Development of an innovative method for analyzing the presence of environmental sustainability themes and an ecological paradigm in science content standards

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A R T I C L E   I N F O

Article history:
Received 16 September 2013
Accepted 6 January 2014

Keywords:
Environmental sustainability
Standards
Ecological paradigm
Curriculum

A B S T R A C T

An iterative process for developing a method for analyzing Florida’s K-12 Next Generation Sunshine State Standards science content was described. For this study, the researchers developed an innovative approach for analyzing the presence of environmental sustainability themes and an ecological paradigm within science content standards. The findings illustrate that detecting ecological thinking within the content standards is a complex and unwieldy process, even when the coders are experts in the content area. Despite this limitation, our expert coders rated the standards document with an overall agreement of 81%. Future research was discussed in terms of how our method could be used to further stakeholders’ understanding about how and to what extent ecological thinking is covered within science content standards.

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How do we determine what students should know and be able to do? Who should determine the outcomes of students’ learning and the experiences they have throughout their education? Curriculum design and development often begin with philosophical questions such as these. Today, our current context of education embodies standards that are developed by various groups of people with specific agendas. As Gorlewski, Porfilio, and Gorlewski (2012) point out, “like anything socially constructed, standards themselves manifest the values and beliefs of their developers” (p. 2). Standards are the foundation from which curriculum design and development begin (Estes, Mintz, & Gunter, 2011; Hale & Dunlap, 2010). It is critical, therefore, to determine what the content standards demand of students and teachers. What exactly are students required to learn? How does the discourse of standards, in this case Florida’s K-12 Next Generations Sunshine State science content standards (NGSSS), convey that requirement?

According to Reuters, President Obama proposed “$80 million in new government funding for a program to boost science and math education in U.S. schools” (http://www.reuters.com/article/2012/02/07/us-obama-education-idUSTRE8161IQ20120207). Echoing the president’s policies, there are a number of sources emphasizing the importance of science education and 21st century skills (National Research Council, 2012). Presently, the National Research Council (NRC, 2012) has developed a proposed framework for K-12 science education stating that this is “the first step in a process to create new standards in K-12 science education” (p. ix). Content standards, defined as what students should know (Korn, 2004; Taubman, 2009), are the body of knowledge that students will cover throughout the K-12 academic years. Like all adopted standards, in the state of Florida, the current science standards provide a body of evidence for science knowledge that is most valued and considered of greatest worth (English, 2010; Gorlewski et al., 2012). It is also important to remember that standards also teach beyond the ‘what’ of content; standards also speak to the skills students are to develop as they learn. Bloom’s taxonomy (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956) offers a framework for the way many standards are written and competencies are assessed (Kennedy, 2008), and “mastery of academic standards requires an alignment of both content and cognition” (Manthey, 2005, p. 14). Establishing a knowledge base of the content of these standards is critical if all stakeholders are to
thoroughly understand what students are expected to know and do, especially given the high-stakes assessment students must take throughout their education (Au, 2007). Texts can impact change; for instance, Fairclough (2003) argues that “texts can bring about changes in our knowledge…our beliefs, our attitudes, values and so forth” (p. 8). Those texts that wield influence on educational systems and determine the content of the written curriculum are the object of the analysis of this study, principally NGSSS science content standards that decree what science content is taught in Florida’s public schools. Thus, in the context of a standards-based approach to knowledge acquisition, the purpose of this paper is to present the methodological findings of an analysis of science content in Florida’s K-12 Next Generation Sunshine State Standards (http://www.cpalms.org/Standards/FLStandardSearch.aspx).

Content selection

One of the most pressing issues for current and future generations is clearly environmental sustainability (ES). In 1972, the first international community met to discuss sustainability as a matter of importance (Fabricatore & López, 2012), but it has taken until recent years for the pertinence and urgency of this matter to be seriously addressed by society in general and the educational establishment in particular (Tilbury & Wortman, 2004). In the past two decades, undergraduate programs have revamped their coursework to include sustainability issues (Aurandt, Lynch-Caris, Borchers, El-Sayed, & Hoff, 2012) and this movement spirals downward through primary grades (Brown, 2010; Frantz, 2010) and even crosses into outdoor adult adventure programs (Mullins, 2011). While many may think traditional science classrooms are the main stakeholder in ES issues, a diverse range of schools, including business, engineering, and family and consumer sciences, have found vital relevance in teaching sustainability within their respective disciplines (Aurandt et al., 2012; Schwer- ing, 2011; Thompson, Harden, Claus, Fox, & Wild, 2012).

