state without assuming that any concrete solution exists (Scheer, Noweski, & Meinel, 2012).

Project based learning is essentially mock environmental problem solving. Requiring long time frames and significant up front instructor effort, project based learning units are very exciting in terms of engagement and educational value (Van Der Valk & De Jong, 2009). Relevancy is a prime consideration for project based learning and students should be deftly persuaded towards interest in local issues (Van Der Valk & De Jong, 2009). Practice makes perfect. Student driven inquiry is an aspect of many of these strategies and should be cultivated at any opportunity.

Other, less explicitly connected instructional strategies support collaborative skill development as well. My personal "go to" is the mindful use of driving questions. The goal is to engage students in metacognition to drive their own investigations (Roth, 1996). Care must be taken not to influence decision making or exhibit judgement. Not only do thoughtful queries

encourage self discovery and move learning forward, they help develop a rapport with students (Roth, 1996). More diverse thinking occurs when students arrive at their own answer with instructor guidance. One's sage like wisdom and mystery manifest as an aura of venerability; as in Master Splinter, or Yoda if one prefers.

Personal Reflection

My well considered position, based on research and experiences, is that education in the US must be public for our national ideals to prevail. To support equitable environmental problem solving, the purpose of education should be to create young adults able to observe, analyze an issue, and conduct accurate research when information is needed for decision making. Armed with these skills, and practiced in meaningful collaboration, these students will be prepared to address any issue and derive mutually beneficial solutions.

It is has been argued that educational systems are most effective when content and processes discussed during learning activities are unbiased in presentation (Hayward, 2012). If corporate or private interests are allowed to fund education, there will invariably be an agenda that the investor wishes to support (or at least one perspective that will be disallowed). Whether this is ideological or purely profit based, objectivity of instruction can suffer.

Research suggests that progress towards government by the people demands state funded education, extensive public involvement in decision making, and transparency in systems (Bishop & Scott, 1998; Conklin, 2001; De Nardi, 2004; Hayward, 2012; Proctor, Smith, & Wallace, 2013; Steffen & McNeill, 2007; White, 1967; Zhou, 2012). If humanity were to acknowledge that we have reached a point in our history at which population, technology, and ambition threaten our continued existence, we could reflect together on our similarities in pursuit

of an equitable, sustainable global society. It is my informed opinion that the establishment of vital collaborative values is critical to this vision.

Retrospecticus

After discussing this research with my distinguished committee and colleagues, I am left with additional questions to investigate. A major consideration is the applicability of CCM activities in schools. We discussed how it may be challenging and intimidating for teachers untrained in this type of instruction. Administrative and community support are key elements in transitioning towards experiential education. A teacher should have professional development opportunities to inform and encourage. Instructional staff should cooperate in a way that somewhat mirrors both major processes discussed herein. When individual staff can utilize the wide breadth of expertise represented by the faculty at large, they will likely find innovative ways to customize and augment their instructional repertoire. The culture of inclusiveness, empathy, and collaboration necessary to implement CCM activities will hopefully diffuse into the community at large.

Towards this goal, It is important to consider the characteristics of the specific CCM process. Due to the scope of this work, my treatment of the "warming trend" in CCM instruction does not faithfully represent its importance in practice. The temperature scale used here illustrates a continuum of characteristics. When activities are geared towards motivating students to master content and incorporate observations into their prevailing conceptual framework and/or cultural relevancy is well considered, the learning is warmer than when student goals are performance based (Sinatra, 2010). Dr. Gale Sinatra researches and expounds the value of "warm" CCM versus "cold" CCM in her work. Evidence suggests that students who participate

in "warm" CCM activities are motivated to master the content with the help of peers and are "more likely to engage in deep processing necessary for knowledge change" (Sinatra, 2010). My research and experience indicates that the "Warming Trend" should be supported and extended.

Next, we should reflect on how CCM activities can hurdle some impediments created by its complexity. Incorporation of cultural knowledge, inclusiveness, and avoidance of dominant viewpoints quashing valuable perspectives are certainly associated challenges. Based on my studies and practice as an educator, I conclude that with extensive practice in meaningful collaboration, beginning early in life, students will recognize that human problem solving potential is maximized through integration of multiple perspectives. They will witness the power of intellectual synergy in developing creative, productive solutions to complex problems.

This is a long term strategy that relies on practice and commitment to common goals. If we stress the importance of collaboration, connection to others, and integrative negotiation early and often, the divisions between school, neighborhood, and home should dissipate. All citizens can consider themselves active learners and community planners. Americans will be ready to confront their beliefs, acknowledge their misconceptions, and work with others to address complicated ecological issues based on reliable evidence.

I will take this opportunity to thank my distinguished committee for their guidance. I look forward to continuing my professional journey through research and practice. Presently, I am most eagerly anticipating my return to professional field education.

