2020

The Great Turning: A Call for Systems-Thinkers

Gabriella M. DeMarce
University of Montana, Missoula, gd117294@umconnect.umt.edu

The Great Turning: A Call for Systems-Thinkers

Senior Thesis Capstone Project

Gabbi DeMarce

University of Montana

TABLE OF CONTENTS

ABSTRACT

David Orr, in an article on ecological intelligence reminds us that the modern world was shaped by people who did not understand that our social and economic systems could not coexist with the rest of the biological or natural systems on Earth (Orr, 1994). My research is rooted in Orr's argument and discovering ways to shift this degrading paradigm. With my belief in the power of education in empowering youth and my background in environmental and climate change studies, I see a future in great need of people who *holistically* understand the functions of all types of systems and can use that understanding to drive intelligent and innovative interactions with them. The purpose of the study was to gain insights from educators around Missoula County in Montana about their perception of systems thinking principles and methods and its role in classroom learning. A mixed-method, 16-question survey was distributed out to K-12 educators around Missoula from various elementary, middle and high schools as well as a few independent schools. The responses suggest that although the majority of educators believe systems-thinking integrated into the classroom is important, many either don't understand it or can't move beyond an abstract understanding. Responses also suggests that some educators utilize systems-thinking methods for classroom activities but don't necessarily identify it as such. Based on these findings, more research is recommended to confirm and compare the data to other schools around the country with the same standards and with other countries with different standards. The next steps are to explore how to successfully integrate systems-thinking principles into the standard classroom setting, which may include additional teacher training, and its outcome on students understanding, decision-making, and critical-thinking in the face of climate change.

INTRODUCTION

In National Geographic's resource library there is an entry for the Anthropocene. They define it as "an unofficial unit of geologic time, used to describe the most recent period in Earth's history when human activity started to have a significant impact on the planet's climate and ecosystems," starting in the 1950s (National Geographic Society, 2019). Climate change, a product of this human epoch, now acts as a defining entity for current and future generations. The 2018 IPCC Report states that if we exceed 1.5 degrees Celsius warming, it will dramatically and detrimentally affect human and ecological systems, that is, if we don't make rapid changes as soon as possible. From sea level rise putting coastal communities at risk, changing weather patterns, food insecurity, and mass species extinctions, our impact will continue to put fatal pressures on all living systems on Earth (IPCC, 2018).

There are global conversations and efforts happening to address this crisis and steer humanity into a new era which Joanna Macy, eco-philosopher and author of *The Work That Reconnects: Coming Back to Life,* refers to as "The Great Turning." She envisions our societies in this era as our next phase of existence following the Anthropocene, or what she refers to as, "The Great Unraveling" (Macy & Brown, 2014, p. 5) The Great Turning, as Macy describes it, "involves the emergence of new and creative human responses that enable the transition from the Industrial Growth Society to a Life-Sustaining Society" (Macy and Brown, 2014, p.5). Can we make such a transition without dramatically changing our institutions? The answer is no. David Orr, in an article on ecological intelligence reminds us that the modern world was shaped by people who did not understand that our social and economic systems could not coexist with the rest of the biological or natural systems on Earth (Orr, 1994, p. 500). If our current understanding of how our Earth's systems function was accurate, wouldn't we have achieved sustainability already? Orr's argument for ecological intelligence is based on the premise that education is our answer to the climate crisis because it can foster a holistic understanding of ecological systems beyond even "elaborate scientific knowledge" (Orr, 1994, p. 500), therefore giving humans the ability to live sustainably. He writes, "The same kind of education that equipped us to industrialize the earth will not do…the development of ecological intelligence will require a transformation of institutional priorities and goals, methods of teaching and, not the least, the organization of knowledge by discipline and subdiscipline" (Orr, 1994, p. 500). Orr's article is a segue into my research which explores how shifting students' thinking, ways of knowing and worldview can be achieved in education in the U.S through a systems-thinking framework.

My initial interest in ecological intelligence and its relationship to systems-thinking was sparked by the article "Forging New Norms in New Orleans: From Emotional to Ecological Intelligence." A case study conducted on a student group in New Orleans in 2009 exemplified the overall beneficial effect that implementing a systems-thinking framework into the classroom had on the students' ability to respond to an environmental issue (Goleman, Barlow, Bennett, 2009). The group, known as the "Rethinkers," took on the task of addressing the recent BP oil spill in the Gulf of Mexico, at the time. Using their holistic understanding of nested systems, the students were able to analyze the various dispersed effects that the spill would have around the country and in their local community and ask deeper questions about the issue at hand. Nested systems, defined by the Center for Ecoliteracy are, "…systems that are nested within systems. Each individual system is an integrated whole and—at the same time — part of larger systems. Changes within a system can affect the sustainability of the systems that are nested within it as well as the larger systems in which it exists…Cells are nested within organs within organisms within ecosystems (2012)." The study on the Rethinkers shows the potential of systems-thinking in education as a guiding framework leading to deeper understanding, intellectual questions, and ultimately better solutions.

VOCABULARY

To aid in a broad audience's understanding of my research, I am providing a brief list of definitions for terms that are used in the environmental and educational fields and are not as commonly seen elsewhere.

» *Sustainability*: "to create and maintain conditions, under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic, and other requirements of present and future generations" (National Research Council, 2011, p. 12)

» *Systems-thinking*: a type of holistic thought process that is achieved by analyzing the interrelated parts of systems, how they function over time, and their role in larger systems

» *Living system:* an open, self-organizing life form that is maintained by flow of energy, matter and information

» *Ecological system (or ecosystem):* a biological community of interacting organisms with living and nonliving components intrinsically linked through energy flows and nutrient cycling

» *Social system:* the organization of humans in society with distinct interrelated relationships between individuals, groups and institutions to form a whole

» *Linear-thinking:* a type of thought process that is achieved in a sequential manner where each step needs the previous one in order to build an understanding, based on logic (if a=b and b=c, then a=c)

- *Reductionism*: a bottom-up approach to understanding something by breaking it down into its simplest component parts

- *Mechanism:* a complex system that produces that behavior by the interaction of a number of parts, where the interaction between parts can be characterized by direct, invariant, change-relating generalizations (Stanford Encyclopedia of Philosophy, 2015), understanding nature as a machine

Essential Questions

Are the U.S. K-12 school systems meeting the current and future educational needs of its students?

What are the detrimental effects that education has on students in the context of social and ecological challenges caused by human-induced climate change?

How can curriculum and pedagogy influence students' ability to think in systems?

LITERATURE REVIEW

CLIPPING WINGS IN K-12 EDUCATION

Young climate activist, Greta Thunberg recently captioned a photo on her social media with, “Some people say we should study to become climate scientists so that we can solve the climate crisis, but the climate crisis has already been solved. We already have the facts and solutions. All we need to do is wake up and change” (Thunberg, 2020). Part of me felt the need to comment on this post and remind her that the education system often keeps us asleep, without providing us a means to wake up and change. Those of us that are awake now share the task of waking up the rest of the planet, and what faster way to accomplish it than by instilling ecological intelligence in students through institutional reform?

