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Potential Support for Sustainability Education in Middle School Science Standards:

An Analysis of Existing State Frameworks in the United States

Scott A. Wahlstrom

A Thesis in the Field of Sustainability and Environmental Management

for the Degree of Master of Liberal Arts in Extension Studies

Harvard University

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Abstract

Pressing global problems related to increasing population, affluence, and consumption create a need for widespread sustainability literacy in citizens who must engage these issues in social and political contexts. Unfortunately, few U.S. citizens are exposed to formal sustainability education (SE). Public schools can fill this gap, but state education frameworks already specify a full program of required content for students to learn, and efforts to integrate SE into public schools must fit this structure.

This study's broad objective was to understand the degree to which existing U.S. public school science education frameworks at the middle school level provide an architecture within which SE can be integrated. Specific areas of inquiry included 1) determining how frequently existing frameworks explicitly require or implicitly invite teaching sustainability, 2) quantifying how frequently they incorporate key concepts of sustainability education, and 3) evaluating their flexibility for supporting integration of interdisciplinary SE concepts into science classrooms.

I hypothesized that there would be only low levels of explicit or implicit inclusion of SE within existing frameworks (less than 3% and 5% respectively). Further, it was expected that less than 10% of standards within existing frameworks would align with key concepts or issues related to sustainability. Finally, it was expected that most states would have structural barriers that hinder integrating SE into science classrooms.

Review of sustainability education literature identified eight recurring sustainability principles across the genre, and three sustainability issues were selected that embody them. Text analysis methods and tools were developed to score all current

science standards in middle school (grades six through eight) on a five-dimension scale against these principles and issues as well as explicit and implicit inclusion of sustainability and structural characteristics of the frameworks.

Analysis of 3,700 state science standards established there is nearly no explicit inclusion of sustainability or its principles at the middle school level. Despite this, 10.7% of standards implicitly invite the inclusion of SE because they overlap with at least one important SE principles, and overlap with individual principles ranged from 0.3% to a high of 13.7%. While findings indicate a sizable fraction of state standards direct student learning toward content and concepts that overlap with SE, a majority of states (27 of 51 including the District of Columbia) restrict curriculum sequencing which could hinder integrating SE into the classroom. Further, there is a deficit of core sustainability themes related to intragenerational equity and viewing humanity as dependent upon and interconnected with nature. These factors are hurdles to be overcome in capitalizing upon the existing capacity of state standards to support sustainability education.

Despite the challenges, this creates a space of opportunity where SE can be implemented as a thematic vehicle for teaching required state content. Advocates for sustainability education can focus on reducing these barriers and promoting wider inclusion of standards that direct student learning toward thematic elements identified as driving most existing support for sustainability principles, understanding the nature of human impact upon the environment, and engaging students with solving environmental problems.

Dedication

I dedicate this work to my friend and partner, Justine Q. Wahlstrom, without whose tireless support, assistance, forbearance, completion would have been impossible. The research, analysis, and writing of this work has been a time of deep satisfaction and pleasure for me, and the foundation of that experience has been the selfless love and care she has given to make this work possible. I cannot adequately express my gratitude and can only hope that I might be at least half as good a husband as she has been a wife.

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Definition of Terms

CORBNR: rating scale used for codifying alignment of a standard with a sustainability principle or issue, stands for Core, Opportunity, Related, Barrier, Not Related

curriculum: lessons, activities, and materials assembled to construct a learning experience that leads students to the attainment of standards

DCI: Disciplinary Core Idea (a component of NGSS)

frameworks: a body of learning standards governing a program of study in a subject area such as science

NGSS: Next Generations Science Standards

PEX: performance expectation (a standard in NGSS)

PEXE: performance expectation equivalent (the equivalent of an NGSS PEX in an independent state framework)

SE: sustainability education

SI: sustainability issue, one of three issue-based metrics used in the study

SP: sustainability principle, one of eight principles of sustainability used as metrics in the stud

Chapter I

Introduction

Humanity's increasing pressure on Earth's systems spurred international calls to implement public environmental education beginning with the Stockholm Declaration in 1972. The need has never been greater than in the world as it stands today. Over time, the advocacy for environmental education has evolved into appeals for widespread public sustainability literacy, and postsecondary institutions picked up this challenge with the Talloires Declaration in 1990 (University Leaders for a Sustainable Future, 2001). Since then, colleges and universities have taken important but uneven steps to address this need (Wright, 2002; Aliperti, 2016; Association for the Advancement of Sustainability in Higher Education, 2017), and although sustainability education (SE) has come a long way since the Talloires Declaration, the level of engagement and progress by individual institutions of higher education is insufficient.

Large segments of the U.S. population continue to receive no formal education in sustainability. According to the National Center for Education Statistics (2016), although 91% of United States citizens have completed a high school degree or equivalent by the age of 29, fewer than half complete a degree beyond that level. Steps taken by colleges and universities to integrate SE into their institutions reach a minority of the population, and it needs to be integrated into the K-12 public education system as well.

Despite calls for widespread sustainability education, and the concomitant efforts by postsecondary educational institutions to meet the need, it is unclear that public school systems in the United States are fulfilling the role they must play to achieve this end. More importantly, the current paradigm in education emphasizes validation of school success through high-stakes standardized testing and is not conducive to fostering SE as a curricular goal. These forces set society's need for increased sustainability literacy in conflict with the demands placed on public schools to demonstrate performance implementing standards as they are written. Whatever the good intentions of administrators and teachers, this conflict exerts heavy influence on classroom practice. Sustainability education cannot thrive or even take root at the secondary level, unless it is articulated within public school frameworks, or it can be demonstrated that it fits within the context of existing standards.

The Need to Study Standards-based Support for Sustainability Education

This need presents a serious challenge. Public school standards are formulated at the state level and are not homogenous across the nation (Feinstein, 2009). This creates a potential barrier to any effort to establish SE on a nationwide basis within the public-school system. Further, public school curricula are oriented toward state standards, and teaching is profoundly affected by standardized testing. This presses educators to focus narrowly on producing student achievement in the explicit goals articulated in each specific standard (Au, 2007). Although many educators value integrating content into more meaningful thematic units, the competing demand for standardized test performance is often perceived as the primary goal in the classroom (Aikens, McKenzie, and Vaughter, 2016). This generally results in a narrowing of curriculum that leaves little room for integrating student knowledge into broad-based concepts like sustainability (Rowe, 2007).

Education Nomenclature: Standards, Frameworks, and Curriculum

Before proceeding, it is necessary to clarify some of the key education nomenclature used throughout the study. The term “standard” is used to represent knowledge, concepts, or skills that students need to be able to know and use. In general, multiple standards are written to break down topics and describe specific knowledge, concepts, or skills in sufficient detail to guide educators towards their attainment. “Frameworks” represent the entire body of standards for a specific subject such as science. They are typically constructed around individual grades or grade spans and may be further broken down into disciplines such a life or earth science. Finally, educators and schools create and implement “curriculum” based upon the standards that are specified for their state. Curriculum consists of the lessons and materials used by an educator to move students towards proficiency in these content and skill-based standards.

Thus, the frameworks for a subject represent all the knowledge, concepts, and skills that students are expected to master at these are organized and broken down into individual standards that guide educators as they create curriculum to help students master the required material.

Research Significance and Objectives

The content and structure of public school learning standards are critical elements to supporting SE at the secondary level; however, no study to date has sought to quantify the level of support science standards in the United States can lend to promoting SE in public schools. This investigation fills that gap with a nationwide assessment and analysis of the current content of public school science standards that quantifies their ability to promote and support sustainability education. This was accomplished by employing text analysis methods that evaluated individual standards against core principles and issues that were identified within the genre of sustainability. State published learning standards at the secondary level in middle school (grades 6 through 8) were investigated.

This study will provide the first comprehensive look at middle school science standards in the United States, examined through the lens of its capacity to support SE. Middle school has been selected because high school standards are largely driven by college preparatory objectives which result in science courses organized in single disciplines such as chemistry, biology, physics, or earth science. Graduation requirements specify that students typically take a subset of the classes offered, and the subjects studied by individual students vary. Although many schools offer classes in environmental science or earth systems science that may be highly relevant to SE, these are typically advanced electives taken by a minority of high school graduates. In 2016, just 5.7% of high school advanced placement exams taken were for environmental science (College Board, 2016).

On the other hand, all middle school students in the U.S. are subject to state specified frameworks that incorporate earth, life, and physical science topics. While the specific content and organization may vary from state to state, all students are exposed to all segments of the published learning standards under normal circumstances. As such, the degree to which middle school science standards offer potential support for SE is of unique value for introducing relevant principles and issues to all U.S. citizens.

Potential Value of This Research and Research Objectives

This study quantified the degree to which existing middle school science frameworks can support sustainability education. For policy advocates, the data that are developed provide a basis of comparison between individual states that can help identify both positive and negative aspects of their various frameworks and their capacity to support SE. This information can support better informed policy discussion and formulation. For entities seeking to encourage SE within public schools, the results of this study will help guide the development of their programs to maximize applicability, acceptance, and efficacy while meeting the ever-present demand of covering the required standards and performance on high-stakes testing.

In the broadest sense, the objective of this study was to examine the content and structure of public school science frameworks across all 50 states and assess the degree to which it is able to support SE. The specific objectives were:

- to understand the degree to which the content and structure of public school learning standards in the United States can support and promote teaching of sustainability to middle school students
- to develop a dataset to compare individual state standards and identify characteristics that may support higher levels of teaching sustainability

- to identify qualities and components of state science standards that can contribute to establishing meaningful levels of sustainability literacy in middle school students

Background

It has been clear for some time that humanity must embrace sustainable practices in our relationship with this planet and its resources. Calls for environmental education and, more recently, SE, go back over four decades to the United Nations Conference on the Human Environment (1972). This meeting produced what has become known as the Stockholm Declaration, which included the following language as principle 19:

> Education in environmental matters, for the younger generation as well as adults, giving due consideration to the underprivileged, is essential in order to broaden the basis for an enlightened opinion and responsible conduct by individuals, enterprises and communities in protecting and improving the environment in its full human dimension. (United Nations, 1972)

This statement was the first in a series of conferences and documents that developed the concept further. Further important steps came with the UNSESCO sponsored Tbilisi Declaration which delineated specifics goals for public environmental education (Global Development Research Center) and The Talloires Declaration issued in 1990 which challenged institutions of higher education to embrace sustainability themes in colleges and universities (University Leaders for a Sustainable Future, 2001). In 2005, the United Nations adopted the Decade of Education for Sustainable Development, a global initiative that "sought to mobilize the educational resources of the world to help create a more sustainable future." (United Nations Education, Scientific, and Cultural Organization, 2005).

Sustainability Literacy in American Education

Although the common thread running through these documents and initiatives was the need to establish public education centered on the environment and sustainability, the effort in the United States coalesced most coherently within institutions of higher education. Beginning with the Talloires Declaration, the 1990s saw a steady progression of colleges and universities integrating sustainability planning into their institutional practices. In a set of case studies of how sustainability has been integrated into postsecondary institutions, Wright (2002) noted that about two thirds made commitments to improving the ecological literacy of their students and three quarters had public outreach policies. He also noted that the specific activities and programs embraced by individual institutions, and their depth of commitment, varied widely. Similarly, the Association for the Advancement of Sustainability in Higher Education developed a rating scale for colleges and universities to self-assess their sustainability performance. As of 2017, 259 colleges and universities had been formally awarded ratings, however just one of these earned the highest level, platinum, by scoring 85% or higher. Overall, 89% of rated institution scored between 45% and 65% (Association for the Advancement of Sustainability in Higher Education, 2017). Finally, The Princeton Review's Guide to Green Colleges (Aliperti, 2016) found that while many colleges have embraced sustainability education, only 361 out of 2000 schools surveyed earned a "Green" rating and among these only 44% of the students on average took at least one course in sustainability. These efforts by post-secondary institutions are important, but insufficient to meet the need for SE in the United States.

Unfortunately, K-12 public education is not making the steps toward wider inclusion of sustainability education that are necessary to fill this gap. A meta-analysis of research into SE conducted by Aikens et al. (2016) revealed some interesting patterns. Where it has been included, SE at the K-12 level has most commonly been conducted under the terminology of "environmental education" or "education for sustainable development" (p. 334). The dominant focus on core standards and high-stakes testing that prevails in this country however, has led observers to describe a prevailing attitude that sustainability is a "fringe subject". Some research has gone into integrating sustainability into an interdisciplinary format, but these efforts have failed to gain much traction and many researchers note that sustainability is marginalized in the curriculum (Aikens et al., 2016). To this point, Coyle (2005) noted that at least 32 states had environmental education programs, but collectively less than $7.3 million had been budgeted for them. He further noted that only four of these states included training in environmental education as a certification criterion. As Stimpson (1997) noted while studying similar environmental education issues in Hong Kong, "there is a reliance on the enthusiasm of teacher educators to provide programmes" (p. 355), an observation that seems to be on point in the U.S. as well.

Læssøe, Schnack, Breiting and Rolls (2009) noted that non-governmental organizations have played a key role in promoting SE through teacher training and the development of program materials, one example of which is the Center for Ecoliteracy. Such organizations promote many good ideas and practices, often expressing a deep commitment to stewardship of the environment. For example, Stone and Barlow (2009) argue the purpose of sustainability education is:

> To nurture communities that are in concert with nature, we must understand nature's principles and processes, the deep facts of life: for instance, that matter cycles continually through the web of life, while living systems need a continual flow of energy; that diversity assures resilience; that one species' waste is another species' food; that human needs and achievements are both supported by and limited by the natural world. (p. 3)

This captures important concepts that drive sustainability education, but is it tied to the learning standards that drives public education?