Today’s ideal of sustainability is one that promotes the security of both human and ecological futures (Adams, 2013). Effective teaching to this extent supports higher level thinking that incorporates economic, environmental, and social issues (Fabricatore & López, 2012). This means that sustainability education involves personal values, social issues and forecasts on complex subjects (Fabricatore & López, 2012). Having ES standards that incorporate reflective opportunities for students to weigh values, see relationships, evaluate situations, and predict outcomes is important. Without explicitly tying critical thinking skills to environmental education, curriculum would be bereft of any level of personal buy-in as students would choose to believe or disregard the content as meaningless propaganda (Seatter, 2011). Some people argue that proper ES development “cannot be integrated into existing frameworks, but requires a transformation of the educational system” (Venkataraman, 2009, p. 8). For example, many of the decision-making processes involving ES require processes that contradict common practices of graduate business programs (Schwer- ing, 2011). Consequently, the next generation of decision-makers needs to be wholly informed on the social and environmental repercussions of decisions as well as the economic ones (Halsey, 2009). Furthermore, educating for ES is a practice that complements the development of the types of creative thinkers and problem-solvers for which governments, corporations and organizations around the world advocate (Stables, 2009). For this and other reasons, some suggest that ES education must break old paradigms and can only be effectively taught as humanized content standards (Stride, 2010). As Frantz (2010) indicates, however, schools are stretched to incorporate sustainability initiatives into their curriculum. When discussing the Science Content Standards for California’s Public Schools, Saylan and Blumstein (2011) argue that “the standards do not provide enough of the tools necessary for students to practically understand the environmental processes that will likely change their world and their lives” (p. 29). There is a consequential need to consider how and to what extent standards writers are embedding ES concepts into existing curriculum (Stone & Barlow, 2005).

Irrespective of the type of change that may occur to science content standards, how do we measure the presence of environmental sustainability’s – or any other new initiatives – integration within existing curriculum? Sterling (2001) developed a conceptual framework that provides a blueprint for analyzing the extent to which science content standards present a systemic, value-laden, and problem solving approach to teaching ES concepts. Sterling’s (2001) framework provides defining characteristics for teachers, standards writers and other educational stakeholders concerning essential elements of ES knowledge and ecological thinking. In light of this inquiry, our research seeks to establish a reliable system to analyze the presence of overarching ES concepts into curriculum standards. In a time of nation-wide educational reforms and initiatives, it is important to develop a system to analyze standards, their content, their targeted skill development, and their interpretation in light of underlying priorities. To respond to these concerns, the researchers developed a research design to systematically address Florida’s K-12 NGSSS science content in order to determine the extent to which they present ES themes and an ecological paradigm as defined by Sterling (2001). It should be noted that the researchers make no claims about the enactment of the science curriculum in the classroom, but rather offer this methodological approach as one way for researchers, educators, and policy makers to rigorously review local, state, and national science education standards.

Purpose of the current study

The purpose of the current research is to report on the development of a methodological approach to analyzing the ES themes and ecological framework present in Florida’s K-12 NGSSS for science. The project involved an iterative approach for the development of a method that began with using key terms to identify the presence of ES themes and an ecological paradigm. The first step in this iterative approach was the identification of key terms that facilitate the development of ES content (Archer, 2013). Categorized and four ES themes emerged: (a) environmental impacts (EI), (b) biodiversity (BD), (c) population dynamics (PD), and (d) energy transformation (ET). Key terms were also used as a novel approach for focusing raters’ attention to the presence of potential ES content that might be found within the standards’ document. Subsequent iterations of the method were needed to enhance the reliability and usability of this method with ES expert analysts.

Theoretical framework

The theoretical framework used by the present researchers in their analysis of Florida’s NGSSS for science derives from Sterling’s (2001) ecological paradigm. The ecological paradigm recognizes humans as one aspect of a multifaceted, dynamic, and intensely interconnected world. Sterling (2001) describes three dimensions in the paradigm: perceptual, conceptual and practice. Sterling’s (2001) framework encourages a relational view of the world focusing on people’s ability to recognize patterns of influence between systems that at first appear fragmented. Practice is the dimension of action arguing that the whole is greater than the sum of its parts; synthesis and purpose are fundamental components in the search for healthy relationships.
The guiding principle of Sterling’s (2001) ecological paradigm is wholeness. Interdependence of all life emphasizes that education, as the principal societal institution, is responsible for the development of humans, and teaches knowledge, skills, and values to each generation. According to Sterling (2001), an ecological paradigm in education focuses on students’ critical and systemic understanding of what they learn and develops their higher order thinking abilities (e.g., analysis, synthesis, evaluation, etc.). Students who maintain a systemic view of their learning use a holistic lens to perceive and understand what they learn. They draw on “systems and humanistic ideas” to make holistic thinking “understandable, accessible and practicable” (Sterling, 2001, p. 52).