General intelligence, as defined by experts in organizational psychology, Schmidt and Hunter, is “the ability to grasp and reason correctly with abstractions (concepts) and solve problems (2000).” Psychologists represent this term as a unit of measurement known as the *g* factor, which calculates an individual’s cognitive ability. The standard categories measured are reasoning, spatial ability, memory, processing speed and vocabulary. In order to simplify comparisons between general intelligence, and other types of intelligence, Schmidt and Hunter’s definition will be used for the purpose of the review. Their definition of general intelligence is an accurate representation of the education system’s learning objectives due to nation-wide standardization of disciplines, learning objectives, and exams such as the ACT and SAT. Most. U.S. students who attend a K-12 school are expected to obtain the same basic knowledge and skillsets for the purpose of “college and career readiness” (CCSSI, 2020). The U.S. public schools will have sent around 50.8 million students through its system as of fall 2019. (National Center for Education, n.d.)

In the U.S. forty-one states have adopted the Common Core State Standards Initiative or CCSSI, a framework that outlines the standard learning objectives for all grade levels in English, Language Arts, and Mathematics as well as suggested curriculum and teaching strategies to achieve them. Upon examination of a range of objectives, many of the directions begin with the words, "determine, identify, read, report, analyze (CCSSI, 2020)," from kindergarten up to grade twelve. In Bloom's/Anderson and Krathwohl's taxonomy of cognitive domain, none of these words exceed the fourth domain, meaning that even in a student's final four years in high school, the standards do not wholesomely achieve the fifth and sixth domains of evaluation and creation –a microcosm of systemic issues with U.S. education and its outcomes on students' intelligence.

THE TRIPLE *S'S*:

SUBJECT-CENTERED, SINGLE DISCIPLINE, STANDARDIZED. To briefly address the many critiques of the standard public-school system, the triple S's: subject-centered, single discipline, standardized, are interconnected elements in K-12 education that can affect a students' ability to understand what they are trying to learn. Bernier describes the education system as a "linear industrial structure," shaped by the goals of the Industrial Revolution which was to prepare a passive workforce that would take orders without question and with adequacy in reading, writing and mathematics (Bernier, 2017 p. 2). Emerging from utilizing compulsory education to stimulate the economy was standardization of subjects and curriculum, which has now become the Common Core State Standards Initiative. Bernier argues, as a consequence, a lack in depth and diversity of learning content and activities hinder students' ability to develop critical thinking skills. A lack in alternative learning paths also becomes a "make or break" scenario with outside disturbances creates high-input, limited outcomes for all parties involved. (Bernier, 2017, p.2) Similarly, Slabbert & Hattingh highlight how the fragmentation of disciplines affects the minds of students, claiming it is detrimental to a clear understanding of the world. They argue our fragmented minds are to be blamed for the widespread disorder seen in ecological and social systems all over the world (Slabbert & Hattingh, 2006).

"It is not surprising that teachers and students find security in a minimalist curriculum where disciplines and departments are isolated, where knowledge is separated from the learner, where meaning is sought without context, where learning is judged on memorization, and where competition is immortalized. Unfortunately, the destructive power of such fragmentation is all too evident and should serve as a strong incentive to attempt, and to arrive at, a contemporary curriculum philosophy." -Slabbert & Hattingh

Lack of 21st Century Curriculum. English, reading, writing, mathematics, social studies, biology, chemistry, geography, civics and economics are common courses found in school systems across the U.S. Not only are these the same disciplines we have seen generation after generation, they have also traditionally been taught in complete isolation from one another with curriculum books and standards passed between classrooms. Slabbert and Hattingh on fragmentation of education write, "Contemporary society, like education, has reached the apex of modernity…self-destruction does not offer a vision of order in chaos, a whole to part relationship, or a global experience in the local context (2006, p.702), and as climate change continues to increase in relevancy and urgency, education has become a target of reform in preparing students for mitigation and adaptation. Mochizuki and Bryan highlight that although education's role in addressing climate change has been recognized, a "coherent framework" has not been provided by stakeholders (2015). They argue for climate change education as an ethical approach to influence decision-making, help deal with emotional responses, foster student empowerment and ultimately enable "social transformation (Mochizuki and Bryan, 2015)."

Jenny Andersson, author of the article, "A Curriculum for Generation Z," takes this idea of a climate change framework and expands it to include other nontraditional and interdisciplinary K-12 topics such as "cultural anthropology, empathetic communication, philosophy, the role of technology, regenerative culture design, leadership and learning, etc. (2019)." Although these classes are not specifically teaching about climate change, her recommendations are rooted in an uncertain and insecure future for the younger generations, therefore arguing that students need more than the "elaborate scientific knowledge," that was previously mentioned from Orr's article on ecological intelligence (1994, p. 500). Andersson's curriculum echoes the arguments of Brett Joseph (n.d.) in "Global Sustainability Education," in that educations should serve the purpose of providing students a *holistic* set of skills to live in a rapidly changing world, rather than the current objectives of preparing for college and a career.

CONSTRUCTING WORLDVIEWS. Surfacing in literature, more commonly in research on environmental and climate change education, is the manipulation of students' minds that perpetuate dominant American values, beliefs and therefore, behaviors. Ultimately, researchers argue that education does not provide an adequate level of autonomy for students and instead instills in them detrimental ideologies of neoliberalism, materialism, consumerism, individualism and even anthropocentrism (Gowdy 2008; Joseph, n.d.; Kopnina, 2015; Orr, 1994; Slabbert & Hattingh, 2006). In short, these ideologies are rooted in our constructed socio-economic narratives of unlimited growth or success being defined by material accumulation and wealth. They are also rooted in how the Anthropocene came to be, which is by our narrative of the existence of a biological hierarchy, where humans are placed at the very top, and therefore are superior to all other life forms.

A prominent voice in this conversation is Dr. Helen Kopnina, currently at Hague University of Applied Science in the Netherlands. In 2015, she called for "radical re-orientation," of environmental education after finding that neoliberalist and anthropocentric doctrines can still dominate classroom learning even on environmental topics (Kopnina, 2015). She argues that there is a falsified sense of diverse, democratic discussion facilitated in environmental education due to a lack of content that teaches alternatives to our current social systems, such as the circular economy and social justice. Kopnina also claims that connotations of teaching equality across the entire biological community (all life forms) as a form of indoctrination lends itself to the education system's unwillingness to provide students alternate ways of thinking and understanding themselves as a species that is not superior to any others (2015). Between 2016 and 2017, she conducted interviews with teachers and students in Amsterdam involved in a school garden project. Kopnina found that the school's goal of students' hands-on learning of horticulture and agriculture instilled a misguided, anthropocentric, or human-centered view in the children of cultivated land as a wilderness (which it is not), weeds as something to be destroyed, and nature as a source of food, rather than emphasizing interdependence and humility (Kopnina, 2018). Her case study reflects the unintended construction of worldviews that shape a student's *mis*understanding of social and ecological systems as an object for unlimited human use, rather than a living system in which we depend on.