Other advocates, such as the Shelburne Farms Sustainable Schools Project, offer professional development tied to sustainability concepts (Shelburne Farms, 2017), and still others, such as the U.S. Partnership for Education and Sustainable Development, have developed full SE curriculum (Sustainable Schools Project, 2014). Unfortunately, while all these programs and curricula may well support legitimate sustainability education, it is unclear the degree to which they are tied to the standards within state frameworks that drive what happens in classrooms.

In a similar vein, many governmental agencies have outreach programs intended to foster an increased focus on environmental issues or even sustainability in public education. The National Environmental Education Act required the United States Environmental Protection Agency to provide leadership in environmental education at a national level (Environmental Protection Agency, 2015) and the United States Department of Education Green Ribbon Schools program was created "to inspire schools, districts and institutions of higher education to strive for 21st century excellence, by highlighting promising practices and resources that all can employ" (U.S. Department of

Education, 2016). The award has encouraged as many as 29 states to submit successful applications, in 2013, but participation has varied with about half of the states not even applying in more recent years (Table 1). This underscores the inconsistent embrace that K-12 public education has given sustainability education in the United States.

Table 1. Program participation, U.S. Department of Education Green Ribbon Schools (U.S. Department of Education, 2016).

Year	**States Earning Award**	**States Not Applying**
2012	28	22
2013	29	19
2014	27	20
2015	26	22
2016	24	26
2017	27	23

Effects of High Stakes Testing on Sustainability Education

There is good reason to believe the lack of consistent progress is impeded by the widespread adoption of high-stakes standardized testing and the heterogeneous nature of public school state frameworks in the United States. Beginning with The No Child Left Behind Act (2001), standardized testing has become a fixture in American education. And, while this testing is constructed around the content and concepts contained in the standards, it still exerts powerful influence over how the curriculum is framed and taught (Au, 2007). Aikens et al. (2016) noted that many studies found a "tensions between SE and the perceived primary purpose of education: preparing students for examinations in core subjects" (p. 348) and that state mandated testing "de-prioritizes sustainability education" (p. 348). Where it has been established, high-stakes testing typically has the effect of narrowing what is taught to tested items (Au, 2007) and increasing the focus on specific pieces of content knowledge versus cross disciplinary connections (Au, 2007). This has lead at least one observer (Feinstein, 2009) to note that standardized testing creates a "hostile climate" for sustainability education where it must "operate at or beyond the margins of core academic areas" (p. 16).

States Control Public School Standards

Public school standards in the United States are developed, adopted and approved at the state level. Feinstein (2009) notes "Decisions about education are often made at the state or local level, and there are few aspects of American education for which a national agenda directly shapes either curriculum or pedagogy" (p. 1). Although Common Core proposes national frameworks for English language arts and mathematics, it has not achieved universal acceptance and has not been adopted by eight states (Common Core State Standards Initiative, 2017). With respect to science, the situation is even less homogeneous. The Next Generation Science Standards (NGSS) were developed as a set of national standards, yet only 19 states plus the district of Columbia have formally adopted them (National Science Teachers Association, 2017), potentially resulting in wide variation in what is taught from state to state.

Current State of Sustainability Education in the United States

Currently, explicit reference to sustainability appears to be relatively infrequent in public education frameworks. Although some sources tout the NGSS for making strides forward in the inclusion of sustainability in K-12 education (Feinstein & Kirchgasler, 2014), an analysis of the core standards suggests these are still early steps. The term "environmental education" is not used at all in NGSS, and the word "sustainability" appears just three times, confined to the earth science discipline at the high school level. Other states include few explicit references as well. Massachusetts, which publishes frameworks that hybridize the NGSS, has seven (Massachusetts Department of Elementary and Secondary Education, 2016) and South Carolina which rejected NGSS entirely has two (South Carolina Department of Education, 2014). As with the NGSS, all or most of these references occur within the earth science discipline at the high school level, though Massachusetts identifies sustainability as a context for teaching science and this may lend it some additional stature when educators design curriculum.

A recent study found that the only factor correlated with improving the student's level of environmental literacy over the course of instruction during the school year was the use of a published environmental education curriculum (Stevenson, Peterson, Bondell, Mertig, & Moore, 2013). Spending time in natural areas and the teacher possessing a master's degree with at least three years of experience were correlated with higher overall environmental literacy but not improvement over time (Stevenson et al., 2013). This supports the supposition that a formal sustainability curriculum is critical to improving sustainability literacy, but current state frameworks appear to offer little explicit guidance to drive such a curriculum.

Warner and Elser (2015) argue that "sustainability education should provide students and communities with the ability to create solutions to complex environmental-social problems" and that it should facilitate the "integration between environmental education and other diverse and relevant disciplines, ideas, and actors in order to teach students that our actions may, and often do, result in unintended consequences in both our environment and our society" (p. 4). The content found in science standards provide the foundation for understanding environmental problems that are central to sustainability, analyzing their nature, predicting their consequences, and formulating solutions.

In general, state standards focus on core content and skills (Rowe, 2007) but avoid codifying specific issues in standards. As a result, the concept of sustainability remains ill-defined and underdeveloped within state frameworks and thus gets treated as an extra burden or 'add on' by many K-12 educators (Rowe, 2007; Læssøe et al. 2009). Unfortunately, this fuels a critical lack of understanding in a significant fraction of the U.S. population with important political, social, and environmental implications that will affect this country and the world. As Feinstein (2009) notes, few states have adopted formal efforts to integrate SE into their standards and sustainability education will only survive if "it is integrated into state or local standards, as is happening in a small number of states" (p. 14). If the United States is to make progress towards establishing widespread sustainability literacy, stakeholders must understand the opportunities and shortcomings currently extant within public school frameworks across all 50 states and develop strategies to exploit and expand them.

Application of Text Analysis Methods in Education Research

To evaluate the state of sustainability education, it is necessary to read standards and compare them to indicators that align with concepts embodied as SE as a genre. Text analysis can be used to identify language within standards that align with SE concepts and coding the degree to which they do so. Text analysis has been used successfully in other research related to educational standards and curriculum. Feinstein and Kirchgasler (2014) examined how sustainability was defined and characterized by the Next Generation Science Standards (NGSS) to assess what "version" of sustainability was integrated therein. As a part of their methodology they systematically tracked the use of certain terms (sustainable, sustained, sustainability, social, and economic) to identify relevant passages for close reading, analysis, and mapping of certain themes through the document. With the document thus mapped, they proceeded to identify and discuss the thematic characterization of sustainability within the NGSS. Although the study did not attempt to quantify specific aspects of the NGSS, it used a systematic approach for identifying the relevant passages for further analysis.

In 2007, Au conducted a meta-analysis of studies that investigated the effects of high stakes testing on the delivery of curriculum within public schools. Codes represented textual data and produced a coding template in two stages. The initial stage was based on a combination of a priori codes and an initial reading and coding of textual data. In the second stage this template was applied to the whole data set, and new codes were added as themes that had not been anticipated were identified. The data set was then back coded so previously covered studies were reanalyzed for the presence of the newly added thematic elements. In so doing, Au developed a database that categorized and quantified the results of 43 separate studies such that patterns could be identified and discussed.

In a similar vein, Aikens et al., (2016) performed a literature review to identify patterns, trends, and gaps in policy research related to sustainability education. The methodology in this study relied upon developing a matrix of search terms related to their target, sustainability education, which also excluded studies that were beyond the bounds of their research such as research related to higher education. Search words and roots such as “environment”, “education”, and “sustainab” were used within databases such as the Education Resource Information Center (ERIC) and Scopus. Several environmental and sustainability journals were also reviewed using similar methodology. After application of the search terms, the set of articles that were identified were manually reviewed to identify work that was relevant to their study and exclude nonrelated articles.

As a second step, Aikens et al. (2016) manually read the research articles that had been identified several times over. An initial reading was used to identify thematic elements that aligned with the focus of their research goals. These thematic elements were then assigned codes and subsequent readings were used to classify the articles using the coding scheme that had been developed. In this manner, they were able to quantify patterns and trends in sustainability education research as described by the published literature.

Successful text analysis methods share certain similarities. In general, researchers begin with certain a priori assumptions of specific textual elements that can serve as markers for identifying information they are interested in. As a second step, a reading of a broad sample of the text to be analyzed is conducted and adjustments are made to the initial list of markers to incorporate newly identified textual elements of interest. This is generally followed by a process of grouping text markers into categories that that can be coded so that similar elements can be quantified within the literature being analyzed. Finally, the literature body is reread and analyzed using the finalized coding scheme that has been developed.

Identification of Structural Level to Be Analyzed

As noted, individual states develop and publish their own learning standards. The NGSS is common to twenty states (including the District of Columbia) and another thirteen have published hybrids that adopt the language to varying degrees. Eighteen states developed frameworks independently and do not share this lineage. As a result, structural nomenclature within public school science standards in the United States varies widely, and it is necessary to look at this body of standards as a whole in order to identify a common "level" that will permit comparison of results between states.

The NGSS builds science standards around Disciplinary Core Ideas (DCI), each of which expresses a concept that students are expected to learn. In parallel with these are a set of Science and Engineering Practices that describe skills that are common to all scientific and technological disciplines and Crosscutting Concepts that articulate thematic elements which cut through different scientific disciplines. Of these, the DCI's are most relevant to this study since they express understanding that a student should acquire as a result of their science education. DCI's are further broken down within the NGSS into Performance Expectations (PEX). A PEX is a more specific expression of understanding that fits within a DCI. They are written as positive statements that express content or concept that students should know and skills that they should be able to do in terms of the ideas expressed by the related DCI.

Further, PEX's express DCI's at the most specific level while incorporating both Science and Engineering Practices and Crosscutting Concepts within their language. Analysis at the level of PEX's permits the most fine-grained review of the NGSS that could conceivably identify knowledge, concepts, or skills that potentially align with those sought by SE. Conversely, neither the Science and Engineering Practices nor the Crosscutting Concepts contain the kind of specific content that would be relevant to making this type of analysis. For these reasons, Performance Expectations within NGSS were judged to be the most appropriate level to use for attaining the objectives of this research.

Despite the differences, all states generally express learning standards at some level that is conceptually similar to an NGSS PEX. To validate this, a first pass survey of five state science frameworks was conducted to determine their structure and use of nomenclature. The survey validated the assumption that each state would express specific learning outcomes for students at some level that was consistent with the NGSS PEX's, so the effort was expanded to include all fifty states and the District of Columbia. A Performance Expectation Equivalent (PEXE) was identified for all non-NGSS states (Table 2) that would permit comparison of data obtained through their analysis as part of the study. From this point forward, the term "standard" will be used generically while PEXE will represent this state specific nomenclature for the exact level at which standards were analyzed to gather the data used in this study. In most contexts, I have used the term 'standard' for readability and because it's generic meaning is readily accessible to the widest possible audience. I use PEXE indicate the specific elements of state frameworks that were analyzed against the SE metrics used in this study.

In order to develop a quantitative assessment of the degree to which public education science standards in the United States support the teaching of sustainability, it is necessary to elucidate a firmly grounded view of what this term means. Moreover, sustainability education (SE) is a distinct genre within the broader discipline of

Table 2. State-by-state Performance Expectation Equivalents (by author).

State	Performance Expectation Equivalent (PEXE)
NGSS *	Performance Expectation
Alabama	Standard
Alaska	Performance standards/grade level expectations (PSGLE)
Arizona	Performance Objective
Colorado	Evidence Outcomes
Florida	Benchmark
Georgia	nomenclature unspecified (lettered sub level below Content
Idaho	Performance Standard
Indiana	Content Standard
Louisiana	Performance Expectation
Maine	nomenclature unspecified (lettered sub level below Performance
Massachusetts	Standard
Minnesota	Benchmark
Mississippi	Performance Objective
Missouri	nomenclature unspecified (Performance Expectation)
New Mexico	Performance Standard
Montana	Performance Expectation
North Carolina	Clarifying Objective
North Dakota	Benchmark Expectation
Nebraska	Indicator
New York	Performance Expectation
Ohio	Content Statement
Oklahoma	Performance expectation
Pennsylvania	Performance Expectation
South Carolina	Performance Indicator
South Dakota	Performance Expectation
Tennessee	Performance Expectation
Texas	Performance Expectation
Utah	Indicator
Virginia	Learning Expectation
West Virginia	Objective
Wisconsin	Performance Standard

*The following states use NGSS: Arkansas, California, Connecticut, Delaware, District of Columbia, Hawaii, Illinois, Iowa, Kansas, Kentucky, Maryland, Michigan, Nevada, New Hampshire, New Mexico, New Jersey, Oregon, Rhode Island, Vermont, and Washington.

sustainability and the focus of this study. The methodology of this study seeks to interpret science education standards against a set of sustainability principles and issues that reflect current thinking within the genre. For this approach to produce useful data, these principles and issues must be distilled from broadly held goals of SE and delving into how sustainability is interpreted in the educational context is necessary.