Sterling (2001) also explains that education has the ability to transform society (where students are aware of humans’ capacity to positively impact their environment), but contends that the current paradigm of education is mechanistic, instrumentalist and transmissive. This transmissive approach to education, emphasizing the “transfer of information” (p. 35), is one of mechanistic management. The mechanistic management paradigm being practiced in most educational institutions results in “rigidity and inability to respond creatively…” (Sterling, 2001, p. 46). Sterling (2001) argues for “management for complexity values” (p. 46) that focuses on “genuine participation and collaboration, flexibility, trust, inclusivity, diversity, autonomy, and the role of local and personal knowledge inherent in the learning processes” (p. 46). He encourages a model of education that is constructive and transmissive, “i.e., engages the learner in constructing and owning meaning” (p. 35), and focuses on education that is participative.

Sterling (2001) maintains that with a transmissive education, students are not provided the opportunity to regulate and determine their learning environment, to have control of their work, or the chance to build upon the knowledge they learn in meaningful and relevant ways. This transmissive approach to education limits what students learn and is what Freire (2003) refers to as the “banking’ concept of education” (p. 72). Under this paradigm of education, teachers are the depositories of knowledge and students the deposits. Freire (2003) states, “instead of communicating, the teacher issues communiqués and makes deposits which the students patiently receive, memorize, and repeat” (p. 72).

A transformative perspective of education encourages students to work in inclusive and dynamic modes to promote the capacity to learn and understand knowledge. Students retain ownership of their work and build meaning as it pertains to their experiences. A transformative education facilitates students’ capacities to use their understanding to transform themselves and society. This type of education informs a systemic, ecological paradigm. Schools, when functioning under an ecological paradigm of education, not only teach students the critical thinking skills required to prosper in a worldwide economy, but more important, offer students a holistic view of the themselves as individuals and their relationship to the society and the organic world.

It is necessary to understand if our approach to educating students embraces this all-inclusive, ecological worldview, a standpoint that emphasizes cooperation and diversity. This viewpoint is student-centered and learner-oriented; it supports education as a means to prepare students for life, not just for work and places students at the center of their educational process. Because Sterling (2001, 2003) posits that education is mechanistic and neither transformative or holistic, it is necessary to have a reliable and valid method for analyzing content standards to determine if these standards offer students an ecological worldview of science content that is aligned with environmental sustainability themes. Again, while this study does not claim to investigate the enactment of the standards as curriculum in the classroom, evidence suggests that standards are the foundation for what is eventually taught in the classroom, in particular due to their alignment to high-stakes tests (Au, 2007; Taubman, 2009). As Stone and Barlow (2005) contend, even when we can connect our solution to publicly recognized problems, we still need to link better food and waste reduction and recycling and farm to curriculum as it is understood in today’s educational climate. And that means as it relates to the standards, by subject and by grade on which kids will be tested. … (p. 254)

The researchers in this study, therefore, argue that investigating the relationship between standards content and an ecological paradigm is a relevant and purposeful agenda. And because Sterling’s theory embodies four major characteristics of an ecological paradigm (value, relationships, higher order thinking and humans’ causal relationship with the environment) it was chosen as the conceptual framework for an analysis of the NGSSS.

Method

Research question

The current study focused on the development of a method for examining the discourse of Florida’s K–12 NGSSS for science. The following question guided the emerging research process: How and to what extent does the coding method assist with identifying the following themes of ES and an ecological paradigm in the discourse of the Florida’s K–12 NGSSS for science: (a) environmental impacts (EI), (b) biodiversity (BD), (c) population dynamics (PD), (d) energy transformation (ET) and other (a key term occurs in the sample text but does not align with any ES theme). Drawing on a large body of Educating for Sustainability and Environmental Education literature, the researchers determined that these themes most broadly represent the concepts and themes of ES (Tenam-Zemach, 2010).

Data sources

Data was collected from the primary text of the science content standards that guide K–12 science curriculum in Florida’s public schools (http://www.cpalms.org/Standards/FLStandardSearch.aspx). The criteria for the selection of texts for data analysis were that the texts describe the broad aims, goals and objectives for the expectations of Florida’s schools and that they offer specific direction for educational outcomes at the state level. According to the 2009 Science Specifications for the 2010–2011 Florida State Adoption of Instructional Materials guide, “All components of curriculum, instruction, and assessment should be developed from the standards” (http://www.fldoe.org/bii/instruct_mat/pdf/ScienceSpecs_2009.pdf, p. 3). This document also states that “Understanding scientific concepts is fundamental to improving quality of life, harnessing natural resources, and preserving the environment” (p. 3). Consequently, the decision to analyze the Florida’s K–12 science content standards addresses Krippendorff’s (2013) contention that “texts inform an analyst about extratextual phenomena, about meanings, consequences, or particular uses” (p. 37). Since the 2009 Science Specifications clearly expect standards to align with instructional learning outcomes, it behooves researchers to scrutinize the content of these standards, in particular as they relate to expectations of students’ understanding of how science contributes to improving quality of life for all.

Instrument

A recording instruction booklet was developed prior to the analysis process. This booklet provided the procedures that coders were expected to follow throughout the examination of the NGSSS.
for science. In addition to the coding booklet, a concordance program was used to isolate the presence and context of each key term being analyzed. The application of this technology facilitated the analysis of the large amount of descriptive data. McCarty (2007) describes the techniques of using a concordance program to assist in the analysis of textual data.