Gowdy, in asking the question of how behavioral science can affect climate policy, found that behavior patterns such as materialism, is also a learned behavior through "cultural systems of rewards and punishment (2008, p. 640)." Unfortunately, education is a fundamental system of reward and punishment that millions of children are sent through in the U.S. These dominating worldviews or learned behaviors limit students' ability to visualize and predict their implications, which explains how we have ended up in an era largely influenced by human activity. His findings set up the question of how students would respond to cultural conditioning in the classroom if they had a holistic understanding of systems. If students continue to follow detrimental ideologies driven by inequality, material wealth, and disconnection, while simultaneously lacking an understanding of living systems, then the threat of ecological and social collapse will likely remain. Although manipulation of student worldviews in the school system is complex and nonlinear, it is worth exploring whether or not systems-thinking in education can prevent the continuation of harmful ideologies. Integrating a systems-thinking framework in the classroom may be a strategy in the classroom for students to avoid cultural and intellectual conditioning, as well as a tool to promote deeper understanding of systems dynamics.

SYSTEMS THINKING IN EDUCATION

OVERVIEW. In the 1920's, three fields of study, organismic biology, gestalt psychology and ecology were the first to explore the meaning of living systems and the question of, when is the whole greater than the sum of its parts (Capra, 1997)? Systems-thinking emerges in answering this question. Fritjof Capra, systems scientist, author, educator and a main inspiration for this research, summarizes the origins of the two important theories that contribute to the contemporary definitions of systems thinking. General systems theory, theory as in theoretical framework, was first introduced by Ludwig von Bertalanffy in the 1940's. His work aimed to change views of science from mechanistic to holistic. He addressed the gap in knowledge of open living systems constantly flowing with matter and energy by stating that standard thermodynamics cannot adequately explain them (Capra, 1997). Cybernetics, a similar theory developed by an interdisciplinary group of researchers, focused on patterns of organization in systems such as feedback loops and self-regulation (Capra, 1997). Together, these two theories would be synthesized by Fritjof Capra, himself, to create living systems theory.

Fast forward to a contemporary definition of systems-thinking, sustainability innovator and systems-thinker Leyla Acaroglu breaks it down into five fundamental concepts which are interconnectedness, synthesis, emergence, feedback loops and causality (Acaroglu, 2019). In her words, interconnection involves shifting one's mindset to see that everything is connected through dependence on something else for survival. Synthesis, as opposed to analysis is understanding the whole and the parts concurrently as well as the relationships and dynamics within (Acaroglu, 2019). Acaroglu describes emergence as the "outcome of synergies," or the outcome of interacting parts that couldn't otherwise exist (2019). Feedback loops and causality involve understanding the dynamics taking place within a system and how one thing effects another in nonlinear ways. Ecological and social systems are in a constant state of change with the flow of energy, matter, and information. By understanding Acaroglu's fundamental concepts, we can make sense of our interactions with complex individuals, communities, environments and our responses to issues. Some examples of ecological systems are weather, solar, the water cycle, and the nutrient cycle. Examples of social systems are transportation, government, school, communication, and the economy. Schulte precisely sums systems-thinking up as:

"A system is a set of connected things or parts forming a complex whole. Think of an ecosystem – different species of plants, animals, fungi, bacteria, etc. all interacting with one another in complex ways. Think of systemic racism – it's not just bigoted individuals,

it's the institutions, laws, beliefs, and language that subtly create an effect of inequality and oppression.

In the past, we might have been tempted to look at individual pieces of a situation or a system. If sheep are disappearing, it must be the wolves. Get rid of segregation and derogatory language and racism is over. Systems thinking asks us to look beyond these surface-level "fixes" toward the network of underlying causes and effects (2016)."

Reinforcing the implications identified in standard U.S. education, in 2005, researchers in Israel discovered deficits in junior high students' ability to conceptualize the fundamental functions and interconnections of Earth's living systems (Assaraf & Orion, 2005). The same functions identified by Acaroglu (2019). To gather data, they created a program to teach science and technology with a systems-thinking approach called "Blue Planet" to answer their initial questions of whether or not students could grasp complex systems, what influences their ability to do so, and what the relationships are between those influences (Assaraf & Orion, 2005). The results of the study showed through a pre- and post-test of concept mapping the water cycle that "initial cognitive potential," in other words, ability prior to the program had a significant influence on their ability to understand Earth's systems after completion. They also found a relationship between student understanding and participation in outdoor and indoor inquiry-based learning. Based on their findings, Assaraf and Orion recommend that basic systems-thinking be introduced at the elementary level to help students develop skills for higher-level thinking in the long-term, along with more inquiry-based learning and outdoor learning environments (2005, p. 558). Their findings both confirm the known implications of standard education on students and provide introductory research into the effectiveness of a systems-thinking approach to teaching.

Supporting research on the transformative effects systems thinking can have on students is not a new discovery given the International Systems Dynamics Society has been active hosting conferences and publishing articles on it since the 1970's. Some experts involved in the fight for a sustainable civilization believe that nature holds the solution to our problems. Janine Beynus, founder of the Biomimicry Institute, catalyzed awareness on this idea in 1997 after publishing her book, *Biomimicry: Innovation Inspired by Nature,* while others have expanded it to encompass other fields of study. Combining the work of Beynus, Capra and those in the International Systems Dynamics Society, my research questions align with the work of researchers who believe that by teaching students, as early as possible, to understand the fundamental functions and interconnections of living systems, they can utilize that knowledge to achieve sustainability and regeneration of ecological and social systems from the micro to the macro level (Capra, 2007; Joseph, n.d., Orr, 1994). Bernier argues that not only do students need curriculum that includes the fundamental principles of living systems (ecology) in the content and learning objectives, but students also need a learning environment that is non-linear and reflects a resilient and diverse living system (2017), just as they are found in nature and just as Janine Beynus would tell us. If students are taught in a way that mimics a living system, while also learning to understand the principles and patterns of a living system, the research asserts that society would see a transformation of our ecological and social systems because students would develop a type of intelligence that would no longer allow for types of thinking that reduce nature down to a machine nor suppress their abilities to understand complex socio-ecological concepts (Joseph, n.d., Orr, 1994).