Breaking Sustainability Education Down into Measurable Components

Sustainability, in its most widespread conception, is a synthesis discipline that integrates sociopolitical, environmental, and economic spheres of knowledge. The purpose of sustainability is to find a balance between the needs of people while protecting the environment and cultivating a vibrant economy. These three spheres of knowledge can be further broken down into sets of component ideas that came together in developing the concept that underpin SE. The sustainability principles of this study are designed to embody these component ideas and thus represent a broad view of sustainability in this context. They serve as metrics for understanding how well a state science framework overlaps with or supports education about sustainability values and concepts. Sustainability issues, on the other hand, can best be thought of as nexus points where multiple principles converge. Together, these principles and issues provide a set of criteria against which standards can be measured to achieve this study's objectives.

This section will proceed to review the development of sustainability as a concept and then focus on how it has been interpreted in the context of SE. From this review, key themes and principles that represent a full range of the goals pursued by sustainability education will be identified and synthesized into a series of eight statements, or sustainability principles, to be used for quantitative analysis of published standards. Following these, three sustainability issues will be identified and justified based upon their capacity to link the sustainability principles together.

The Historical Context of Sustainability

Sustainability is a term that has been so widely co-opted it is at risk of being rendered meaningless (Pollan, 2007; Stone & Barlow, 2009; Yates, 2012). For this reason, it is necessary to establish a working definition of the term and to unpack its meaning, so it can function as a metric against which the standards in state science frameworks are measured. Ultimately, it should be clear what elements are widely held to contribute to a broadly agreed-upon understanding of what 'sustainability' encompasses, while recognizing it is a contested term (Feinstein & Kirchglaser, 2014) and a full consensus is unrealistic.

The origin of the modern usage of sustainability likely lies in the early 1970s when the budding environmental movement focused attention on connections between economics, population growth, and increasing levels of environmental degradation (Yates, 2012). The United Nations Conference on the Human Environment in 1972 focused on the need to reduce poverty and improve human quality-of-life through development while acknowledging that this can lead to both positive or negative consequences for humans and the environment.

> In our time, man's capability to transform his surroundings, if used wisely, can bring to all peoples the benefits of development and the opportunity to enhance the quality of life. Wrongly or heedlessly applied, the same power can do incalculable harm to human beings and the human environment. (Declaration, 1972)

The de facto assumption that unbounded growth is 'good' was being increasingly scrutinized by some who perceived it as clashing with the finite nature of the environment and the resources it could provide. These concerns coalesced in the milestone book The Limits to Growth which described the development and results of a computer simulation that showed, under some circumstances, resource depletion threatened human civilization with collapse sometime during the latter part of the 21st century (Meadows, Meadows, Randers, & Behrens, 1972). This work identified and described social patterns and choices that could lead to sustainable human societies which are still being discussed today.

Sustainability made a more general entry into the lexicon during the 1980s. One of the early users of the term, Lester R. Brown, authored Building a Sustainable Society (1981) which envisioned a world that managed population growth, relied on renewable sources of energy, stabilized soil loss and degradation of croplands, stabilized the biological systems of the earth, and embraced the recycling of materials and the conservation of energy resources. Brown's sustainability was largely concerned with human interactions with the Earth's physical systems, and along with The Limits to Growth, established an important thematic element within sustainability; the idea that environmental problems can be managed through quantitative analysis leading to engineered solutions. This idea has persisted within the discipline and will be revisited.

The next important step in the evolution of sustainability came from the United Nations World Commission on Environment and Development (UNWECD) in 1987 with the drafting and publication of Our Common Future. This report picked up where The Stockholm Convention left off and offered a vision of political action to synthesize the need for development to alleviate poverty with the necessity of reigning in environmental degradation. Our Common Future (United Nations, 1987) described sustainable development as meeting “the needs of the present without compromising the ability of future generations to meet their own needs” (p. 16). This language has widely been adopted as a definition of sustainability.

Note that the UNWECD used the term “sustainable development” but this is not universal. In the context of education, “education for sustainability” or “sustainability education” have generally supplanted it in more recent years (Bonnett, 1999). I have adopted the terms “sustainability” and “sustainability education” and the UNWECD language as a starting point for unpacking and describing a fuller and more contemporary meaning of sustainability.

Our Common Future declared that sustainable development must maintain a primary focus on the “essential needs of the world’s poor”, and “limitations imposed by the state of technology and social organization on the environment’s ability to meet present and future human needs” (p. 41). With this wording, the UNWECD introduced new dimensions to sustainability that persist into the modern context.

First, there is the elevation of the concept of social equity. The document notes that even the narrowest vision of sustainability “implies a concern for social equity between generations, a concern that must logically be extended to equity within each generation” (p. 41). Thus, a sustainable society must do more than meet its overall needs, it must also meet the needs of its individual citizens. In 1992, The United Nations Conference on Environment & Development expanded upon this call for a fully inclusive equity in its report, Agenda 21, noting “Sustainable development must be achieved at every level of society” (p. 15).

The second important distinction is the idea that technological and social systems produce feedback upon the ability of the environment to provide resources and services for humanity. From this, a more nuanced vision of sustainability emerges that includes the following two concepts:

- Technology affects the capacity of the environment to support human needs.
- Human social structures affect the capacity of the environment to support human needs.

This further reinforced the idea that sustainability problems can be broken down, quantified, and address through engineered, technological solutions. Feinstein and Kirchglaser (2014) identified this is an important thematic element in the NGSS and labeled it as techno-centrism; the idea that management of physical systems is key to increasing sustainability in human society. As we shall see, this orientation permeated into the genre of sustainability education which incorporates strong elements of quantitative systems thinking.

The second theme evolving here is the idea that human social structures also impact the environment’s capacity to support humanity. This was anticipated in Our Common Future (1987) which noted “A world in which poverty is endemic will always be prone to ecological and other catastrophes” (p. 16), and Agyeman, Bullard, and Evans (2003) compiled compelling evidence supporting the view that poverty and social injustice are direct causes of environmental degradation. This element creates a state of tension with techno–centrism. From this perspective, addressing sustainability challenges requires the application of social perspectives, and this sets the stage for one of the key challenge to achieving sustainability: balancing our scientific and technological understanding of the associated problems with social factors and the ethical imperative of addressing human needs.

Our Common Future was born out of an effort to address a set of global problems, one of which was economic inequity and endemic poverty in many parts of the world. As a framework for structuring global action on these problems, it assumes that economic development and growth are necessary conditions for addressing core human needs. Given the spectacular rise in affluence and standards of living that have resulted from economic prosperity in developed nations, this is hardly surprising and has resulted in the third thematic element which has coalesced in the concept of sustainability. This idea is that economic prosperity is necessary for human sustainability.

The result and enduring legacy of the UNWECD report was the emergence of this three-part framework for conceiving of sustainability as "the interrelatedness of environment, economy, and social justice (Stone, 6)." This framework has been rendered as a Venn diagram which, in various forms, has become common in sustainability literature (Figure 1).

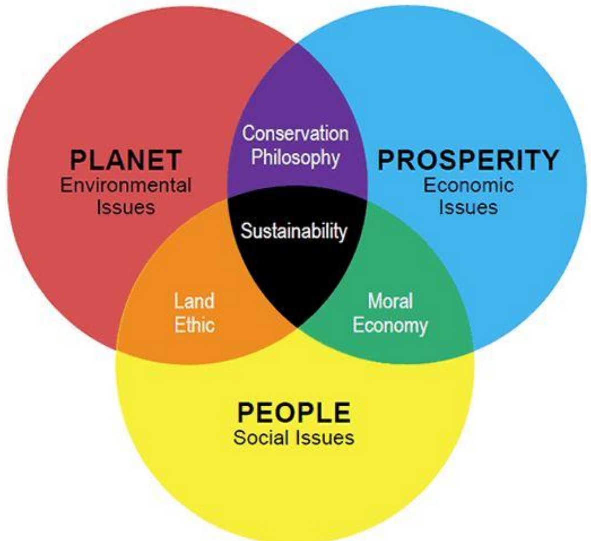


Figure 2. The relationship of sustainability to people, planet, and prosperity (Yates, 2012).

Figure 1 provides a visual synthesis of the social, environmental, and economic themes that developed and were elaborated over this 20-year period. Techno-centrism exists within the intersection between planet and prosperity. It is an enduring element of sustainability philosophy as is the tension with it produced by the needs of human societies and people. It is the intersection between the spheres that represents the goal, and "according to many advocates, these three interrelating spheres represent sustainability in the most complete sense of the word" (Yates, 2012).

Defining Sustainability

While the UNWECD definition of sustainability is widely recognized, it is deficient because it leaves much of the meaning embodied by the term to be inferred. Agyeman, Bullard, and Evans (2003) offered a more complete definition:

> Ensure a better quality of life for all, and now, and into the future, in a just and equitable manner, while living within the limits of supporting ecosystems. (p. 2)

This definition expands on the implications of the UNWECD version and contain similar concepts. For this reason, the definition offered by Agyeman, Bullard, and Evans was used as a working definition of sustainability with a slight modification; the term "supporting ecosystems" has been replaced with the term "Earth's supporting systems" to reflect a slightly broader view of the ways humans are supported and interact with the planet's full range of physical and biological systems. In sum, the working definition of sustainability used in this study is as follows:

> Ensuring a better quality of life for all, now, and into the future, in a just and equitable manner, while living within the limits of Earth's supporting systems.

This definition captures the important themes of caring for human needs, equity between all peoples, and protecting the health and function of Earth's natural's systems that support humanity. The concept of prosperity is implicit within the call to provide a "better quality of life" for all people without tying it to any particular culture or standard of living. With this definition in hand, it is now possible to proceed to how these ideas have manifested in the education context.

Key Principles Drawn from Sustainability Education

Sustainability education (SE) is a distinct genre within sustainability, because it must meet the pedagogical needs of teaching and learning. Education is heavily influenced by the needs of audience, school children, and the limits to what children can understand and apply at any given age. For this reason, SE literature must be examined to identify the version of sustainability that advocates seek to implement with students.

I reviewed SE literature to derive sustainability principles (SPs) that occur across the genre. These SPs (Table 3) are to serve as metrics to evaluate state frameworks for their capacity to support SE as it currently exists in education literature. To structure this effort, the three spheres of sustainability-- people, planet, and prosperity-- were examined separately and relevant principles drawn from each.

People

The “people” sphere of Figure 1 can be broken down into components of equity, community, human well-being, and inclusive decision making. A theme of equity is consistently found throughout SE literature. ‘Equity and justice’ are one of the eight big ideas identified by the Facing the Future project (Facing the Future, 2017), and Bijur, et. al. (2015) note “resources need to be shared to meet the needs of living things across places and generations” (p. 46) as one of the ‘big ideas of sustainability’. Similarly, Stone (2009) cites *Our Common Future* as originating the idea that intergenerational equity is a central tenet of SE. A meta-analysis by McMillan and Higgs (2003) notes a nearly ubiquitous focus on what they call a “long-term futures approach" (p. 2) and cite frequent social equity themes in terms of “fair access to resources, opportunities, and power" (p. 3). Ben-Eli (2015) also advocates for this, declaring sustainable societies must “ensure equitable access to life nurturing resources” (p. 7). In a subtle but useful nuance, he casts intergenerational equity as living within an ecosystem’s carrying capacity in order to ensure resource availability into the future.

Table 3. Eight principles extracted from sustainability education literature (by author).

Principle	Text
SP1	Human use of natural resources and environmental services must respect limits on their ability to be renewed to ensure continued availability and function for future generations.
SP2	Human interactions with the environment, including consumption patterns and use of natural resources, should produce widespread well-being and equitable benefits for all peoples.
SP3	Decision making about human interaction with Earth's physical and biologica systems must include and respect all affected peoples.
SP4	Decisions about sustainability issues must include social, cultural, economic, political and ethical perspectives as well as scientific knowledge.
SP5	Humans depend upon Earth's physical and biological systems for environmental services and natural resources. Our collective well-being depends on maintaining and protecting their healthy and stable function.
SP6	Sustainable systems are characterized by diversity, recycle matter continuously, and rely on renewable or inexhaustible energy sources. Disruption of these beyond limits can cause the system to become unsustainable.
SP7	Human social and economic systems are highly interconnected with Earth's physical and biological systems. Changes to any system produces effects on others.
SP8	Economic development and environmental protection must go hand in hand. Both are necessary for human well-being.

Consumption equity. Stark differences exist in the access to resources and consumption levels between different nations and cultures of the world, primarily due to the degree of affluence (Lahoti, Jayadev, and Reddy, 2014). Our Common Future (United Nations, 1987) recognized the problems associated with differential consumption patterns noting "many of us live beyond the world's ecological means" and "living standards that go beyond the basic minimum are sustainable only if consumption standards everywhere have regard for long-term sustainability." The document envisions this as an issue of values and suggested policy was needed to "encourage consumption standards that are within the bounds of the ecological possible and to which all can reasonably aspire." (p. 42). The phrase 'to which all can reasonably aspire' is notable because it introduces an imperative for fostering equity in consumption patterns. The United Nations further expanded upon these ideas in Agenda 21 (United Nations, 1992) stating "the major cause of the continued deterioration of the global environment is the unsustainable pattern of consumption" and noting that while "consumption patterns are very high in certain parts of the world, the basic consumer needs of large sections of humanity are not being met." Demand amongst richer segments of the world population is described as "excessive" and their lifestyles "unsustainable" (p.18).