Data collection

When conducting a systematic review of texts, researchers should limit that body of texts to that which will answer the research questions. The researchers utilized a relevance or purposive sampling procedure. Relevance sampling allows analysts to examine the texts to be analyzed in a multitape process (Krippendorff, 2013). Krippendorff’s assertion that relevance sampling “aims at selecting all textual units that contribute to answering the given research questions” (p. 120) underscores the choice of Florida’s science content standards for data analysis. The researchers collected Florida’s K-12 NGSSS science content standards and constructed a sample of the text. The standards are organized by grade levels K-8 and by grades 9-12. Grades 9-12 include standards and benchmarks from four Bodies of Knowledge: Nature of Science, Life Science, Earth Science, and Physical Science. In addition, there are 18 Big Ideas that interweave throughout all grade levels and develop in depth and rigor as students progress (http://www.heartland.org/mathsscience/documents/science-k-12_standards.pdf). To ensure a representative sample, random sections of the text were chosen based on the grade level, the inclusion of each Big Idea and high school level Standard at least once in the document, and a random selection of benchmarks across all four bodies of knowledge.

Environmental sustainability themes

Tenam-Zemach (2010) pinpointed five dominant themes in the area of ES that offer an interrelated ecological framework to understand the science content students are expected to learn: (a) climate change indicators, (b) biodiversity, (c) human population density, (d) impact and presence of environmental pollution, and (e) Earth as a closed system. Tenam-Zemach (2010) generated these themes after reviewing a cross section of environmental education (EE) literature (Boyer, 2002; Fien & Gough, 2001; Krebs, 2008; Martusewicz, Edmundson, & Lupinacci, 2011; Orr, 1994), the literature on ES (Bonnett, 2002; Kates, Parris, & Leiserowitz, 2005; Paden, 2000; Stone & Barlow, 2005) and educating for a sustainable future (Fien, 2001; Tilbury & Fien cited in Tilbury, Stevenson, Fien, & Schreuder, 2001), as well as several discussions with experts in the field of EE. This also explains the method for the development of the key terms list in both studies. However, in this research project, the researchers modified these themes to be broader and more encompassing. As stated earlier, four ES themes were identified and used in the analysis of the text: (a) environmental impacts (EI), (b) biodiversity (BD), (c) population dynamics (PD), and (d) energy transformation (ET) and other (a key term occurs but does not align with any ES theme).

Environmental impacts (EI). Karl, Knight, Easterling, and Quayle (1996) generated two indices that provide a framework of the quantifiably observed changes in climate across the contiguous United States. The first, the Climate Extremes Index (CEI) (http://www.ncdc.noaa.gov/extreme/cei/), is based on a combined set of representative climate extreme indicators in the U.S. The second, the Greenhouse Climate Response Index (GCRI), measures changes in the country’s climate that occur as a product of increased greenhouse gas emissions. Both indices provide crucial information for monitoring changes to the environment, and include fundamental ES concepts. Some key terms associated with these

indices are volcanic eruptions, tornadoes, hurricanes, earthquakes, tsunamis, U/V radiation, water, air, pollution, and acid rain. Some of the indicators measured include precipitation, much-above-normal temperature, and monthly maximum and minimum temperature. Another indicator of climate change is ecosystems. Various indicators of climate change provide necessary information to determine how the climate of the United States is changing and what various causes of these changes may be. There are many climate change indicators. Other examples are glaciers, oceans, the atmosphere, the ozone layer, and temperature variability, types of pollution, etc. EI was developed as an essential theme to analyze in the science content standards because of the impact it has on students’ immediate and future lives.

Biodiversity (BD). The variety of species on earth defines biodiversity. From a biological standpoint, biodiversity is a diverse population of organisms (Krebs, 2008). Geographically, biodiversity is the numbers of individuals that define where this biodiversity is found in the biosphere, e.g., deserts, tropical rainforest, tundra, temperature woodlands, oceans. Chiras (2010) inquires as to “why should disappearing beetles, plants, or birds concern us” (p. 203). Providing students with the opportunity to learn about biodiversity is critical for many reasons. There is an ethereal dimension to “one’s understanding of the impermanence of other living things to the functioning of the planet...” (Chiras, 2010, p. 203). Second, students need to understand that biodiversity strengthens species’ relationships with each other. It also strengthens the genetic diversity found within all species that pass along traits necessary for organisms to survive in their environments. Some important key ES terms associated with biodiversity include ecology, taxonomy, speciation, biomes, ecosystems, communities, genetics, competition, evolution, natural selection, and biosphere. Students’ understanding of the relationship between biodiversity and the health and well-being of ecosystems is critical to their own present and future existence.