Appendix A: Sample Application

Conceptual Change Model

Topic: Phases of Earth's Moon
Essential Questions: What is the mechanism responsible for creating the different appearances of the moon?
Objectives:
- Students record nightly observations of the moon in a journal.
- Students attempt to explain the mechanism responsible for the changes in the appearance of the moon that they observe.
- Students engage in an activity to create a discrepant moment that they will attempt to reconcile.
- Students modify their understanding of the moon's astronomical processes in accordance with new information and the outcomes of investigation.

Procedure:
Context - progression over multiple weeks culminating with 2 hour evening program investigation. [soccer balls, lacrosse balls, and flashlights] Field group of 12 students will be divided in groups of 4 for the entirety of the lesson.
Night time journaling activity: Students will sketch the moon as they observe it during several field observations.
Students make scientific observations, build interest in the topic of lunar phases, but do not yet confront misconceptions.

Engagement Activity 1: Students are provided with materials and prompted to arrange representative elements to illustrate the general position and relative movement of the moon, earth, and sun. Instructors will monitor student progress, answer questions, and provide minimal guidance.
- "Once your group is satisfied with their model representation of the earth, moon, and sun, I want everyone to reconvene so that we can agree upon a model of relative motion."
This activity will take place after students have observed the moon, nightly, for at least 2 weeks. The activity is meant as a foundational event supporting a culminating moon investigation activity. We want to ensure that students have time to become familiar using models to represent lunar activity, and ensure that all students are aware of the basic processes of lunar orbit around the earth and earth's orbit around the sun. Students should begin the conceptual change model some baseline knowledge. We feel that observations of the moon's changing appearance and basic understanding of lunar orbit will support the successive activities.

Discrepant Moment Activity:
- "Now that we have an understanding of relative motion and position of the moon to the earth and sun - everyone grab their journals and revisit your moon observations. What's causing the changes in appearance that you see? Spend 5 minutes trying to write an explanation for these changes in the moon's appearance."
After spending time writing explanations on their own, students will meet back their group members, discuss their explanations and have 15 minutes using the materials from the previous activity to try to

construct a physical representation that explains the observed changes in the moon's appearance. Students will mark a dot on the ball representing earth to show where he/she, the observer, would be.

- Each group will present their model representing their idea of how the phases of the moon occur.
- As groups present, an instructor will record key points and ideas for each group's argument of how phases of the moon occur.
- Comprehensive list will be discussed by the class.
- Instructors will use student ideas to demonstrate why the model does not work. Instructors will attempt to recreate a model based off of students' ideas, and identify and expose to the students where that explanation breaks down.

This is where the intended discrepant moment takes place. Identified as a best practice by numerous authors, the discrepant moment challenge will confront student misconceptions. We take time here to ensure that students understand why their initial understanding of lunar phases is incorrect. They need to see the inconsistencies in their model.

- Instructors will then demonstrate the correct model representing the mechanism responsible for the observed changes in the moon's appearance.
    - allow time for questions and clarification
    - send students back into small groups (shuffle group members here into different groups than before) to discuss new information and ideas about the moon phases.

This is a crucial moment in the lesson plan. Students need to reconcile new information with their previous understandings. As we have pointed out inconsistencies in the previous model of lunar orbit, we repair those inconsistencies with new information. We will support students as they accommodate new ideas by reevaluating their preconceptions. Allowing time for discussion and clarification questions promotes success in this endeavor.

Final Activity:
Have students write independently in their journals with this prompt -
"Revise your original explanation for the mechanism responsible for the changes in appearance of the moon. Include 4 sketches with labeling and notes."
This gives students an opportunity to synthesize their revised knowledge by clearly illustrating their understanding of the apparent phases of the moon. This individual task will require students to internally revisit the process that led them to conceptual change and thus, provide repetition that will allow novel explanations to persist.

Extension: Go home and try to teach this to your parents.
Encouraging students to pass on their knowledge by explaining what they have learned to others further solidifies the cognitive revision that has occurred. Care must be taken to ensure that students have achieved this level of understanding to avoid the proliferation of misconceptions.

-From Teton Science Schools Graduate Program. (2016). *Advanced Instructional Strategies Class Project: Teacher's Handbook*. Section authored by Samuel Murray and Tom Desiderio. Kelly, WY.

Collaborative Environmental Problem Solving

"Spartanburg, South Carolina:

Located within Spartanburg County, the city of Spartanburg (population 40,000) has been profiting from a downtown renaissance, with a new hotel, new business ventures, and new goals for growth. However, less than 2 miles from the city center—literally, on the other side of the tracks—lie the Arkwright and Forest Park communities, with a combined population of about 5,000. These neighborhoods were established around textile mills and Applying the Model 19 industrial facilities, many of which have since closed—a place where residential neighborhoods and industry exist side by side, due to few zoning restrictions or land use controls in the 1970s.