Well-being. Well-being is "having healthy physical and psychological living conditions in which to live" and demands that basic material needs be met" (McMillan and Higgs, 2015). While this theme is less clearly and consistently articulated within the domain of SE literature, it is substantial within the sustainability canon writ large (p. 3). For example, Ben-Eli (2015) calls for "a measure of well-being and human development in economic calculations" (p. 5) and argues for tolerance, universal rights, inclusive governance, and the elimination of war as part of creating a sustainable human culture (p.7). And, the U.N. has called for intensified efforts to eradicate poverty, provide opportunity for all persons to earn a sustainable livelihood, meet basic health care needs, and for access to safe and healthy shelter, all as goals toward promoting well-being of all humans (United Nations, 1992).

Well-being seems to be treated as something expected to emerge from SE. As Stone notes, "commonly, minority children suffer disproportionately from problems that schools often exacerbate…a sustainable school promotes the health and learning of all students regardless of income or background" (p.8). In a similar vein, The Guide to

Education for Sustainability (Bijur et. al., 2015) describes well-being as leading to sustainability by stating “when we design curricula that emphasize understanding and contributing to economic social and environmental well-being, we work to ensure a better life now and for future generations” (p. 4).

These themes suggest two core sustainability principles are in play. The first is inter-generational equity; the idea that resources must be managed to insure their continued availability into the future and for the benefit of future generations. The second is a principle of intra-generational equity or fairness with respect to resource consumption patterns and availability for all people living on Earth today. Each of these ideas has been distilled into its own sustainability principle (SP) (Table 3).

SP1: Human use of natural resources and ecosystem services must respect limits on their ability to be renewed to ensure continued availability and function for future generations.

SP2: Human interactions with the environment, including consumption patterns and use of natural resources, should produce widespread well-being and equitable benefits for all peoples.

Community. Another dimension of equity explored by several authors relate to themes of participatory decision-making, tolerance, acceptance of diversity, and community involvement as noted by McMillan and Higgs (2003) who suggest this is grounded in the belief that a “stable society is crucial to maintain a high quality of life over the long-term" (p. 3). Bijur et. al. (2015) identified community as a core concept of sustainability, seeing it as “an outcome of relationships” and noting that each person is part of one or more communities and both shapes them and is shaped by them (p. 44). Ben-Eli (2015) calls for societies to "maximize degrees of freedom and potential self-realization of all humans without any individual or group, adversely affecting the others." and he further makes the case that respect for diversity, encouraging variety, and plurality in society gives it vibrancy and resilience that protects its long-term viability (p. 7). This is echoed by Capra (2005), who argues that ethnic and cultural diversity make social systems more resilient and open the door to different approaches to solving the same problem (p. 25). These ideas were integrated into sustainability principle three.

SP3: Decision making about human interaction with Earth's physical and biological systems must include and respect all affected peoples.

Inclusivity and interdisciplinary nature of sustainability. A great deal of value was placed upon diversity as a characteristic of sustainable ecological systems, and this is extended to include social systems across the literature. Capra (2005) points to ethnic and cultural diversity for creating resilience within social systems, and as Stone (2009) relates it "qualities that keep natural ecosystems vibrant and resilient, such as diversity and interdependence, shape healthier schools and other human communities as well." (p.11). This theme is similarly embodied by Ben-Eli (2015) who calls for "inclusion in effective democracy and governance" and declared "tolerance is a cornerstone of social interactions and ensuring universal rights" (p. 7). This respect for diversity and inclusiveness was identified as pervasive within the discipline by McMillan and Higgs (2003) who noted "because issues of sustainability involve the interaction of social, environmental, economic, political, historical, and cultural forces, SE aims to teach students to examine the interactions between these systems" (p. 3). Similarly, this conclusion is also supported by Summers, Corney, and Childs (2003) who found a "consensus that sustainable development is about bringing together social, economic, and environmental factors" (p. 329) and Rowe (2007) who notes:

> All students need to learn, through an interdisciplinary approach, not only the specifics of our sustainability challenges and the possible solutions, but also the interpersonal skills, the systems thinking skills, and the change agent skills to effectively help to create a more sustainable future. (p. 323)

Bringing these ideas together, the Sustainable Schools Project (Bijur et. al., 2015) identifies civic engagement as the "keystone of all education for sustainability work" (p. 11) and concludes:

> When an educational curriculum or program demonstrates the interdependence of the economy, environment, and society, it is reaching into the depths of sustainability. Using an integrated, interdisciplinary curriculum to show how individual systems are interwoven helps students study, experience, and understand the connections between all of the elements of their own lives. This in turn encourages them to expand that knowledge to the workings of their community, helping them become thoughtful and engaged citizens in the process. (p. 11)

These strong themes of including diverse perspectives when considering sustainability problems were synthesized into sustainability principle four:

SP4: Decisions about sustainability issues must include social, cultural, economic, political and ethical perspectives as well as scientific knowledge.

Planet

The planet perspective of sustainability focuses on the interdependence between humans and the larger earth environment. It emphasizes the use of systems and systems thinking for understanding the quantitative aspect of environmental issues.

Interdependence. The first thematic element that characterizes SE is the placement of humanity within nature as opposed to existing separately from it. This theme emphasizes interconnectedness between humans and the Earth's natural systems, and that the well-being of each is intertwined and inseparable. Human reliance upon the physical and biological Earth is clearly contingent upon "the integrity of the ecological systems upon which all life and all production depends." (Viederman, 1994). By placing humankind within nature, SE seeks to dispel the notion that humans and human social systems are somehow above, beyond, or separate from nature. As Ben-Eli (2015) puts it, "honor the Earth with its intricate ecology, of which humans are an integral part" (p. 8), a sentiment echoed by Stone (2009). The implication is that care for the Earth's environment is essential but also inseparable from our economic and social interactions with it (Gough, 2002). Or, as the big ideas of sustainability published by the sustainable schools Project (Bijur et. al., 2015) put it, "All living things are connected. Every organism, system, and place depend on others." The themes of dependence and protection were integrated into sustainability principle five:

SP5: Humans depend upon Earth's physical and biological systems for environmental services and natural resources. Our collective well-being depends on maintaining and protecting their healthy and stable function.

Systems and systems thinking. Sustainability often perceived as a technical problem, and important aspects of it are quantitative in nature (Viederman, 1994) an observation echoed by Feinstein and Kirchglaser (2014) who labeled it 'techno-centrism.' For this reason, systems thinking is a useful tool for analyzing and understanding the nature of environmental problems that result from disruptions in the flow of matter and energy, and systems models are widely seen as useful for identifying, understanding, and developing solutions to physical sustainability problems.

A finer grained view of system thinking within the discipline of sustainability emerges from the literature. Capra notes that "the most useful framework for understanding ecology today is the theory of living systems" (p. 19). Systems thinking permits a focus on how parts function together as a whole revealing larger relationships and processes (Capra, 2005; Stone & Barlow, 2009; Bijur et al., 2015) and permit a full accounting of the Earth's ecological processes (Ben-Eli, 2015). Several sources refer to the critical necessity of maintaining cyclical flows of matter and relying upon renewable sources of energy (Capra, 2005; Stone & Barlow, 2009; Bijur et al., 2015), and diversity is identified as increasing resilience in both biological and human systems by providing a level of redundancy (Capra, 2005; Stone & Barlow, 2009; Ben-Eli, 2015). Further, Earth is viewed as consisting of many systems operating at different scales that are nested within one another and form complex networks (Capra, 23). Some authors emphasize interconnectedness between various human and earth systems (Cirillo & Hoyler, 2015). MacMillian and Higgs note "because issues of sustainability involve the interaction of social, environmental, economic, political, historical, and cultural forces, SE aims to teach students to examine the interactions between these systems" (p. 2). The collective understanding that emerges is that perturbations to any one system has an impact on others. There seems to be wide agreement in education to teach the skills needed to think in terms of systems. In doing so we shift the emphasis "from the parts to the whole, from objects to relationships, from structures to processes, from contents to patterns" (Stone & Barlow, 10). This set of ideas were integrated into sustainability principles six and seven.

SP6: Sustainable systems are characterized by diversity, recycle matter continuously, and rely on renewable or inexhaustible energy sources. Disruption of these beyond limits can cause the system to become unsustainable.

SP7: Human social and economic systems are highly interconnected with Earth's physical and biological systems. Changes to any system produces effects on others.

Prosperity

In the modern world, economic activity is closely tied to human prosperity and makes important contributions to human well-being. Poverty is one of the factors that influences the amount of environmental harm that humans inflict upon the environment. At the same time, economic development, which can function to reduce poverty, has a demonstrated history of inflicting its own set of environmental harms. Sustainability, and by extension sustainability education, seeks to balance the human need for a vibrant economy and a healthy environment.

Economic development. Economic considerations are a core theme in sustainability with roots that trace back to the earliest United Nations declarations and conferences. The Stockholm Declaration (1972) noted that in "developing countries most of the environmental problems are caused by underdevelopment." A prevailing perception was that economic growth was an essential tool in the global fight against poverty, and this ethos was embodied in principle eight of the document.

> Economic and social development is essential for ensuring a favorable living and working environment for man and for creating conditions on earth that are necessary for the improvement of the quality of life. (Declaration of the United Nations conference, 1972).

At the same time, the conference clearly saw that a host of environmental problems were linked to economic activity and that a new focus on environmental protection was a pressing necessity.

Balancing the economy and the environment. The Stockholm Declaration (1972) further recognized a need for balancing the environment with the economy noting that ecosystems “must be safeguarded for the benefit of present and future generations” and that “The capacity of the earth to produce vital renewable resources must be maintained and, wherever practicable, restored or improved.” (Declaration of the United Nations conference, 1972) This theme was expanded upon in Our Common Future (United Nations, 1987) which envisioned a form of development that “sustained human progress… for the entire planet into the distant future.” Coining the term ‘sustainable development,’ this document called for the evolution of economic and social institutions to provide equitable welfare for all peoples of the world while maintaining environmental health. The United Nations reiterated the two-sided nature of development in Agenda 21 (United Nations, 1992) stating “development policy that focuses mainly on increasing the production of goods without addressing the sustainability of the resources on which production is based will sooner or later run into declining productivity” (p.14). The view that evolved during these two decades is that societies must seek to balance economic needs with environmental care, all the while advancing the goal of reducing poverty and inequity on a global basis.

Economics in sustainability education. The tension between economics and environment exists in the genre of SE as well. McMillan and Higgs (2003) noted that economically sustainable systems would not *deplete* (my emphasis) financial, natural, or social capital and Gough (2002) argues that economics are inseparable from environmental concerns. Summers, Corney, and Childs (2003) document this tension extensively and other voices have called for replacing traditional measures of economic progress with more inclusive ones that include environmental and social costs that are linked to development (United Nations, 1992; Ben-Eli, 2015). It is perhaps for this reason that SE speaks of economic development in terms of limitation and balance. The Sustainable Schools Project shows “economic vitality" as one of three outcomes in its big ideas of sustainability and emphasizes limits on systems, interdependence humans and the Earth, maintaining equilibrium, and considering long-term effects. Similarly, the Facing the Future program emphasizes Earth’s finite capacity to supply resources and interconnectedness, and the application of justice to social, economic, environmental issues. The view that develops in sum is that while economics are important for meeting human needs, there must be restraint of the excesses that characterized human development in the past. What materializes is a message of shifting values away from the primacy of growth as the key driver of prosperity toward what Tillbury (1995) describes as “developing the target values of social responsibility, concern for others, and harmony with nature” (p. 202). Thematic elements related to justice and equity here been captured by sustainability principles two and three, but the elements related to the dual need for a healthy economy and a healthy environment not yet been elaborated. Based upon the juxtaposition of economic growth and ecological limits, sustainability principle eight was drafted.

SP8: Economic development and environmental protection must go hand in hand. Both are necessary for human well-being.

The eight sustainability principles capture the range of ideas and ethics that are broadly evident within sustainability education literature. They are presented as declarative statements to reflect the necessity of adhering to their precepts in order to fully pursue sustainability as it is conceived articulated within this body of thinking. This format also provides a workable metric against which a content standard within public education frameworks can be measured in order to quantify the degree to which each aligns with the principle.

Sustainability Issues

In addition to the eight sustainability principles derived from SE literature, three a priori sustainability issues (SI) were used as additional metrics against which standards were evaluated. The purpose of this approach was to look for other potential within frameworks to integrate sustainability education. The issues were selected because multiple sustainability principles converge in them and were presented as descriptive statements concerning the relationship between a certain standard and an issue presupposed to be relevant to SE. Human interactions with climate, water, and resource consumption were selected for these nexus points. Each SI is applicable across different scales ranging from local to global and widely understood to be tied to human security, well-being, and impact upon the planet. These issues are summarized in Table 4.

Table 4. Three sustainability issues used as metrics for learning standards (by author).

Issue	Text
SI1	The standard concerns understanding how humans have contributed to a rise in global temperatures over the last century and the consequences of this for humans and other living things.
SI2	The standard concerns understanding how humans affect the quality and availability of fresh water and the consequences of this for humans and other living things.
SI3	The standard concerns understanding factors that affect the level of human impact on the environment and/or our consumption of natural resources.

Sustainability issue 1 (SI1): climate change. Climate change is unique as a sustainability issue because it is caused by human activities that cross all cultures and it produces global impacts that will be felt everywhere and by all peoples. There is an enormous asymmetry between the causes of climate change and the impacts it produces with respect to different groups of people across the globe. Because of this, climate change connects full range of sustainability principles in this study.