Energy transformations (ET). Because Earth is a closed system, everything within the planet remains on the planet; nothing, except the sun’s energy, can leave and nothing can enter. Although energy is finite, it can be converted from one form to another. Krebs (2008) provides an interesting example of the importance of energy transformation within ecosystems: “we can ask questions about what happens to the energy and materials fixed in primary production, and what fraction flows on to other trophic levels” (p. 15). This is just one example of the complexity of this theme in relation to ES. In order to develop an understanding of the interrelated and systemic nature of the environment, students need opportunities to learn about how these multifaceted yet unified systems function. This is also the first theme that lends itself to EI on the microscopic level. Various key terms associated with ET are finite, recycle, system, cycle, entropy, carnivore, producers, herbivores, decomposers, trophic levels, thermodynamics, photosynthesis, carbon dioxide, oxygen, chlorophyll, carbon cycles, and conservation.

Population dynamics (PD). Individuals of the same species that coexist within communities are members of a population. Potentially, these members interbreed, share, and consume similar resources within the environment that they inhabit. Human population density is the number of humans inhabiting a particular area (Krebs, 2008) and has been a disconcerting issue for scientists around the world. Any organisms’ density affects the carrying capacity of the environments of all species existing within that ecosystem. Carrying capacity does not just apply to lower species; it applies to all organisms and their environments. Humans, like all species, necessitate specific resources to perpetuate their existence. We have a finite capacity to increase despite the belief that technology will increase that capacity.
It is critical for students to understand the relationship between the number of people occupying the earth and the available resources to sustain current and future populations, especially considering that environmental impacts, biodiversity and energy transformation, as themes, are interrelated and influence each other. How temperature changes, for example, not only influences the prosperity of species diversity but also the quality of life for people on earth. These interconnected concepts are important for students to understand in order to address future problems and issues they may confront. Some key terms for population dynamics include population, carrying capacity, future, limits, migration(s), limiting factors, genes, mutations, diversity, density, and habitat.

**Data analysis**

To scrutinize the data using content analysis, the researchers (a) examined the frequencies of the keywords, (b) analyzed the context of each occurrence, and (c) determined the relationship of these terms to the four themes of ES and an ecological paradigm (e.g., do the standards offer a systemic worldview?). Our rationale for choosing key terms was that, collectively, these words could represent one or more themes of ES within and across the K-12 science content standards.

Consistent with good practice in content analysis, we used a common classification procedure, the four themes of ES and the key knowledge term list to hand code the sample data. Following strict coding instructions, in the initial coding process, each of the analysts read the sample of the standards document including the Big Ideas. Initially, a coding scheme was developed to isolate the presence and context of each key term: (a) Eco-Knowledge Term (EKT), (b) Knowledge Term (KT). First, the coders thoroughly read the sample document. Next, referencing the keyword list, they hand coded (using various colored highlighters) each key term that occurred. Coders completed a coding form to note the context of each key term to determine its relationship to one or more of the four themes of ES and an ecological paradigm. No major challenges emerged when coding the data for the presence of key terms that represented ES themes. However, identifying the context of a particular term as expressing the ecological paradigm was problematic. The coders deliberated on the various issues preventing them from being able to determine the extent to which a particular key term could be coded as ecological (see Findings section). They decided to once again carefully review Sterling’s (2001) framework. After deliberating on this process, the researchers developed criteria that would encompass the paradigm and facilitate the coding process. Thus, in addition to the four ES themes, another coding scheme was later developed for the ecological paradigm that included four criteria: (a) value, (b) relationship, (c) analysis/synthesis/evaluation, and (d) cause/effect. The researchers contended that, collectively, these criteria embodied an ecological paradigm as expressed by Sterling (2001).

After all the data were hand coded and evaluated, the researchers entered the data and the entire list of keywords into a concordance program to again search for keywords in context. It is through the concordance Keyword in Context (KWIC) display (see Fig. 1) that the coders could more closely isolate the keywords and scrutinize the context of each term in the NGSS for science (McCarry, 2007). A critical feature of a simple concordance is the KWIC display that offers a particular keyword to be promptly viewed in the text’s context. It provides a listing of token words that are flanked by the words that immediately precede and follow them in the original text. Tokens are the total number of keywords present in a document. Fig. 1 illustrates how the KWIC display appears in the concordance program.

By centering the keyword within its context, as demonstrated in Fig. 1, the KWIC display window readily provides the occurrence of the keyword in relation to its context. The analyst need only click on the line in the display to view the entire section of text providing immediate access to the context of the token word for deeper analysis (see Fig. 2). Weber (1985) argues the necessity of returning to the original text under analysis to locate examples of the themes being investigated as an important final step in any computer-aided content analysis. KWIC programs quickly and easily allow the researcher to authenticate that interpretations of the data are contextually valid.