PEDAGOGICAL APPROACHES. Pedagogy is the theory and practice of educating, not to be confused with curriculum which consists of the content and materials utilized throughout the learning process. Persaud expands on pedagogy as "…the relationship between learning techniques and culture and is determined based on an educator's beliefs about how learning should, and does, take place. Pedagogy requires meaningful classroom interactions and respect between educators and learners. The goal is to help students build on prior learning and develop skills and attitudes and for educators to devise and present curriculum in a way that is relevant to students, aligning with their needs and cultures (2019).

Similar to the findings of Assaraf and Orion's study on high school students, Mainaki and Kastolani conducted research on varying levels of ecological intelligence of students in Cimahi City, Indonesia (2018). This study was particularly interesting because the researchers used a combination of Daniel Goleman's definition of ecological intelligence

(2010), and Muhaiman's (2015). They categorized ecological intelligence into four major categories as: "1) knowledge of the impact of human activities, including know the impact we cause, how to impact a) Geosphere (spatial impact); b) Biosphere (impact on organisms); c) Socio-sphere (social impact); 2) attitude improvements favor in care for the environment including transmitting his understanding to others (share the new knowledge with others); 3) skills in environmental conservation and 4) involvement in participatory environmental activities. (Mainaki, Kastolani & Setiawan, 2018, p. 2). Their data and discussion identified the main factors of influence when it comes to ecological understanding and application. Beyond initial cognitive capacity and personal perceptions of the world, they found that teachers and other school faculty members play a major social role in shaping a student's ability to develop ecological intelligence (Mainaki, Kastolani, & Setiawan, 2018) as well as the overall infrastructure and facilities of the school. Students who attended private schools scored, on average, higher in ecological intelligence than those in public schools, however, students, whose teachers incorporated ecological intelligence into the initial learning objectives, also scored high (Mainaki, Kastolani & Setiawan, 2018). These findings carry over into a conversation on effective pedagogical approaches to systems-thinking and how they can have influence on learning outcomes.

In 2014, a group of researchers conducted a three-year study on a second-grade class at Sycamore Elementary School which practiced systems-thinking pedagogy with the students. The study identified various approaches by the teachers and students to establish the fundamentals of systems-thinking, apply systems-thinking contextually (drought crisis), while maintaining that understanding through reflection and family/peer engagement (Curwen, Ardell, MacGillivray, Lambert, 2018). In discussing the outcomes of the study, the researchers stated that the students were able to understand their role in the larger context, "…consider their agency (p. 8)" and use that new understanding to address complex environmental problems (Curwen, Ardell, MacGillivray, Lambert, 2018).

Sycamore's second-grade class is a prime example of a systems-thinking framework that attempts to mimic a living system. It is important to note that the students, teachers and parents were all involved and engaged in this learning process, which has already been identified as a major influence in learning outcomes for ecological intelligence (Mainaki, Kastolani, & Setiawan, 2018). When we reflect on a living system, emergent properties, such as ecological intelligence in students, cannot be achieved without its smaller components working as a whole. In this case, the researchers have identified other people in the students' lives that have to participate in the system in order for their students and children to emerge. The class exemplified many of the "shifts in emphasis" (Capra, 2007, p. 12) defined in Capra's article. To shift from observing objects to relationships, the students engaged in dialogue about incidents and negative social interactions in the classroom to examine how their actions affects the whole (Curwen, Ardell, MacGillivray, Lambert, 2018). To shift from structure to process, the students were deeply involved in community project-based learning, which Capra argues, "emphasizes the application of knowledge within evolving real-life contexts (2007, p. 12)."

It is important to emphasize that although student understanding is my focused outcome of systems-thinking, it is next to impossible to achieve without the educator having a thorough understanding, as highlighted in the Sycamore Elementary example (Curwen, Ardell, MacGillivray, Lambert, 2018) and Cimahi City, Indonesia (Mainaki, Kastolani & Setiawan, 2018). In 2010, Puk and Stibbards tested a cohort of teacher candidates, all with four to five years of higher education, on their understanding of complex ecological concepts. The concepts were "The Environment, sustainability, green, fossil fuel, entropy, waste, ecological literacy, ecological integrity and ecological consciousness." There data was used to test different teaching models on the candidates, but their pre-survey findings exemplified that most educators maintain their initial perception and understanding of complex concepts even after several years of higher education. Their definitions of the concepts were described as "absent entirely, very vague, or missing essential criterial attributes (Puk & Stibbards, pg. 191, 2011)." They suggest that a lack of embodied experiences causes misunderstanding. Pedagogically, this means teaching students concepts through hands-on, outdoor and immersive activities can be more effective in providing robust means of understanding, echoing Assaraf & Orion's study (2005).

Furthermore, Mulej introduces a less obvious systems-thinking approach known as a dialectal system, following the same holistic principles of understanding an issue where students participate in conversation over a problem by initially hearing varying perspectives on it before engaging with it (2007). Mulej argues that facilitating a dialectal system in contrast to a "one-view-point-based-system" (2007, p. 348) prevents reductionist thinking in conversation and allows for robust understanding on a topic at stake because it highlights potential biases and interests and creates more informed decision-making (Mulej, 2007). A pattern emerges throughout the research, on the necessity of cultivating systems-thinkers in the classroom in order to avoid a narrowed mindset incapable of fully understanding and engaging with a concept. It is up to the educator to not only fully understand the complex concepts themselves, but also to promote and facilitate pedagogical approaches such as a dialectal system and outdoor learning experiences to help guide transformation of their students into systems-thinkers.

CURRICULAR APPROACHES. Curriculum, as defined by The Glossary of Education Reform, is "…the lessons and academic content taught in a school or in a specific course or program." It can also refer to the learning objective put forth by the framework.

Referring back to Assaraf and Orion's research on junior high school students and their understanding of complex earth systems, the first part of their study involved developing a program or curriculum that will produce the learning objectives of transitioning students to systems thinkers. The necessary components of their development included identifying a current environmental problem, asking an open-ended question about it, nature-immersion, exploring the integral parts of water systems, identifying the relationships between them, as well as internal and external influences on those systems. The researchers found that although the student's initial ability to understand complexity had an influence on the post understanding, the curriculum played an imperative role in the success of those that were able to understand the concepts and issues at hand (Assaraf & Orion, 2005).

An example of systems-thinking curriculum implementation in primary and secondary education comes from Fisher's 2011 article in *Systems Dynamics Review*. Fisher provides lesson plan topics for this method based on students' developmental learning phase, including children only five years of age. It is important to know that even though systems-thinking reflects ecological systems, it is universally applicable, and in fact, Fisher refrains from utilizing ecological or environmental terminology throughout the review. This may be vital information for future success in convincing institutions to integrate systems thinking frameworks. Some examples of themes in the lesson plans range from interconnectedness, stocks and flows, structures, to organizational change (Fisher, 2011).