To start, it threatens the environmental services upon which humanity depends (SP1) and produces impacts that vary so widely among the different cultures and nations of Earth that serious issues of equity and ethics produced (SP2). Further, the inherent social and environmental justice concerns linked to climate change require inclusive decision-making that integrates a full range of human and scientific perspectives (SP3, SP4). In addition to its social implications, climate change poses real threats to the health and function of earth systems. Understanding the risks requires ecological and earth systems knowledge along with quantitative analysis supported by systems thinking (SP5, SP6, SP7). Finally, most if not all the human activity that leads to climate change is tied to economic activity on a global basis. Overconsumption and affluence in developed nations has produced most of the forcing to Earth's climate, while widespread poverty within developing and underdeveloped nations requires increased economic activity to provide for human well-being. These dual forces are producing a trajectory where human activity increasingly threatens the stability of the earth environment because of our efforts to meet human needs, the subject of SP8. The inclusion of this sustainability issue in a learning standard has the potential to create an opportunity for the exploration of the full range of sustainability principles.

Sustainability issue 2 (SI2): water. The case for including water quality/availability as a sustainability issue is very similar to that supporting climate change. Water issues exist on all continents affect all nations, and in one way or another impact nearly all people on earth. The principal difference between water issues and that of climate change is they tend to be more locally or regionally focused. Despite this, the common themes of pollution driven by human economic and social activity, consumption levels that exceed the capacity for renewal, and unequal impacts upon various social and economic groups seem to occur everywhere. Similarly, water issues are best understood through quantitative analysis supported by systems thinking and the application of both environmental and earth systems knowledge. For these reasons, water issues also engage the full range of sustainability principles.

Sustainability issue 3 (SI3): environment. Human impact upon the environment varies widely in degree and character from culture to culture. In developed nations, high level of affluence drives consumption behavior that produce external impacts upon the global environment. This consumption pushes against environmental limits (SP1) while threatening the well-being of many people (SP2). Frequently, these impacts are displaced upon other peoples and cultures which engage issues of equity, justice, and the need for widespread perspectives in understanding and dealing with the resulting problems (SP2, SP3, SP4). These principles are engaged in other contexts as well. In underdeveloped nations, for example, lack of economic security and population growth produce environmental impacts that tend to be local and threaten human well-being on a widespread basis. In many nations, a mixture of these factors come into play. The nature of these issues equally engages these sustainability principles.

Environmental understanding, quantitative systems analysis, and the environmental impact of economic activity are equally relevant here as well. Scientific knowledge and tools are necessary for understanding system function, quantifying impacts, and formulating potential mitigation strategies. Human consumption behaviors are deeply tied to economic activity and the western paradigm of growth-based consumerism simultaneously drives the economy and subsequent environmental degradation. These issues engage SPs five through eight.

In addition to this reasoning, these three sustainability issues (Table 4) were chosen because they are topical, broadly relevant on a global basis, and cross cultural, political, ethnic, and social lines. They are worded as neutral descriptions of the issue so that the degree to which an individual learning standard is related to the issue can be gauged. Because these issues are tied to the full range of sustainability principles, the inclusion or occurrence of any of them within a science standard invites exploration of sustainability in an integrated format. Together with the eight SPs they form a robust set of metrics that has the capacity to identify a full range of sustainability conceptual thinking in the science frameworks of U. S. public education systems.

Potential Barriers to Sustainability Education in Public School Frameworks

As noted, there is evidence of potential barriers to integrating sustainability into the public education context. Of interest are issues related to language within standards that may present an obstacle to including SE in the classroom, and structural components in state frameworks that may make it difficult to implement SE. As a study of the capacity for existing middle school science frameworks to support and promote SE, an effort to explore and quantify of these potential barriers is relevant. Sustainability is interdisciplinary by nature and SE advocates almost universally promote it being taught in that context (McMillan & Higgs, 2003). Structural barriers that may inhibit flexibility in curriculum need to be explored. One key issue is the separation of science into discrete disciplines that may discourage the integration of content and concepts that cut across discipline lines. Most, if not all, sustainability issues include dimensions of biology, earth science, and physical science intersecting with social, political, and economic concerns (Rowe, 2007; Summers, Corney, & Childs, 2003). In high school, science disciplines are almost universally taught in a single subject model with the notable exceptions of environmental science and earth systems science. This is one of the reasons why middle school frameworks present an important opportunity for sustainability advocates. As Schmidt (2003) explains in his work on creating coherent science curricula:

> What is missing is an organizing principle that weaves this reduced set of topics into a sequence that is logical and that leads to an unfolding of a key story or stories in science that are intrinsically interesting to students and that provide the needed basis for understanding science by future literate citizens and not just the memorization of isolated facts to be forgotten as school finishes. (p. 571)

But even at the middle school level, states may require, or schools may choose, to organize standards with a single discipline covered in a grade year (i.e. earth science in grade 6, life science in grade 7, physical science in grade 8). This sort of organizational model creates real obstacles to integrating ideas in an SE context. For example, attempting to understand the cycling of matter in an ecosystem without integrating certain principles and knowledge from chemistry will lead to incomplete comprehension of important ideas. In a similar vein, some state or school models specify a spiraled curriculum which specifies the standards from each science discipline to be taught in each year. This might represent an improvement over the single subject model but is similarly constraining when needed content is located in different grade levels and the flexibility alter the sequence may not exist. And, both restrictive models hinder educators who might otherwise seek to coordinate their curriculum with other subjects such as social studies, mathematics, or language arts.

The optimal degree of freedom is achieved in those states that provide for a flexible model in which science content is specified for the entire grade band of six through eight. In this model, individual schools or districts may sequence and integrate content as they see fit to build a meaningful program with coherent story lines that are, Schmidt puts it, “intrinsically interesting.” This model offers the maximum flexibility and potential for sustainability education within the science classroom context. Some effort to identify these structural factors are relevant to the study.

Another potential problem can be found in the wording of individual learning standards which may also present barriers to sustainability education. Ideally, standards that invite students to mesh scientific thinking and understanding with social, political, and economic considerations in the context of problem-solving open the door to SE. Standards that engage this type of thinking can provide useful portals into SE themed units are lessons. But, barriers may also arise within the wording of the performance expectations of a given standard. Science may be presented as the best, preferred, or only method for dealing with environmental issues that have wider social, political, cultural or economic implications (Feinstein & Kirchglaser, 2014). In this case, an unintentional but subtle bias against the inclusion of sustainability principles may exist. Further, because certain sustainability issues and concepts are politically contentious, and learning standards are written at the state level, there is potential for actual bias against certain ideas to be written into learning standards of individual states that may not exist in others. For this reason, some provision needs to be made for identifying and coding these content barriers to SE where they may occur within state standards.

Research Questions, Hypotheses and Specific Aims

Four discrete areas of inquiry were examined in this investigation. For each question, hypotheses were formulated based upon my experience with the Next Generation Science Standards and the Massachusetts Science and

Technology/Engineering Curriculum Frameworks. The research questions and associated hypotheses examined were:

1. How frequently is teaching sustainability either explicitly required or implicitly invited by the existing public middle school science learning standards in the United States? This was examined using a coding rubric to score each individual Performance Expectation Equivalent (PEXE) in a database matrix that permitted analysis for large-scale patterns. The following hypotheses were tested:

- Sustainability is explicitly required by fewer than 3% of the middle school PEXEs of all 50 states.
- Fewer than 5% of the middle school science PEXEs in the United States implicitly invite teaching sustainability through content that aligns with the goals of sustainability.

2. Where content standards do not explicitly require or implicitly invite teaching sustainability, to what degree do they incorporate key concepts that are embodied within sustainability education? This was examined using a coding rubric that scored the level of overlap between the content and concepts contained within PEXEs and eight sustainability principles and three a priori sustainability issues. The following hypotheses were tested:

- Fewer than 10% of middle school PEXEs will specify teaching content and concepts that are aligned with at least one of the key sustainability principles embodied within sustainability education (Table 3).
- Fewer than 10% of middle school PEXEs will specify teaching at least one of three a priori sustainability issues used in this study (Table 4).

3. To what degree do state science frameworks allow for integration of required science content from different domains of science into flexible presentations that best support sustainability education? This was examined by looking for relevant language and structure within individual state frameworks documents that either required or promoted specific organization models. The following hypothesis was tested:

- Most state published public school science frameworks will include elements of structure that create potential barriers to constructing flexible, integrated presentations of content which best support sustainability education.

4. How many middle school students could potentially receive sustainability education within the public-school science frameworks currently established in the United States? To contextualize and understand the findings of first three research questions, it is necessary to integrate public school enrollment data so the impact on students can be properly evaluated. This was examined using state-level public school enrollment data and the occurrence of individual standards that were identified as able to support SE within the frameworks to produce an estimate of how many students could potentially be exposed to SE. The following hypotheses were tested.

- The majority of students in the United States public schools are subject to middle school frameworks that presents significant challenges to integrating sustainability education into their science classes.

Specific Aims

To investigate these research questions and hypotheses, the following set of specific aims were completed:

1. Develop a template spreadsheet matrix for assessing science PEXEs consistent with research questions 1 and 2, identify relevant standards from all 50 states and the District of Columbia, and transfer the PEXEs into spreadsheets (one per state) based on the template developed for this purpose.
2. Develop coding scales, coding criteria, and repeatable coding procedures for evaluating state standards consistent with attaining the objectives of research questions 1, 2, and 3.
3. Code all state standards consistent with research questions 1 and 2.
4. Use the coded spreadsheet matrices to build a database that reflects the current level of potential support for sustainability education consistent with research questions 1 and 2.
5. Develop a spreadsheet matrix for assessing the degree of flexibility extant within state science frameworks to integrate content from different science disciplines into presentation that best support sustainability education. Assess and code the structural flexibility consistent with research question 3.
6. Develop an estimate of the number of students who can potentially be exposed to sustainability education or related principles using population demographic data and information contained in public science school frameworks at the secondary level consistent with research question 4.
7. Develop a system of ranking different aspects of support for sustainability education within state frameworks and an overall assessment that permits comparison between states.

Chapter II

Methods

Accomplishing the objectives of the study required the creation of two separate spreadsheet matrices. The first was used for coding individual standards for explicit/implicit inclusion of sustainability and against eight sustainability principles (SPs) and three a priori sustainability issues (SIs) on a scale that measured the degree to which each standard supports important principles or concepts relevant to sustainability education (SE). To produce meaningful information, coding scales and procedures had to be developed that can produce repeatable quantitative data. The second matrix was employed to organize data on potential structural barriers within state frameworks that could either facilitate or interfere with implementing SE. Again, this required the development of coding criteria that would lead to meaningful quantitative results. Finally, analytical procedures had to be created that allowed for producing a summary of the current state of U.S. public school science frameworks and its ability to support SE.

Developing a Spreadsheet Tool for Assessing Science PEXEs by State.

I developed a spreadsheet template with a format flexible enough to accommodate the differences in framework size, nomenclature, and structure among the various states and the District of Columbia. This template could then be duplicated for individual states yet still permit direct comparison of the data generated when coding was complete.

Figure 2 shows an overview of the SSPEC MS Frameworks Analysis Template which was developed for this purpose. It organizes individual science standards in rows with columns that are used to represent various metrics related to sustainability education. The color-coded sections are focal area with key features related to this specific aim.

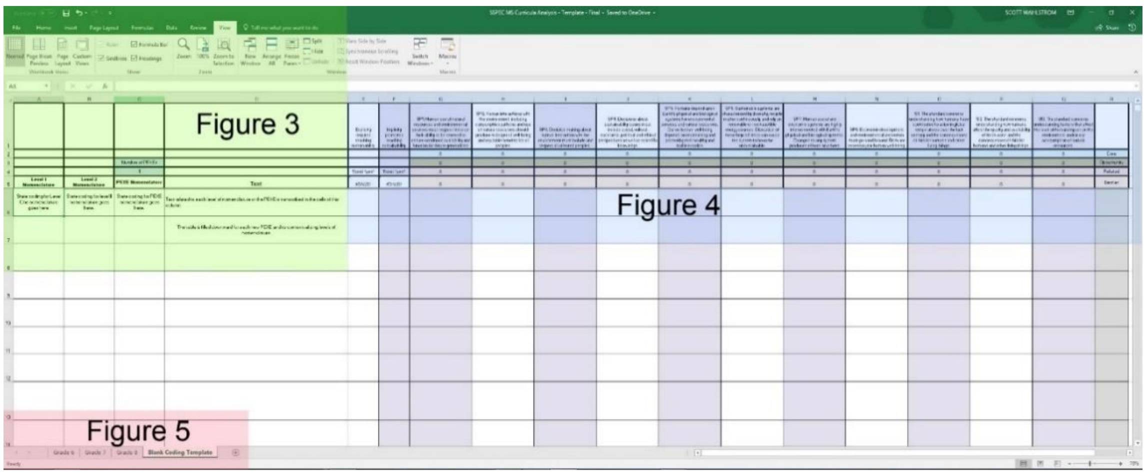


Figure 3. SSPEC MS frameworks analysis template, navigation key (by author).

The features for organizing the language of state standards and related nomenclature are shown in Figure 3. Columns A, B, and C, were allocated for recording the structural nomenclature used by the state in organizing its frameworks, including its Performance Expectation Equivalent (PEXE). In many cases, these columns recorded information related to discipline, strand, and standard, but this information varied widely among states that developed frameworks independent of the Next Generation Science Standards (NGSS). Column D was populated with any supporting text the state published related to each level of nomenclature or PEXE, and cell (C4) calculates and displays the total number of PEXEs in the state framework. Finally, the first five rows of the SSPEC MS Frameworks Analysis Template were dedicated to organizing this information. Rows six onward were used for transcribing each state's standard's text and entering the coding data.