In order for a content analysis to be considered valid and reliable, it is essential for the researcher to generate “translation rules” (Busch et al., 2005). These rules ensure that analysts code for
Findings

Quantitative analysis

We examined the degree to which content experts agreed with respect to how they rated each keyword in terms of the following: as being or not being an exemplar of an Eco-Knowledge Term, each of the four environmental sustainability themes, and finally, each of the four ecological paradigm criteria. We computed the percent of agreement of ratings, defined as the percentage of key terms that raters coded in the same way. This percent agreement measure does not account for chance agreement or differentiate between the propensity that coders rated keywords as “present” or “not-present”. Instead, percent agreement provides a readily interpretable description of the similarity of the reviewers’ codings. As can be seen in Table 1, the majority of keywords were coded the same by the coders. The percentage of agreements ranged from .56 to .95, with a mean of approximately 80% agreement. While there was substantial agreement, it is also clear that the two reviewers did not agree on a considerable number of keywords (especially for relationship). For example, with 700 keywords present in the NGSS, a percentage of 80 indicates that 700 x .80 = 560 keywords that were coded the same while 700–560 = 140 keywords were coded differently. Clearly, much room exists for improving the consistency with which reviewers code the keywords.

Qualitative analysis

We utilized a qualitative analysis of conversations between the coders to facilitate an understanding of why coders disagreed. There were several interesting findings concerning the utilization of this method of analysis. First, coders often struggled to interpret the coding instructions in terms of rules of translation. In other words, while many key terms in their context were interpreted by coders similarly, they struggled with the context of some specific key terms in relation to a theme and/or the ecological paradigm. For example, in the standard apply the mole concept and the law of conservation of mass to calculate quantities of chemicals.

![Fig. 2. KWIC display.](image-url)
participating in reaction, one coder rated the term conservation as other (indicating that in its context the key term did not fall under any of the four themes) and a zero (0) for EKT. Another coder, however, coded the term conservation as an EKT term and ET for the theme. After a series of discussions following the coding process, one coder wondered if she should have coded this as ET because of its alignment to the definition of ET provided in the coding booklet. In her interpretation of the coding instructions, she unintentionally imposed a qualification on the Energy transfer category that requires the energy to be involved in an organic process, yet this is not what the instructions stated. This point is a helpful illustration of how complex processes of quantifying language can be. Energy transfers involved in the cycling of matter as well as organic energy transformation conceptually fit environmental sustainability, but ones involving only ‘physics’ of energy transfer do not necessarily meet the criteria of the theme. They do, however, meet the recording instructions definition for the theme of energy transfer, which states that the Earth is a closed system... nothing can leave and nothing can enter.

Another example involves the term extinction in the following standard: explore the scientific theory of evolution by relating how the inability of a species to adapt within a changing environment may contribute to the extinction of that species. In this standard, one coder coded the term extinction as PD, but another coder coded it PD and BD. After revisiting the standard and considering it more intently, the coder agreed that it should also qualify as representing BD. Thus, this disagreement was a simple oversight, an example of human error.

While the recording instructions presumably employed “communicable instructions” (Krippendorff, 2013, p. 273), the interpretation of the instructions was often problematic. According to the coding instructions, the term water is listed in the coding booklet as a geological force that has an effect on environmental sustainability; therefore, this term should be coded EI. The term water occurred in the document 16 times. One coder coded the term as an ES theme in six of the 16 occurrences while another coded the term water as an ES theme in eight instances. No coders coded the term as an ES theme in the following standard: observe and describe water in its solid, liquid, and gaseous states. Most would probably agree that this term has no inherent environmental sustainability connection, but if the coders followed the codebook definitions carte blanche, this standard, and others, might have fallen into the ES theme. By qualifying the context and meaning of each instance of terms individually, and not restricting one’s interpretation of the term to the intent of the codebook, there was greater flexibility in the coding of the key terms. However, this may partially explain why there were areas of disagreement across coders in their coding outcomes.

Krippendorff (2013) posits that one of the requirements of replicability is that coders “work independently of each other” (p. 273) in order to rule out “covert consensus” (p. 273). During the initial and developmental stages of the current study, coders often found themselves discussing the causes of their disagreement in an attempt to reconcile differences. Krippendorff (2013) states that “such consultation is a response to a common problem: The writers of the coding instructions may not have been able to anticipate all possible ways relevant matter is expressed, leaving coders at a loss” (pp. 273–274). This assumption was clearly supported in the present study. Coders concluded that with some key terms they would agree to disagree. Krippendorff (2013) states, “systematic disagreements are more serious. They occur when observers agree to disagree, unwittingly apply different coding or unitizing instructions, or consistently apply an agenda that is not shared with others” (p. 279). While none of these behaviors were performed on a conscious level, coders did admit, despite being warned to avoid applying a different coding scheme, that they often coded the data beyond the scope of the recording instructions, employing a “teacher’s,” not “researcher’s” perspective of the interpretation of the key words in context. With a background in Environmental Science Education, one coder found it “difficult to separate what the standards say from what [she] knows many teachers interpret the same standard to mean” (personal communications, March 10, 2013). Only after multiple conversations with extensive explanations of their coding processes was this problem discovered.