Another similar example to Fisher's systems thinking curriculum taught in education is The National Research Council. They took strides in 2012 to implement a small-scale integration of systems dynamics, referred to as "crosscutting concepts," into their science and engineering standards for primary education (National Research Council, 2012). In doing so, the Council believes students can apply this type of thinking to real-world biological systems (2012). The outcomes of the newly proposed curriculum were not identified, but it would be worth finding out given these concepts are only a small component of an entire discipline. The Council's example highlights the issue of sufficiency in teaching systems thinking in the classroom and creates conversation about how different approaches should be pursued in an integrated fashion for optimum results.

From the fundamental level, Collen and Minati (1997) offer seven activities that engage learners with basic concepts around systems-thinking. Their activities are based Bertanaffly's general systems theory. They are not specific to any one discipline or grade level and can be adapted to any classroom setting. An example is "Mixing Water Colors" (Collen and Minati, pg. 3, 1997), where the students are given three cups filled with dyed blue, red and yellow water. The progression of the lesson involves mixing these colors to create and observe a spectrum of colors. In their dialogue following the instructions, the authors discuss the learning objectives which involve emphasizing the concept of emergence, which Acaroglu previously defined as a fundamental function of systems (2019). Furthermore, Minati (1997) explains that this activity teaches students to think about the difference between to add and to combine, between reversible and irreversible processes, and to think about their role as the observer of the interactions occurring in a system. Although this activity may come off as abstract, the goal, the authors state, is for is them to act as a steppingstone in becoming systems-thinkers. "We would hope ideally for their applications to create connection among the many peoples, cultures, language group, occupations, professions, disciplines and fields of study" (Collen and Minati, pg. 12, 1997).

Conclusion

Education is a powerful tool of influence. Its potential to provide us knowledge is does not discredit its potential to limit our understanding, skills and attitudes towards things that will one day shape our civilization far more than our traditional life paths ever have. Research in various disciplines suggests that while the standard U.S. education system continues to send its students through the same set of classes that are structured for standardization and life in the work force, it fails to provide students both curricular and pedagogical structures that allow for critical thinking at the complex level, more specifically in the context of climate change-related issues. It instills ideologies that shift values and behaviors towards favoring our socio-economic and biological narratives of success in monetary accumulation, unlimited growth and human superiority over all life forms. Kopnina emphasizes that even in environmental education, certain pedagogical and curricular approaches can still perpetuate anthropocentric and neoliberal ideologies (2015).

Systems-thinking, an approach to understanding biological, ecological and social systems, has existed since the 1920's. Over the years, it has transformed from general systems theory, to living systems theory, and systems scientists such as Leyla Acaroglu, have emerged with contemporary definitions and applications. Across the globe, researchers have conducted studies analyzing students' abilities to holistically understand systems such as the hydrosphere (Assaraf & Orion, 2005), and found that prior to a systems-thinking teaching method, the students had major deficits. In addition, a second-grade classroom, in 2014 immersed their students' learning experience in systems-thinking, both pedagogically and in content. Researchers found that not only were the students able to understand things in their larger context, they understood their roles as agents of change in addressing complex environmental issues (Curwen, Ardell, MacGillivray, Lambert, 2018). There is significant research that systems-thinking classrooms can provide students the tools they need for critical thinking in the face of complex challenges. The threat of climate change makes this need even more prevalent. As Bernier described, like a resilient living system, the learning environment needs to be diverse and holistic, involving all the interacting parts including teachers, parents, students, curriculum, pedagogy and classroom space.

METHODOLOGY

Research Design

The purpose of this study was to gain insights from educators around Missoula County in Montana about their personal understanding or interpretation and opinion of systems thinking and its role in their classrooms. For example, some educators already integrate systems-thinking principles into their curriculum without knowing that is where their content and activities are drawing from.

Research Approach

The respondents were K-12 teachers in Missoula County from both public and private schools. There were no limitations on disciplines or grade levels. The sampling method was a convenience sample via an online 16-question survey sent by email. It was distributed to 335 teachers at three public elementary schools, three public middle schools, two public high schools and one independent school. 32 teachers responded.

The survey was expected to take respondents fifteen minutes to complete dependent on thoroughness of responses. The questions were intentionally comprised of questions heeding both quantitative and qualitative results and were formatted and ordered for chronologically specific outcomes. The questions took on various forms of open-ended, multiple choice, and ranking order. For example, a demographic question followed by a personal goals question were the first two questions of the survey. This was important in order to gather an unbiased idea of what each teachers' overarching learning objectives were before introducing them to the concept of systems thinking. From there the survey questions took on various forms of open-ended, multiple choice, and ranking order.

Coding Framework

For questions 6 & 7 of the survey, a coding framework was used for an organized analysis of the variant responses.

Q6: Based on this infographic, describe any curriculum/content/activities you teach (past or present) that lean toward the graphics on the right side of each pair.

Q7: Based on this infographic outlining methods to conceptualize systems, describe any curriculum/content/activities that you teach (past or present) that integrate system mapping?

Questions 6 & 7 were the main focus of the survey because the educators 1) already had a definition of systems-thinking at that point and could articulate their understanding of the definition in their responses and 2) responses were aimed to heed results for the gap in research which is identifying and evaluating curriculum, content or activities used in the classroom to develop systems-thinkers.

The code is as follows:

- » **Concept association (CA)** – associated systems thinking with subjects, topics & concepts
- » **Expression through explanation (EE)** – expressed understanding through explanation
- » **Expression through activity example (EA)** – expressed understanding through activity example
- » **Vague response (VA)** – vague description that did not express adequate understanding

These codes will be utilized in the analysis and findings to answer the research questions.

Research Questions

How do K-12 educators in the Missoula public school system perceive systems-thinking as a method for teaching their students complex concepts?

How are systems-thinking principles translated into classroom learning activities?

DATA ANALYSIS

The data analysis of the research is presented in both quantitative and qualitative manners, given the formatting of the survey questions.

64% of the respondents in the survey were high school teachers, 9^{th}-12^{th} grade. The following open-ended questions revealed that the high school-level respondents were more likely to complete the entire survey than the remaining 46% of K-8^{th} grade teachers.

57% of the respondents stated that their curriculum model is a single discipline, while another 27% stated that they teach multiple disciplines. 13% said interdisciplinary.