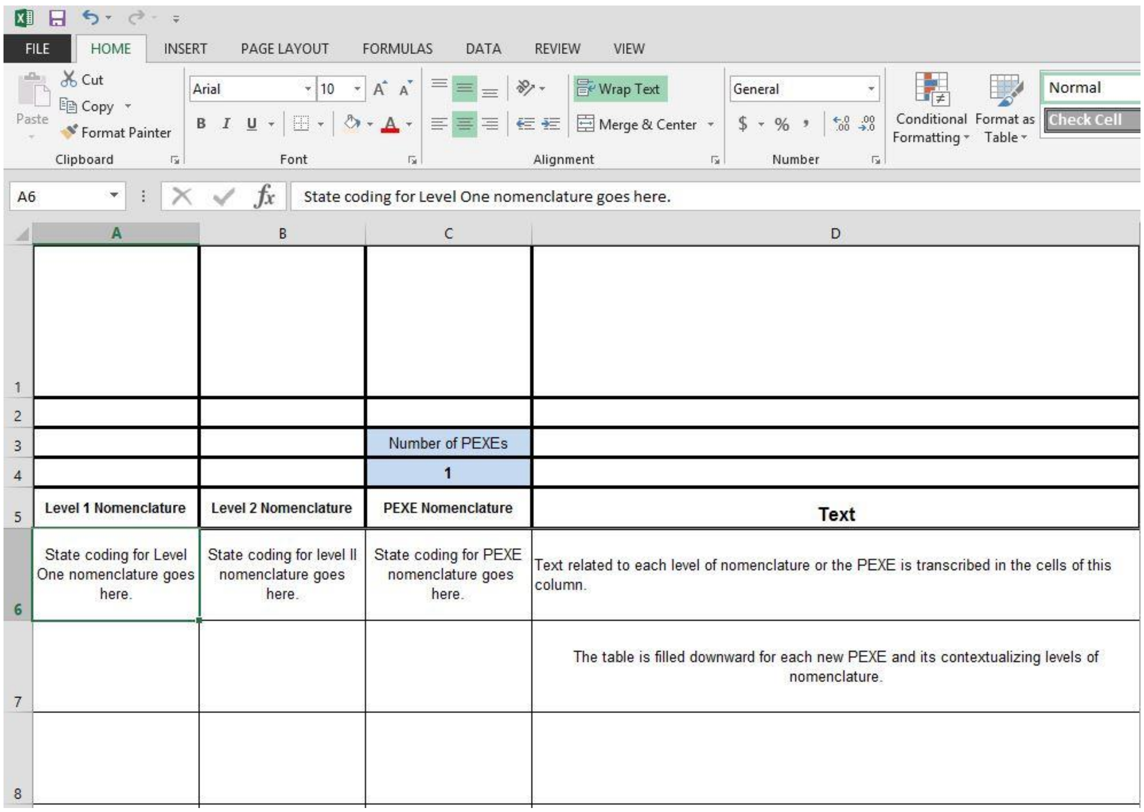


Figure 4. Template section organizing state specific nomenclature and text (by author).

Figure 4 shows the features that were included for coding the thirteen-metrics included in this study. Because of the width of the spreadsheet tool, this figure has been split in half and presented as two images. Columns E and F record coded data related to the explicit requirement or implicit invitation to teach sustainability. Columns G through N were allocated for the eight SPs, and columns O, P, and Q were used for the three SIs. Cells located in the top row of these columns include the text of the individual SP or SI. Directly below each SP or SI are cells that calculate the total number of PEXEs that score for the coding categories "core," "opportunity," "related," and "barrier".

E	F	G	H	I	J	K
Explicitly requires teaching sustainability.	Implicity promotes teaching sustainability.	SP1. Human use of natural resources and environmental services must respect limits on their ability to be renewed to ensure continued availability and function for future generations.	SP2. Human interactions with the environment, including consumption patterns and use of natural resources should produce widespread well-being and equitable benefits for all peoples.	SP3. Decision making about human interaction with the environment must include and respect all affected peoples.	SP4. Decisions about sustainability issues must include social, cultural, economic, political and ethical perspectives as well as scientific knowledge.	SP5. Humans depend upon Earth's physical and biological systems for environmental services and natural resources. Our collective well-being depends on maintaining and protecting their healthy and stable function.
		0	0	0	0	0
		0	0	0	0	0
Total "yes"	Total "yes"	0	0	0	0	0
#DIV/0!	#DIV/0!	0	0	0	0	0

L	M	N	O	P	Q	R
SP6. Sustainable systems are characterized by diversity, recycle matter continuously, and rely on renewable or inexhaustible energy sources. Disruption of these beyond limits can cause the system to become unsustainable.	SP7. Human social and economic systems are highly interconnected with Earth's physical and biological systems. Changes to any system produces effects on others.	SP8. Economic development and environmental protection must go hand in hand. Both are necessary for human well-being.	SI1. The standard concerns understanding how humans have contributed to a rise in global temperatures over the last century and the consequences of this for humans and other living things.	SI2. The standard concerns understanding how humans affect the quality and availability of fresh water and the consequences of this for humans and other living things.	SI3. The standard concerns understanding factors that affect the level of human impact on the environment and/or our consumption of natural resources.	
0	0	0	0	0	0	Core
0	0	0	0	0	0	Opportunity
0	0	0	0	0	0	Related
0	0	0	0	0	0	Barrier

Figure 5. Template sections for coding sustainability inclusion, SPs and SIs (by author).

Separate tabs were provided in the spreadsheet for each grade level or discipline along with a "Blank Coding Template" that was used to populate these, or other new tabs, needed to mirror the architecture of the state framework.

Middle school science frameworks for all 50 states plus the District of Columbia were located and downloaded. An individual copy of the SSPEC MS Frameworks Analysis Template was created for each state and set up with the nomenclature used by that specific state. Following this, the framework standards down to the level of the PEXE were copied and pasted into the spreadsheet tools for further analysis.

Developing Coding Scales and Methods for Assessing PEXEs

The clearest path for sustainability education (SE) into the public-school classroom would be through standards that specify its inclusion. To develop a coarse-grained view of this potential, public school standards were analyzed for the explicit inclusion of sustainability in learning standards and for the inclusion of concepts that are embodied within sustainability which might implicitly invite its inclusion. The goal was to determine how frequently education about sustainability was explicitly required or implicitly invited within a state framework.

The original project proposal anticipated coding scales that were judged to be inadequate to attain the objectives of this study for two reasons. First, the original scales were potentially too subjective in their category ratings and this raised questions about the reproducibility of the data. The second issue was that the category ratings themselves appeared to be inadequate with respect to capturing key information related to the study's objectives-- to determine the degree to which a state framework provided language capable of supporting sustainability education. For this reason, the rating scales needed to be redeveloped to 1) better match the study's objectives, 2) provide a framework to promote consistency in coding application from state to state, and 3) provide a rating system that captured as much information as possible relevant to the study's objectives.

Research question one seeks to quantify the degree to which teaching sustainability is either explicitly required or implicitly invited by individual standards. In order to determine whether a standard required or invited teaching sustainability, operational definitions of these two classifications were developed based upon the definition of sustainability identified in the background section.

> Sustainability: Ensuring a better quality of life for all, now, and into the future, in a just and equitable manner, while living within the limits of Earth's supporting systems.

This definition was deconstructed to identify goals of sustainability that could be detected in standards:

- Promoting a better quality of life for <u>all</u> peoples living today
- Protecting the rights of future generations to a better quality of life
- Promoting justice and equity as principles for using the Earth's resources to meet the needs of all people
- Protecting earth's systems to insure their healthy function (now and into the future)

To be identified as explicitly requiring the teaching of sustainability, a standard had to meet two criteria: 1) include the term 'sustainability,' and 2) direct student learning toward understanding or application of one or more of the goals listed above.

Determination of compatibility with the first criteria was handled using a simple word search. Compatibility with the second criteria however required further definition of what would be judged to be 'consistent with one or more of the goals.' In order to clarify this, each of the four goals were further interpreted in the context of common educational objectives that are consistent with it. These objectives were used to assist in identifying standards that were consistent with the goal.

1. Promoting a better quality of life for <u>all</u> peoples living today.

Related educational objectives:

- Solving human problems
- Solving environmental problems
- Recycling, conservation of resources
- Understanding the impact of human activities on society, well-being, etc.
- Promoting or protecting human health and safety
- Use of natural resources by humans
- Value/benefits of natural resources to humans

2. Protecting the rights of future generations to a better quality of life.

   Related educational objectives:

   - preserving/protecting the environment
   - understanding/limiting/reducing human impact on the environment
   - understanding/limiting/reducing human consumption of resources
   - recycling, conservation of resources
   - comparing/contrasting renewable and non-renewable resources

3. Promoting justice and equity as principles for using the Earth's resources to meet the needs of all people.

   Related educational objectives:

   - understanding or limiting consumption levels, reducing overconsumption
   - Recycling, conservation of resources

4. Protecting earth's systems to insure their healthy function (now and into the future.)

Related educational objectives:

- understanding the value of the environment to human well-being
- understanding or analyzing the nature of environmental issues
- actions related to solving or mitigating environmental problems
- understanding the impact of human activities on the environment
- understanding large scale (global impacts) of human activities

Standards meeting both criteria (i.e. included the term “sustainability” and was consistent with one or more of these goals) were coded “yes” to indicate it explicitly called for sustainability education, while any standard that failed to meet either of these criteria was coded “no" to indicate it did not.

To qualify as implicitly inviting the teaching of sustainability, a standard had to meet the criteria of 1) directing student learning toward a curricular goal similar to one or more of the goals of sustainability and 2) it could not explicitly refer to ‘sustainability’ in its language. Standards that met both criteria were coded “yes” indicating it implicitly invited sustainability education, while any standard that failed to meet either of these criteria was coded “no" indicating it did not.

Development of CORBNR rating scale. Sustainability education may also be supported by public school science frameworks through opportunities that exist within the various standards required by a given state. To understand this potential, it is necessary to apply a fine-grained analysis of existing standards against a more detailed set of principles and issues embodied by sustainability education. The sustainability principles and issues identified from the review of relevant sustainability education literature, provide the basis for investigating the potential to support sustainability education at a fine-grained level.

In order to quantify support for the concepts embodied by sustainability education, a rating scale was developed to classify each standard. This scale included categories of ‘core’, ‘opportunity’, ‘related’, ‘barrier’, and ‘not related’, producing the acronym CORBNR. Conceptually, each of these categories is designed to represent a distinct level of overlap between a given state standard and a specific sustainability principle or issue.

Core rating. Standards rated as “core” express content and ideas that are effectively synonymous with a SP. To assist in making this determination, each principle was broken down into component ideas termed core characteristics. Each core characteristic expresses a concept central to the SP and serves as a guide to help identify standards that overlap with it. When a standard overlapped all the core characteristics of a given SP, it was rated as “core.” This can be thought of as two circles, one of which represents the content and concepts within a standard while the other represents the core characteristics of this SP. When these two circles are coincident, the standard is judged “core” to the sustainability principle (Figure 5).

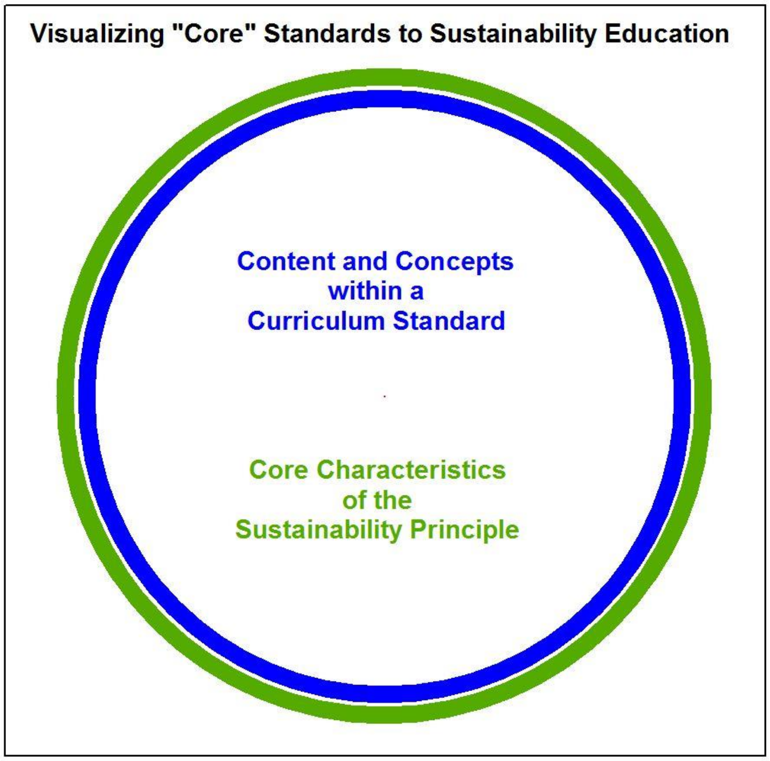


Figure 6. Visualizing the core rating.

Opportunity rating. The rating of 'opportunity' reflects a standard which contains a partial expression of the core characteristics of a sustainability principle. As before, the standard was evaluated against the core characteristics of that principle. When a subset of these were identified, it was rated as an "opportunity" for potential inclusion of that principle as an overarching idea for teaching the content required by the standard. This can be visualized as a Venn diagram where one circle represents the core characteristics of a SP and the other represents the content and concepts contained within a specific standard. Where these two circles are judged to overlap represents an "opportunity" for using the standard to help build an understanding of sustainability (Figure 6).