Based on the 2000 U.S. Census, the poverty rate in Arkwright and Forest Park was 25 percent, and 10 percent of the population was unemployed. Residents of these predominantly low-income and African-American communities live among two hazardous waste sites and an active chemical manufacturing plant.

This area is, in many ways, just like many other communities in the United States, where people of color or indigenous or low-income populations may be disproportionately exposed to environmental hazards. In these communities, environmental issues are often linked to other concerns such as: 1) lack of access to adequate healthcare, 2) public safety problems, 3) substandard housing, 4) transportation problems, 5) lack of economic development, 6) high rates of unemployment, and 7) lack of social services. In these neighborhoods, residents often feel helpless, and the broader community often seems indifferent, with no one willing or able to reverse the downward trend. Change requires new thinking, new strategies, new models—and new partnerships.

The Process:

ReGenesis and its partners and stakeholders continue to forge ahead with its vision for the community. The way that this Spartanburg community developed its vision and is bringing all its stakeholders together to realize it, despite all odds and obstacles, is a prime example of how the CPS Model works. Here is a synopsis of the seven elements in terms of ReGenesis' experience:

Element 1: Issue Identification, Community Vision, and Strategic Goal Setting – For example, Harold Mitchell initially identified health issues and brought them to the attention of EPA and state and local officials. The residents of Arkwright and Forest Park developed a vision to improve the community. And, through the use of charrettes, the stakeholders and partners crystallized that vision and developed strategic goals.

Element 2: Community Capacity-Building and Leadership Development – Through Harold's leadership and the support of partners and stakeholders, ReGenesis improved its capacity to represent the community in the ongoing dialogue and redevelopment activities. One result of this process is that more and more residents have signed up for city- or county-sponsored training to learn new job skills.

Element 3: Consensus Building and Dispute Resolution – Through the facilitated dialogue among ReGenesis, Rhodia, and EPA Region 4, these entities agree by consensus to make specific improvements in Spartanburg.

Element 4: Multi-Stakeholder Partnerships and Leveraging of Resources – Over time, ReGenesis successfully built the essential partnerships to revitalize Spartanburg. Through the partners, ReGenesis was and continues to be able to leverage much needed resources through grants, technical assistance, and in-kind assistance.

Element 5: Constructive Engagement by Relevant Stakeholders – As the community's representative, ReGenesis has been able to engage members of the community as well as industry, academia, and civic organizations, and all levels of government in order to work together to realize the community's vision.

Element 6: Sound Management and Implementation – The Environmental Justice Partnership steering committee has built in the administrative, management, and coordination processes needed to ensure that the project activities are implemented as planned.

Element 7: Evaluation, Lessons Learned, and Replication of Best Practices – Evaluation processes have been instituted in the activities of the steering committee, grant projects, and the facilitated dialogue. The lessons learned and best practices have been documented and shared across the country through speeches, presentations, training workshops, educational seminars, a video, and publications such as this one.

ReGenesis and its stakeholders and partners have made an indelible impact on Spartanburg for generations to come. Through the use of collaborative problem-solving, they are on their way to realizing the community's vision to revitalize the community. Almost a decade has passed since Harold Mitchell began his quest and now, thanks to this amazing partnership among many stakeholders, Spartanburg has come a long way. Harold's words best sum up his experience with using the CPS Model:

'The satisfaction out of this is looking back nine years ago and thinking I was like some of the other community members at the big public forums in Washington, not knowing where to go or who to turn to, to resolve the major issues in my community. But now, by being a part of the CPS process, we have a roadmap that other communities can use to find out what they need to do and with whom they need to engage, to turn around those complex issues that are impacting their communities.'

— Harold Mitchell, ReGenesis"

Results:

● Critical transportation changes now mean that the only road into the communities is no longer blocked by standing trains. With the addition of a vital second entrance into and out of the community, residents are no longer isolated. Emergency response drills mean that the community is prepared for any potential incident that could occur in the area.
● The creation of several community health centers means that residents no longer have to travel long distances for medical care. The centrally-located facilities not only support school and behavioral health initiatives, but serve migrant healthcare needs as well.
● More than 500 new affordable housing units for residents and workers led to the removal of severely distressed public housing and new homeownership opportunities.
● Job training and employment programs that empower residents through economic opportunity.
● Environmental cleanup of formerly contaminated properties have turned brownfields into viable properties, removing eyesores and affording other redevelopment opportunities, such as a solar farm that is planned.

- Increased retail development, such as a long sought after grocery store, a pharmacy, and other shops located within the community.
- A new state of the art community center that serves as a hub of activity for the community, from young to elderly residents.

-From Environmental Protection Agency. (2008). *EPA's Environmental Justice Collaborative Problem Solving Model.* Washington, DC.

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