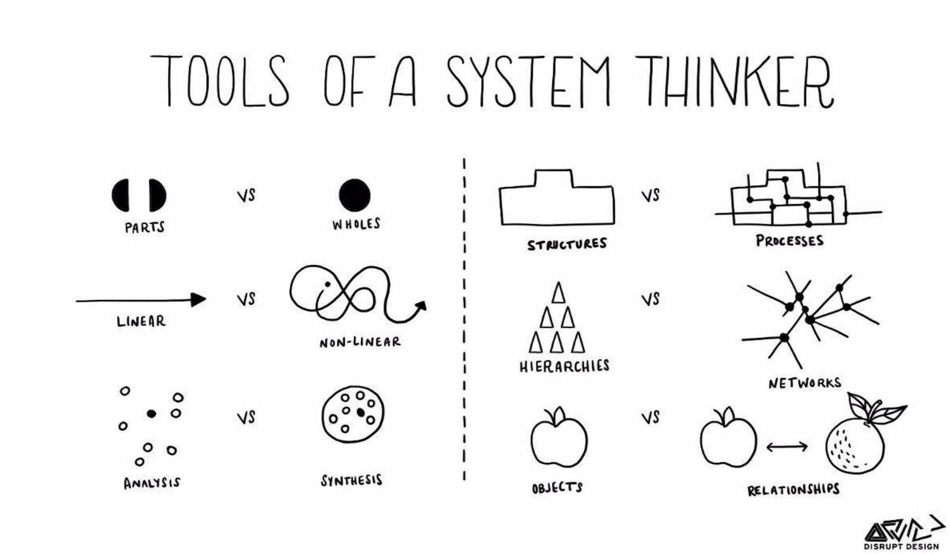
The educators were asked in the beginning of the survey if they had their own definition of systems-thinking. 86% of them said no, while 14% said yes. Out of those that claimed to have their own definition, *none* of them had a description that reflected an adequate understanding of systems-thinking. One educator stated that they were guessing their definition.

Given this definition, *"Systems-thinking is a framework for teaching that studies the functions of interrelated parts of systems in order to understand them as a whole,"* the educators were asked to rate the importance of its integration into student learning. 89% rated it as either very important or extremely important. 11% said moderately important. None said slightly or not important.

- The numbers highlight that 1) interdisciplinary curriculum models are uncommon in the Missoula school system, 2) that while the majority of educators, given a definition of system-thinking, believe that it is an important approach in student learning, they had no prior knowledge of what the term and/or concept meant. Later on, I address that some responses suggest that educators utilize systems-thinking principles and methods in their classroom but are not familiar with the language used in this survey

These brief, multiple choice questions laid the foundation for the more in-depth and complex questions that require educators to examine the principles and methods used in systems-thinking. Given two comprehensive infographics on 1) principles and 2) mapping methods, educators were asked to *describe* curriculum, content or activities they use in their classroom that integrates the concepts in the infographics. The word *describe* was intentionally used to ensure that the respondents gave a thorough explanation; that they will both identify and explain with specificity where they see systems-thinking in their classroom.

Q6: Based on this infographic, describe any curriculum/content/activities you teach (past or present) that lean toward the graphics on the right side of each pair.



36% of educators expressed their understanding through explanation (EE) of where the systems-thinking principles fell into their classroom learning. These educators did not provide specific examples but were able to exemplify adequate understanding of the infographics and the difference between systems vs linear thinking. Although their understanding of systems-thinking may suffice, they did not identify any concrete examples of how it is used in their classroom, even though the question asks them to do so.

- This suggests that 1) systems-thinking was an abstraction for the educator and/or 2) systems-thinking is used in their classroom, they just don't know where and how.

14% of educators expressed their understanding through activity example (EA). This means the educator provided specific examples of activities and lessons taught to their students alongside an explanation of how those activities align with systems-thinking principles.

- The responses suggest that the educators not only grasp the concept, they can also concretely translate its principles into classroom activities with their students. It is surprising that only two of the fourteen that responded were able or willing to be thorough and specific in their responses. It is important to note the small fraction of educators that exemplified an adequate understanding of systems-thinking and how it can be applied in classroom learning.

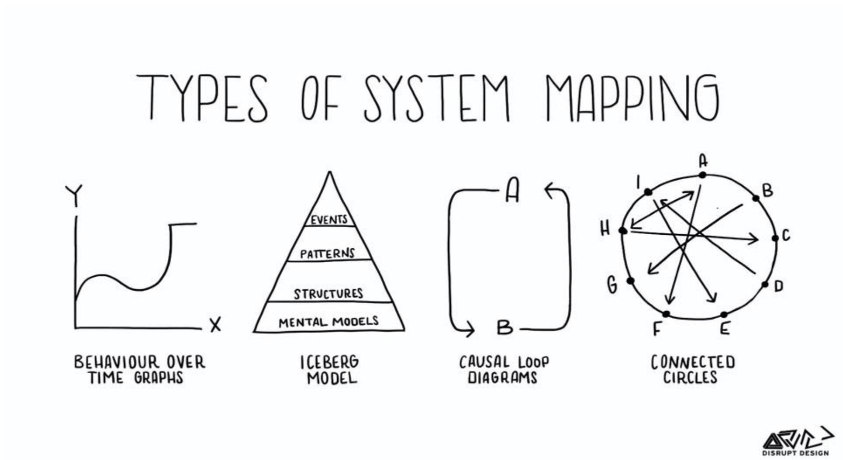
21% of educators associated systems-thinking principles with topics, concepts and subjects (CA). Rather than going through the describing process, the responses simply identified various learning foci that they either think or know involves some degree of systems-thinking. Some examples include AP History, AP Geography, climate change, and ecology.

- Without an explanation or description of how systems-thinking applies to the identified courses and concepts, it is unclear to what degree the educators understand it. That is not to claim they don't understand it, but it is worth noting that the listed subjects and concepts can be taught linearly. Supplemented by the fact that only 13% of the educators claimed that their curriculum model was interdisciplinary, it is probable that any responses that choose not to describe how, for example, climate change can be taught utilizing systems thinking principles (which includes a holistic, interdisciplinary approach), do not know or understand how to execute it, concretely.

21% of educators responded with vague descriptions that did not express an understanding of systems-thinking (VA).

- Reponses with vague descriptions that varied from statements such as "Everything I teach" to "I can't think of any activities that I do that do not lean to the right" suggest that although the educator claims to have systems-thinking weaved into the fabric of their teaching method, they were unable or unwilling to describe even one or two examples of activities in their classroom. This may not be the case but based on the survey question and the intentional use of the word describe to heed specificity and thoroughness, their responses suggest that they do not understand systems-thinking and its application for learning.

Q7: Based on this infographic outlining methods to conceptualize systems, describe any curriculum/content/activities that you teach (past or present) that integrate system mapping?



- *21% of educator responded with vague descriptions that did not express an understanding of system mapping (VA).*
- 43% o*f educators expressed their understanding through activity example (EA).*
- *21% of educators expressed their understanding through explanation (EE).*
- *1 educator stated they do not use system mapping.*

Question 7 followed Question 6 because its infographics needed the foundational introduction of principles before seeing the types of mapping used. The responses to this question were interesting because there is a spike in expression through activity example (EA). In question six, only 14% of the educators provided specific examples of how systems-thinking principles were used in their classroom, whereas 43% of the respondents were able to provide them prior to seeing the visual.

- The responses to this question suggest that more educators incorporate varying levels of systems-thinking into classroom learning without knowing it.