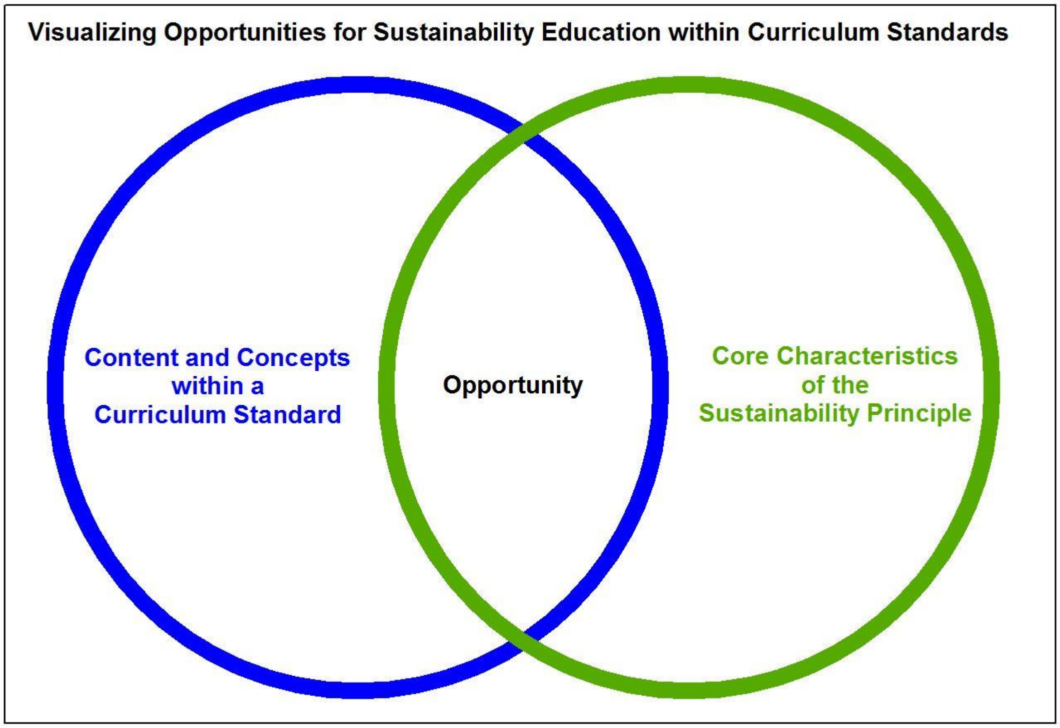


Figure 7. Visualizing the opportunity rating.

Related rating. Standards deemed 'related' contain content that is topically relevant to the SP but does not clearly incorporate any of the ideas embodied by the core characteristics. These standards best thought of as foundation knowledge or examples that would be useful or necessary for teaching one or more of the core characteristics. The purpose of this category is to identify standards that enable a student to build a coherent understanding of a SP despite being conceptually separate from its core characteristics. As a practical matter, educators would pre-teach this content integrate it into an SE themed unit intended to develop the principle. This can be visualized as circle representing the core characteristics of the sustainability principle with the content and concepts contained within a particular standard representative by arrows pointed into the circle to show that they are necessary elements that go into understanding that particular SP (Figure 7).

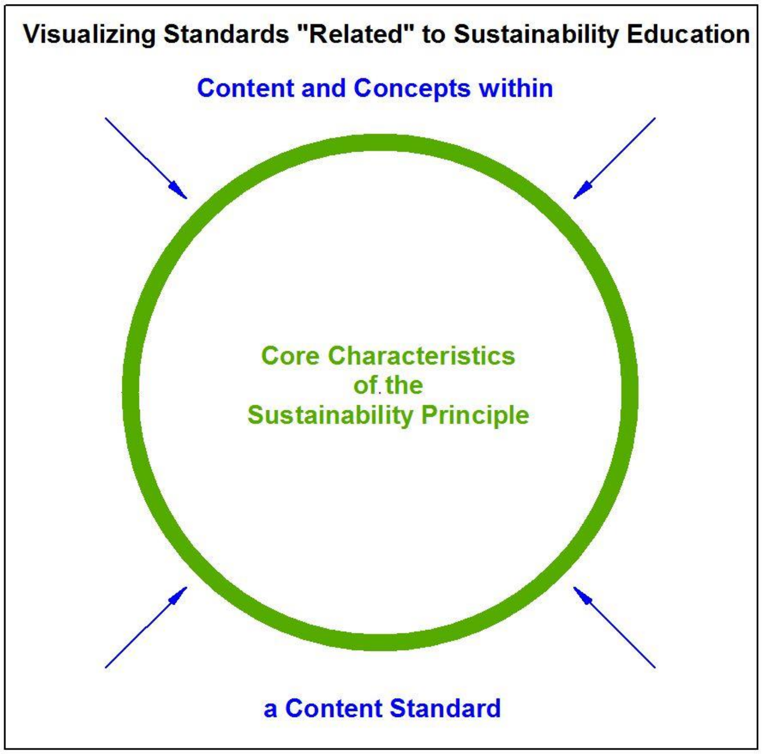


Figure 8. Visualizing the related rating.

Barrier rating. Given the heterogeneous nature of science frameworks in the United States and a perception that certain ideas are sometimes resisted or contested along political or ideological lines, it was anticipated that certain barriers might exist within a given state curriculum to some ideas contained within sustainability education. For this reason, a rating of 'barrier' was created. For a standard to be rated as a barrier to attaining a given sustainability principle, it needs to contain language that directed student learning away from the concepts expressed by some its core characteristics. The language of the standard might exclude a core characteristic by developing an idea that is not compatible with it or place constraints that do not permit its interpretation in the broader context of the SP. Barriers might also result from language that introduces a bias against one or more of the core concepts contained within a SP. This can be visualized as a circle represents the core characteristics of the SP with arrows that represent the content and concepts within a standard pointing away from the circle (Figure 8) to show that they direct student understanding away from the SP.

Not related rating. A rating of “not related” was applied to standards for two reasons. First, some standards concerned topics or ideas that were entirely separate from the core characteristics of a SP and thus earned this rating. Standards related to biological evolution and the origin of the universe are examples of this condition. This can be visualized as two separate circles, one representing the content and concepts contained within a standard, and the other the core concepts of a particular SP. The circles do not intersect to show they represent distinct and separate domains of knowledge (Figure 9).

A rating of “not related” was also applied to standards that had only indirect connective relationships to a sustainability principle. Typically, these standards concerned fundamental science content broadly applicable across multiple disciplines and their inclusion as “related” would risk inflating the estimate of potential connection to SE within the frameworks. For example, a standard concerning the nature of matter, such as those related elements or atomic structure is clearly connected to nutrient flow within ecosystems, but is several times removed from more direct connections such as the water

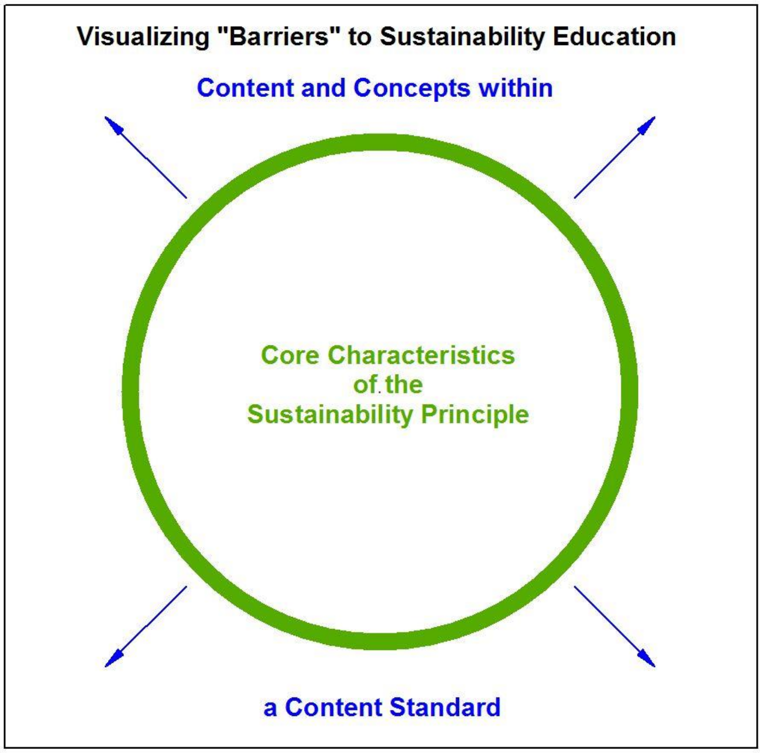


Figure 9. Visualizing the barrier rating.

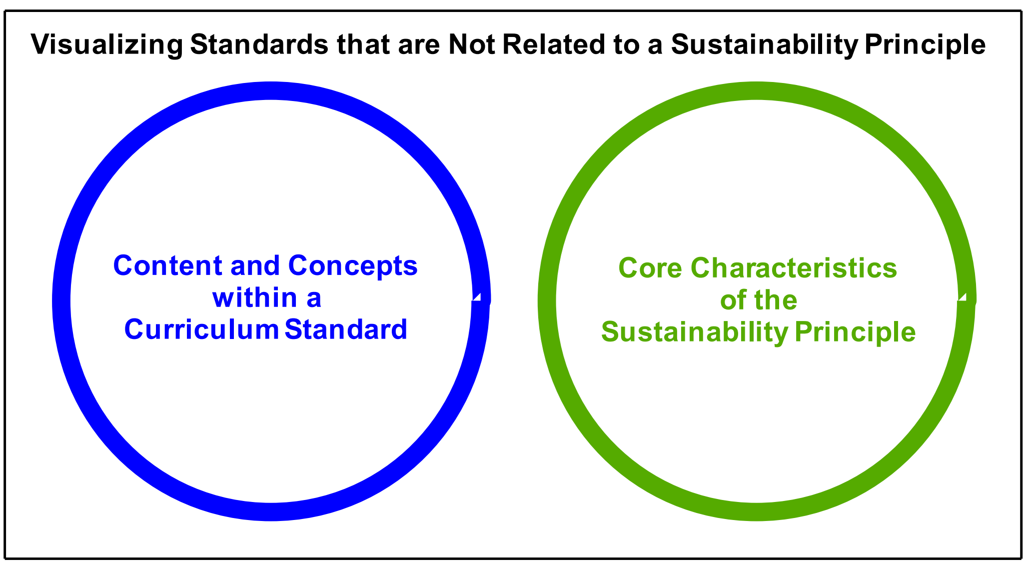


Figure 10. Visualizing the not related rating.

or carbon cycle. Topics like these apply to literally all biological, physical, and earth science because they are fundamental to understanding the structure of the universe we live in. Their inclusion as “related” would overstate the relevant connections to SE that lie within a state framework.

Rating example statements. Each SP has its own set of core characteristics and represents a distinct idea within the thematic framework of sustainability. By reading a variety of state standards, it was apparent that the various states expressed content and concepts compatible or related to the core characteristics of each principle in a variety of ways. For this reason, the “opportunity,” “related,” and “not related” categories were further clarified with ‘rating example statements’ to help illustrate the range of language that fit within a rating category. Writing the rating example statements occurred through an iterative process during reading and preliminary analysis of the first 10 state frameworks, by progressively adding new statements that captured similar ideas that were expressed in different ways. As each new rating example statement was added, back analysis of the 10 trial frameworks was completed to maintain consistency in coding. This approach was consistent with the text analysis methods described in Chapter I.

Development of coding flowcharts. In order to promote consistency of coding from state to state, coding flowcharts were developed to organize the coding criteria in a logical and consistent format that help to assure coding consistency (Figure 10). Each flowchart begins with the sustainability principle/issue and clarifying descriptions of its core concept and core characteristics that are each identified with gold labels.