While the coders were extensively trained on the coding procedures at the beginning of the process, at times, coders found themselves unable to understand or apply the procedures of the instructions. They found that the theoretical framework, the ecological paradigm, often posed a complex and unwieldy approach to analyzing the standards via the keywords that represented the ES themes and the paradigm. For instance, one coder consistently found herself struggling with how to factor human-involvement (in terms of human impact on the environment and environmental outcomes) into determining ecological

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Table 1
Percentages of agreement between.

<table>
<thead>
<tr>
<th>Category</th>
<th>Percent agreement</th>
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<tr>
<td>ES Themes</td>
<td>82</td>
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<tr>
<td>Environmental impacts</td>
<td>83</td>
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<tr>
<td>Biodiversity</td>
<td>84</td>
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<tr>
<td>Energy transformation</td>
<td>75</td>
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<tr>
<td>Population dynamics</td>
<td>86</td>
</tr>
<tr>
<td>Others</td>
<td>67</td>
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<td>Environmental knowledge theme (EKT)*</td>
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</tr>
<tr>
<td>Value</td>
<td>95</td>
</tr>
<tr>
<td>Relationship</td>
<td>56</td>
</tr>
<tr>
<td>Synthesis, analysis, evaluation</td>
<td>85</td>
</tr>
<tr>
<td>Cause/effect</td>
<td>86</td>
</tr>
</tbody>
</table>

* This category is interpreted as whether or not the coder considered the keyword to be associated with any environmental knowledge theme.
knowledge terms; for this coder, who was far more liberal with EKT coding, it seemed as though human involvement was often implicit in many of the expectations contained in the standards. She felt that her sensitivity to the relationship between humans and EKT terms in the context of many standards stemmed from the recording instructions. The recording instructions provide the criteria of an ecological paradigm and four of the seven listed criteria reference humans (e.g., acknowledges human beings as only part of a complex, interconnected organic world; encourages individuals to include others in their interactions). This became a dominating factor for her selection of whether or not to code a term as EKT. Often during follow-up discussions, she would ask for clarification of others coders’ perspectives on the relationship between the key term, ES themes and an ecological paradigm as they related to human roles in the standard.

There were several conversations with the coders to facilitate their comprehension of these complexities in the hopes of generating meaningful and consistent understanding of how to apply the theoretical lens to the analysis. Finally, another problematic issue raised during the coding process was simple human error, exemplified earlier. For instance, in one email exchange, the following benchmark was addressed in a conversation: weigh the merits of alternative strategies for solving a specific societal problem by computing a number of different benefits, such as human, economic, and environmental. The question posed to the coder was, “When you coded this benchmark for alternative, you placed a one (1) for each criterion. But when you coded it for benefits you put a zero (0) for relationship. Why do you think that happened since both words are in the same benchmark?” (personal communication, March 6, 2013). The coder’s response was, “My mistake… it [the coding of each cell] is clearly all four [criterias]” (personal communication, March 6, 2013). This is an example of human error, something that occurred occasionally during the coding process.

Another issue coders confronted occurred during the second iteration of coding. In this iteration, researchers incorporated another document to determine how skills such as “analyze” and “describe” related to Bloom’s Taxonomy (http://achieve.psd3.org/bloom.html; http://www.clemson.edu/assessment/assessment-practices/refencematerials/documents/Blooms%20Taxonomy% 20Action%20Verbs.pdf). This taxonomy was used to assist in coding for the presence of higher order thinking skills that are proposed by the standards and supported by the ecological paradigm. While the goal of using the taxonomy was to help clarify the extent to which standards offered students opportunity to think critically and systemically, and to bring uniformity to the coding process, it too created ambiguity. Occasionally, skill terms fell into multiple categories depending on their context in the standard. For example, one high school standard states, discuss basic classification and characteristics of plants. Discuss falls into the lower Bloom’s taxonomy of comprehension, while classify can fall into the category of comprehension, application or analysis. This particular standard could thus be read as fitting a higher or lower order of thinking. Because it was intended for high school audiences, one coder took this standard to mean more of a compare and contrast skill outcome, and rated it a one for analysis/synthesis/evaluation. Another coder rated it a zero, interpreting it as a lower order thinking skills based on the action verb discuss, as the goal would be to discuss plants and not classify them. Additionally, one coder also noted that nearly identical standards represented at different grade levels implicitly demonstrated higher thinking levels as the grades progress. Yet, often these standards would be rated the same by another coder. This led one coder to observe that “it seems as though many of the skill terms selected by the authors of the Florida NGSSS are selected randomly, without much thought to the skills demanded by the content itself or as being appropriate to the learning at the grade level” (personal communications, March 6, 2013).