Something to note, is that often educators in the arts, such as music, orchestra, and drama, expressed a thorough understanding of these shifts in emphasis in the classroom. Responses suggest that not only does music inherently lends itself to systems-thinking, it is also very. In Collin & Minati's, "Seven Activities to Engage Systems-Thinking," the fourth activity, titled "Harmony in Music" explains the emergent properties of playing instruments separately and together. The students are asked to reflect on the separate elements and their roles in the larger symphony (Collin & Minati, 2012), which is system of parts creating a better functioning whole. Similarly, the educator's responses reflect on their student's experiences in similar ways, such as these responses from different educators:

"analysis of character relationships, thematic pairings, impact of context on art"

"Rehearsing, studying, and performing a band composition that gives students diverse roles, textures, and expressive targets throughout the piece. For example, a piece may have rhythm, harmonic accompaniment, and melody. Discovering more about our role in a

music ensemble challenges the student to listen and perceive the intent of the composer. Once we rehearse the three parts individually (exposure), the students combine them into the whole part, aka the full composition."

"Students perform, listen to, and evaluate optimal balance and blend concepts. In a particular moment in a composition, students learn a balance system based on listening and intelligent musicianship and decision-making? I want students to effectively do this in rehearsals without guidance. Various shapes, such as blocks or pyramids, are used to reflect visually the concept of the balance system."

"Most of the music curriculum that I am using leans toward the right side of the pairs. We focus mostly on how sounds function together, how instruments function together, and how we can get to a place of playing music at a similar level."

On the other hand, many responses did not express an understanding of how the subjects and activities they teach align with a systems-thinking approach. This raises a red flag as to what level of understanding the educator has for the content they are teaching because 1) if the educator had robust knowledge and understanding of the concepts in their curriculum, they would understand it in a systems, and/or real-world context 2) would be able to describe activities used to achieve conceptual understanding (where or not they knew the terminology was systems-thinking). The words used to describe the shifts in emphasis from question six, are not uncommon words. Surely, educators could see the word relationship and pick an example or two from their curriculum that highlights this. This is especially true for the educators that simply listed the concepts they teach such as:

"Climate change, DNA" and *"Climate change, organ systems vs cell structure/function, ecology, energy sources"*

Puk & Stibbards addressed this deficit in teacher conceptual understanding in their study conducted on a cohort of teacher candidates in 2010. Alarmingly, these candidates, pre-study had four to five years of university education and prior to taking a course for environmental education, had immature and misperceived definitions of complex ecological concepts (2011). Fortunately, post-training, with the help of "emergent instructional activities" beyond simply transmission of information, significantly increased understanding of concepts.

Their study, alongside the responses from the surveys, suggest that this deficit may reach beyond the realm of ecological/environmental literacy. Complex concepts exist in all disciplines and are often, transdisciplinary. In fact, the survey asks the teachers to select various concepts that are intentionally either a part of ecological systems or social systems, such as ecology, sustainability, climate change and gender, culture and racism. On average, 6-7 educators selected at least one of the concepts that they teach to their students.

RECOMMENDATIONS

My data is unique in that it contributes to systems-thinking from the perspective of K-12 educators across various disciplines. Two significant takeaways from this research that are important to highlight for further suggestions is that the majority of Missoula, MT educators believe that systems-thinking is important for developing student understanding. This is the first step for its application in the classroom. The second is that a significant portion of the educators, especially those teaching advanced subjects and complex concepts such as climate change, ecology, and other AP classes, could not list specific examples of systems-thinking activities that their students engage in. All this in mind, I recommend that researchers begin looking to develop comprehensive guides for educators in various disciplines that want to implement more systems-thinking pedagogies and curriculum for their students. I also recommend that we take a systems-thinking approach in the research itself, given that education is a system. This involves taking Mulej's suggestions on dialectal systems by researching various perspectives in order to gain a holistic understanding of how to best implement systems-thinking into the classroom. It is motivating to know that educators in Missoula see the value ins systems-thinking for their students. They may just need to be pointed in the right direction.

Preview of Questionnaire

1) What grade level(s) do you currently teach?

2) What model(s) does your curriculum use?

3) What are your main objectives for your students after they complete their school year/semester with you?

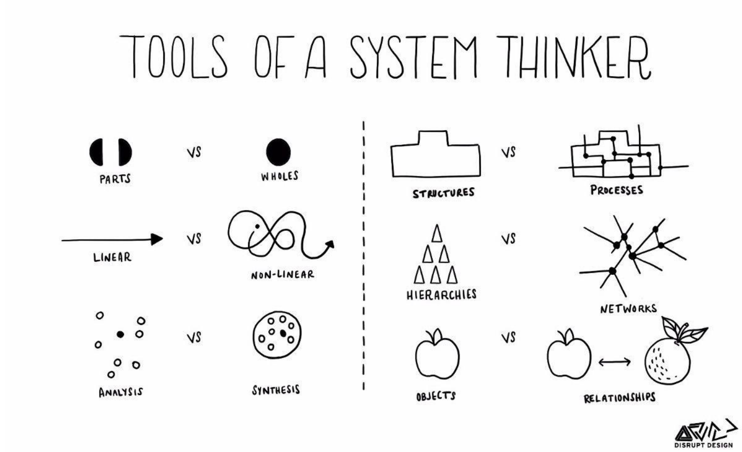
4) Do you have your own working definition of systems thinking? If yes, please summarize below.

5) If yes, based on your own definition of systems thinking, rate its importance for integration into student learning.

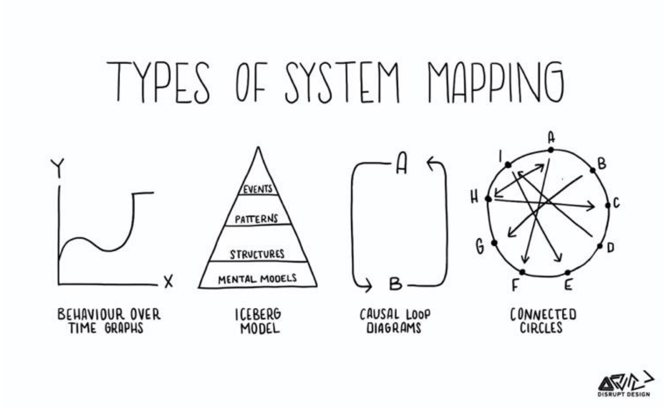
6) If no, based on this definition of systems thinking, rate its importance below.

   "Systems-thinking is a framework for teaching that studies the functions of interrelated parts of systems in order to understand them as a whole"

7) Based on this infographic, describe any curriculum/content/activities you teach (past or present) that lean towards the graphics on the *right side of each pair.*



8) Based on the infographic outlining methods to conceptualize systems, describe any curriculum/content/activities that you teach (past or present) that integrate system mapping?



9) Choose the phrase that best describes how your students think.