Toward the end of the initial coding process, because of several iterations of coding and additional training, understanding of the theory deepened in relation to the analysis of the data; coders were then able to more consistently code the terms using Sterling’s (2001) framework. In addition, the recording instructions transformed over this period to include “rules for coding or measuring every possible instance” (Krippendorff, 2013, p. 274). Consequently, while the percent of agreement may not represent the replicability of the method, it does indicate that the recording instructions have improved and become more reliable.

Limitations

Regarding future research, several potential limitations of this work could be addressed with further study. While for most criteria the percentage of agreement between coders met or exceeded 80%, there were several limitations revealed during the analysis of the data. First, the data source was not the complete body of K–12 NGSSS standards. Further work could be done to examine the quality of the standards in a more comprehensive manner by analyzing the entire body of K–12 science content standards and analyzing the complete data set would potentially improve the percentage of coding agreement. However, even this is speculative given that of the 742 key words that were inputted into the concordance program, 196 were present in the sample document while only 294 were present in the total document. Even then, the majority of these key words were repeated terms. For example, in the sample document, the key term water occurred 16 times, and in the entire body of standards, it occurred 41 times. The key term species, on the other hand, occurred twice in the sample document, but only six times in the total body of standards.

A second limitation of the study is that it does not inform the reader as to what actually is being taught in classrooms, only what is required by the state of Florida. There is no way to know how standards are being addressed in instructional practice without classroom observation. Further work could be done to see how teachers’ interpretation of the standards becomes translated into their instructional practices. A third limitation is the lack of generalizability of the current findings to other coders. In particular, it is unknown how teachers of various levels of ecological and environmental education expertise would interpret the standards. Nor is it clear how teacher interpretations of standards translates into their instructional practices. Another limitation of this research is that although there was a substantial amount of agreement among the coders, there still was some disagreement that could be resolved with further understanding of how they interpreted the standards differently. For example, coders could provide verbal protocol analysis of their interpretations of standards and subsequent analyses can reveal how coders construed these standards differently.

Additionally, the findings of this study may not generalize to another set of coders. The initial disagreements and challenges faced by the coders as they attempted to identify which ES themes were included in the data to illustrate how even scientists and teacher educators can interpret the same simple sentence in varying ways. It would be interesting to see if a group of K–12 teachers had such a wide range of interpretations as our coders experienced in this study. Teachers may have a varied set of understandings of the meaning and context of the standards in relation to ES themes and an ecological paradigm. This means that any set of teachers may potentially have a wide difference in how they interpret and apply the standards in curriculum design and development.
Significance

There is a dearth of research that systematically analyzes the extent to which science content standards include ES themes and ecological paradigm. In this study, we focused on how well EE experts consistently identified the ES themes and ecological thinking (as defined by Sterling, 2001) found in science standards. The findings suggest that at times, the standards are written in such a way that it is not always clear whether the standards represent an ecological paradigm. If experts struggle with interpreting the presence of an ecological paradigm, how can we expect teachers to consistently interpret the same body of standards? It can be presumed that the writers of the science content standards expect unanimity in the interpretation of standards content. Another area of significance was the effectiveness of this method for identifying the problem of multiple interpretations that can be made when reading standards. Our research design provides a useful method for determining which science standards cover content pertaining to Environmental Education and Educating for a Sustainable Future. Our findings also suggest that the approach can be used to assess teacher’s understandings of specific science content standards thereby potentially promoting more comprehensive coverage of ES themes and ecological thinking during classroom instruction. Additionally, the significance of this study is that it offers the use of a systematic approach for stakeholders to unpack the ES themes and ecological paradigm content in science content standards.

Conclusion

The novelty of using content analysis to inform stakeholders’ understanding of science content standards in relation to ES themes and an ecological paradigm is an insightful and engaging approach for learning how EE experts can understand and interpret the discourse of standards documents. The use of keywords to prompt the experts to identify the exemplars of the ecological paradigm content in the standards allowed the researchers to discover that the standards documents are not explicit, clear texts consistently interpreted by expert coders. Furthermore, even though the ecological paradigm is a complex theoretical construct, its use as a conceptual framework reveals that the science content standards themselves are ambiguous and difficult to interpret, even for content experts in the area of EE and ES. That coders understood the intention to a particular standard and how or if it conveys value, higher order, systemic thinking, or develops relationships between and across standards, speaks to the need to be even more diligent of how standards writers generate standards documents. This lack of certainty also places a greater burden on all stakeholders to be even more diligent in applying methods such as ours to determine if the meanings of the standards are aligned with our goals and values as a society. Our society does value the environment and ecological thinking, but to what extent the science content we generate is representative of these values is left indeterminate, in part, because of the standards’ discourse.

Acknowledgments

We are grateful to Dr. Barry Barker whose input in this project was invaluable. We would also like to thank Dr. Ron Chenail for his steadfast contribution to the ideas and design of this study. Finally, this research project was supported by the President’s Faculty Research and Development Grant at the Abraham S. Fischler School of Education at Nova Southeastern University.

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