Break things into component pieces	○ ○	Are concerned with the whole
Are concerned with content	○ ○	Are concerned with process
Find patterns amid chaos	○ ○	Control chaos to create order
Are concerned with root causes	○ ○	Focus on fixing symptoms
Care about content of conversation	○ ○	Are concerned with the interaction
Explore perspectives and evidence	○ ○	Obtain the right answer quickly

10) Select the topics that you either introduce or integrate into your current curricula. (ecology, climate change, environment, sustainability, other, n/a)

11) How do you evaluate your students' understanding of your selected topic(s).

12) On a scale of one to five, no ability to full ability, rank your students' ability to understand the selected topic(s).

13) If your rating is anything below a five, please explain.

14) Select the topics that you either introduce or integrate into your current curricula. (culture, racism, governance, gender, other, n/a)

15) How do you evaluate your students' understanding of your selected topic(s).

16) On a scale of one to five, no ability to full ability, rank your students' ability to understand the selected topic(s).

17) If your rating is anything below a five, please explain.

18) Please share any further comments, feedback or questions below.

References

Acaroglu, L. (2019, September 7). Tools for Systems Thinkers: The 6 Fundamental Concepts of Systems Thinking. Retrieved April 24, 2020, from https://medium.com/disruptive-design/tools-for-systems-thinkers-the-6-fundamental-concepts-of-systems-thinking-379cdac3dc6a

Assaraf, O. B.-Z., & Orion, N. (2005). Development of system thinking skills in the context of earth system education. Journal of Research in Science Teaching, 42(5), 518–560. doi: 10.1002/tea.20061

Atlas, C. (2018, June 29). U.S. College Dropout Rate: College Statistics. Retrieved February 14, 2020, from https://www.collegeatlas.org/college-dropout.html

Bernier, A. (2017). From Linear Industrial Structures to Living Systems: A Design Shift in Education for Sustainability. Education Sciences, 7(2), 43. doi: 10.3390/educsci7020043

Biello, D., Robbins, J., Jones, N., & Victor, D. (2017, January 18). How Far Can Technology Go to Stave Off Climate Change? Retrieved February 17, 2020, from https://e360.yale.edu/features/how_far_can_technology_go_to_stave_off_climate_change

Capra, F. (2007). Sustainable Living, Ecological Literacy, and the Breath of Life. Canadian Journal of Environmental Education, (12), 9–18. doi: https://files.eric.ed.gov/fulltext/EJ842778.pdf

Center for Ecoliteracy. (2012, July 25). Apply Ecological Principles. Retrieved March 16, 2020, from https://www.ecoliteracy.org/article/applying-ecological-principles#

Common Core State Standards Initiative. (2020). Retrieved February 13, 2020, from http://www.corestandards.org/read-the-standards/

Dgadmin. (2009, April 20). What is ecological intelligence? Retrieved January 17, 2020, from http://www.danielgoleman.info/ecological-intelligence-definition

Fisher, D. M. (2011). “Everybody thinking differently”: K-12 is a leverage point. *System Dynamics Review*, *27*(4), 394–411. doi: 10.1002/sdr.473

Goleman, D., Barlow, Z., & Bennet, L. (2009, November 30). Forging New Norms in New Orleans: From Emotional to Ecological Intelligence. Retrieved January 17, 2020, from https://eric.ed.gov/?id=EJ904902

Gowdy, J. M. (2008). Behavioral economics and climate change policy. *Journal of Economic Behavior & Organization*, *68*(3-4), 632–644. doi: 10.1016/j.jebo.2008.06.011

IPCC, 2018: Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty, from http://www.ipcc.ch/sr15/chapter/spm

Joseph, B. (n.d.). An Evolutionary Framework for Global Sustainability Education: An Integral, Posthuman Perspective. Retrieved January 8, 2020, from https://www.academia.edu/14461022/An_Evolutionary_Framework_for_Global_Sustainability_Education_An_Integral_Posthuman_Perspective

Kopnina, H. (2015). Neoliberalism, pluralism and environmental education: The call for radical re-orientation. *Environmental Development*, *15,* 120–130. doi: 10.1016/j.envdev.2015.03.005

Mainaki, R., Kastolani, W., & Setiawan, I. (2018). Ecological Intelligence Level Of Hight School Students In Cimahi City. SHS Web of Conferences, 42, 00062. doi: 10.1051/shsconf/20184200062

Mochizuki, Y., & Bryan, A. (2015). Climate Change Education in the Context of Education for Sustainable Development: Rationale and Principles. *Journal of Education for Sustainable Development*, *9*(1), 4–26. doi: 10.1177/0973408215569109

Mulej, M. (2007). Systems theory: a worldview and/or a methodology aimed at requisite holism/realism of humans thinking, decisions and action. Systems Research and Behavioral Science, 24(3), 347–357. doi: 10.1002/sres.810

National Center for Education Statistics. The NCES Fast Facts Tool provides quick answers to many education questions. (n.d.). Retrieved April 13, 2020, from https://nces.ed.gov/fastfacts/display.asp?id=372

National Research Council (NRC). (2011). Sustainability and the U.S. EPA: Consensus Study Report. Washington, DC: The National Academies Press.

National Research Council. (2012). A framework for K-12 science education: practices, crosscutting concepts, and core ideas. Washington, DC: The National Academies Press. 83-102

Orr, D. W. (1994). Ecological intelligence. Trends in Ecology & Evolution, 9(12), 500. doi: 10.1016/0169-5347(94)90331-x

Persaud, C. (2019, March 1). Pedagogy: What Educators Need to Know. Retrieved February 5, 2020, from https://tophat.com/blog/pedagogy/

Schmidt, F., & Hunter, J. (2000). Select on intelligence. In E.A. Locke (Ed.), *The Blackwell Handbook of Organizational Principles.* 3-14. Oxford: Blackwell.

Schulte, P. (2016, August 31). Systems thinking, in five minutes. Retrieved April 28, 2020, from https://kindling.xyz/next-systems/systems-thinking/#

Slabbert, J. A., & Hattingh, A. (2006). 'Where is the post-modern truth we have lost in reductionist knowledge?' A curriculum's epitaph. *Journal of Curriculum Studies, 38*(6), 701–718. doi: 10.1080/00220270600608023

Stibbards, A., & Puk, T. (2011). The Efficacy of Ecological Macro-Models in Preservice Teacher Education: Transforming States of Mind. Applied Environmental Education & Communication, 10(1), 20–30. doi: 10.1080/1533015x.2011.549796

Thunberg, G. (2020, January 29). Retrieved January 30, 2020, from https://www.facebook.com/gretathunbergsweden/

U.S. Bureau of Labor Statistics. (2017, May 22). Retrieved February 14, 2020, from https://www.bls.gov/opub/ted/2017/69-point-7-percent-of-2016-high-school-graduates-enrolled-in-college-in-october-2016.htm