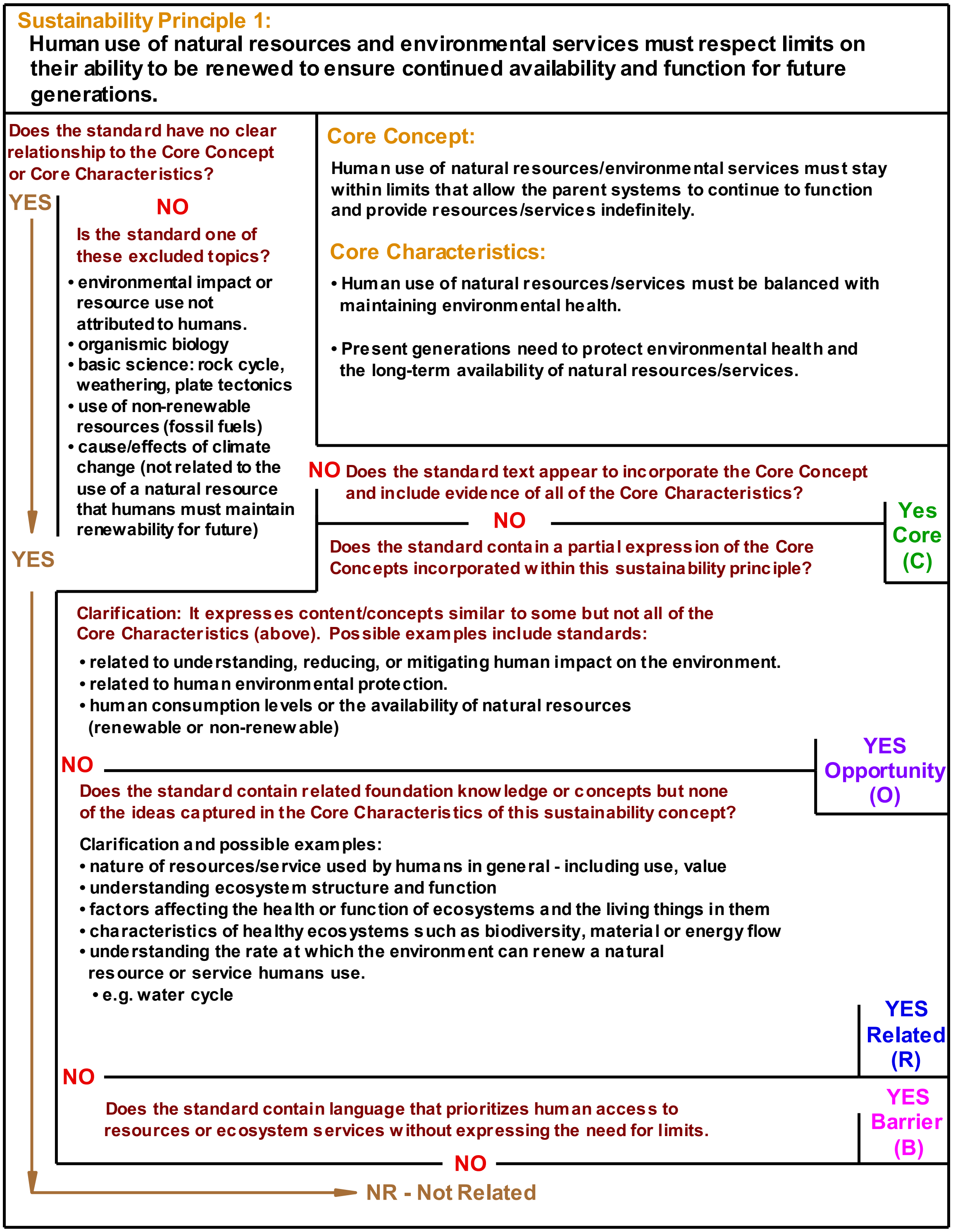


Figure 11. Sample CORBNR scale coding flowchart (by author).

The flowchart is functionally built around a series of yes or no questions identified by brown colored headers. Scoring begins at the top left corner of the flowchart with the question "Does the standard have no clear relationship to the core concept or core characteristics?" The standard is evaluated against this question with the help of the rating example statements located underneath it. Based upon a determination of either "yes" or "no" a path is determined through the flowchart that either leads to a new question (in brown) or a rating of the standard on the CORBNR scale (each assigned a different color for visual clarity). By proceeding through the flowchart, a series of logical tests are applied to each PEXE that yields a unique rating code. A set of coding flowcharts for each of the eight SPs and three SIs are in Appendix 1.

Procedures for coding PEXE's by State

This specific aim was a prerequisite step in analyzing state frameworks for support of SE. The coding scales developed in specific aim two were applied here to generate the data used for answering the research questions this project. The overarching goal of this specific aim was to develop procedures that maximized repeatability in the coding of individual PEXEs.

Individual PEXE's were first analyzed to determine whether they explicitly required teaching sustainability. A character search of all PEXEs was conducted using the root string "sustain" to identify any PEXE of interest. The PEXEs identified were then read and compared to the goals of sustainability as described by the related educational objectives that were identified as part of the attainment of Specific Aim 2.

PEXEs that contained a form of the word "sustainability" and incorporated one of these objectives were coded "yes" and all others coded "no."

Next, all Individual PEXE's were read and analyzed to determine whether they aligned with any of the goals of sustainability as described by the related educational objectives that were identified as part of the attainment of Specific Aim 2. Any PEXE that aligned with even one of these objectives was coded "yes" for implicitly inviting SE, provided it made no direct reference to sustainability or a related form of the word (these were coded as explicitly requiring SE). PEXEs that failed to align with any objective were coded "no."

After this initial pass of coding, the PEXEs were analyzed against the eight sustainability principles and three sustainability issues using scoring flowcharts based upon the five-dimension CORBNR rating scale. The rating codes were recorded on the coding spreadsheet in the column appropriate to each individual sustainability principle/issue. To maximize the consistency of PEXE analysis, all state standards were coded for SP1 using its flowchart (Appendix 1) before proceeding to SP2. The SP2 flowchart was then applied before proceeding to SP3 and so on until all SPs and SIs were coded.

Developing Statistical Analysis Tools and Methods for Coded Data

This specific aim is tied to research questions one and two:

1. How frequently is teaching sustainability either explicitly required or implicitly invited by the existing public middle school science learning standards in the United States?

2. Where content standards do not explicitly require or implicitly invite teaching sustainability, to what degree do they incorporate key concepts that are embodied within sustainability education?

Answering these questions required the development of summative statistics relevant to the coding that was completed as a part of specific aim three. The purpose of structuring coding data in a spreadsheet platform was to facilitate the application of analytical components that would develop the necessary data to answer these questions.

To build a summary picture of the level of potential support for sustainability education provided by current middle school public science frameworks in the United States, a spreadsheet analysis template was developed to tabulate summary statistics for each state (Figure 11).

The number of PEXEs in any given state framework varied from 52 (Montana) to 167 (Virginia) (Table 5). For this reason, the summary of spreadsheet codes was expressed in terms of percentages and the analysis template was designed accordingly. The percentage of occurrence for each code category (e.g. explicit requirement for SE or “core” alignment with an SP) was calculated by dividing the number of occurrences of the code category by the total number of PEXEs in the entire framework. This was done separately for the two code categories (i.e. yes or no) for the “explicitly requires” and “implicitly promotes” SE metrics and for each of five code categories (i.e. core, opportunity, related, barrier, not related) applied to each of the eight SP and three SI metrics.

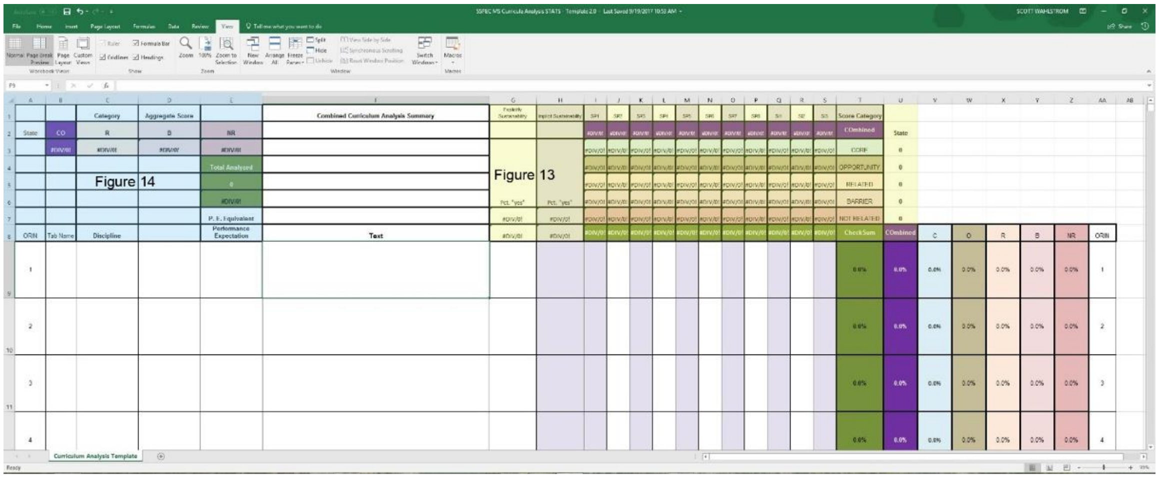


Figure 12. SSPEC MS frameworks analysis STATS template.

Table 5. Number of PEXEs by state.

Hybrid (NGSS Modified)		NGSS Adopted		State Specified	
State	Number of PEXEs	State	Number of PEXEs	State	Number of PEXEs
AL	53	AR	59	AK	95
ID	53	CA	59	AZ	167
LA	54	CT	59	CO	101
MA	72	DC	59	FL	109
MO	54	DE	59	GA	66
MT	52	HI	59	IN	58
NE	61	IA	59	ME	79
NY	62	IL	59	MN	98
OK	54	KS	59	MS	109
SD	52	KY	59	NC	64
UT	59	MD	59	ND	73
WV	67	MI	59	OH	62
WY	58	NH	59	PA	146
---	---	NJ	59	SC	121
---	---	NM	59	TN	70
---	---	NV	59	TX	127
---	---	OR	59	VA	164
---	---	RI	59	WI	63
---	---	VT	59	---	---
---	---	WA	59	---	---
Average	57.8	Average	59.0	Average	98.4

Framework origin color key: green: NGSS; blue: NGSS highbred; yellow: state specific

This is summarized as follows:

$$Percentage\ Occurance\ Rating\ \text{i" in Metric "}j\text{"}$$

$$= \frac{Number\ of\ PEXEs\ Rated\ \text{"i" in Metric "j"}}{Total\ Number\ of\ PEXEs\ in\ Framework}$$

Where: *j = Rating Metric (explicit, implicit, SP1, SP2, SP3, SP4, SP5, SP6, SP7,*
SP8, SI1, SI2, SI3)
i = Rating (yes, no, C, O, R, B, or NR)

The results were organized in tabular form in the first eight rows of columns G through T of the SSPEC MS Frameworks Analysis STATS Template (Figure 12). It should be noted that the "opportunity" (O) and "core" (C) categories were also combined into a single metric (CO) shown in the top (purple) row as a means of gauging overall support for each SP and SI. For example, for SP8, 1.7% of the standards were rated as "core," 5.1% were rated as "opportunity" and the sum of these produced a "CO" composite of 6.8%.

G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
Explicitly Sustainability	Implicit Sustainability	SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SI1	SI2	SI3	Score Category	
		5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%	COmbined	State
		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%	CORE	NGSS
		5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%	OPPORTUNITY	NGSS
		13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%	RELATED	NGSS
Pct. "yes"	Pct. "yes"	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	BARRIER	NGSS
0.0%	18.0%	81.4%	93.2%	84.7%	86.4%	74.6%	71.2%	69.5%	86.4%	84.7%	88.1%	86.4%	NOT RELATED	NGSS
		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	CheckSum	COmbined

Figure 13. Tabulated statistics, SSPEC MS frameworks STATS template.

The analysis spreadsheet was further programmed to calculate an overall level of occurrence of the "core-opportunity" (CO) composite, related (R), barrier (B), and not related (NR) categories as an average across all SPs and SIs for all the PEXE's in an entire framework as shown in Figure 13. In this instance, the CO score of 8.01 means that, for the entire NGSS framework, 8.01% of the standards scored as either "core" or "opportunity" for one or more of the SP2 or SIs. Cumulative scores for the related, barrier, and not related categories are also shown here.

	A	B	C	D	E
1			Category	Aggregate Score	
2	State	CO	R	B	NR
3	NGSS	8.01	9.40	*0.15*	82.43
4					Total Analyzed
5					59
6					100.00
7					P. E. Equivalent
8	ORIN	Tab Name	Discipline		Performance Expectation

Figure 14. Coding summary, SSPEC MS frameworks STATS template.

To assure the fidelity of the coding process, several checksums (cell E6, Figure 13, and cells I8 through S8, Figure 12) were calculated to determine whether all performance expectation equivalents were assigned a valid code for each of the eight SPs three SIs. In each case the number of valid coded responses was counted and compared against the number of coded responses that should be expected given the total number of PEXEs in the framework. Where anomalies were noted, spreadsheets were examined manually to identify missing or spurious data so that corrections could be made. In total, 43 missing or invalid coding designations were identified out of 48,139 coded responses indicating a coding error rate of 0.1%. In each case, the appropriate coding templates were subsequently used to correct the missing or incorrect data.

Finally, to address research question one, summary statistics for explicit and implicit inclusion of sustainability in the framework (columns G and H, Figure 12) were transferred from individual state analysis spreadsheets into a summary table. Likewise, to develop an answer to research question number two, the summary statistics located in columns I through S (Figure 12) from each state spreadsheet were copied onto summary tables that organized the data by state and coding category for further examination.

Assessing the Flexibility within State Frameworks for Supporting SE

Sustainability is widely regarded as an interdisciplinary field. Separation of curriculum into discrete disciplines presents potential barriers to sustainability education which optimally requires integrating concepts that cut across discipline lines. Standards that include elements which invite students to mesh scientific thinking and understanding with social, political, and economic considerations in the context of problem-solving open the door to sustainability education. Yet, even within the science context, constraining a course to a single discipline can present a barrier to this type of integrative thinking. For this reason, it is important to investigate the presence of these potential barriers in public school frameworks.

This specific aim was tied to research question three: to what degree do state science frameworks allow for integration of required science content from different domains of science into flexible presentations that best support sustainability education? The underlying assumption in this question is that SE is facilitated by integrating standards from different disciplines into thematically grouped arrangements that permit the exploration of sustainability-based concepts and topics. For this reason, it was necessary to understand how much flexibility the state granted educators, schools, or districts in the sequencing of middle school science curricula.

A spreadsheet was created for recording data related to structural and organizational characteristics relevant to question three. Each framework was read to determine whether it was organized according to one of three categories (Table 6).

Table 6. State framework organizational classifications (by author).

Category	Description
Single Discipline	The state organizes the framework so that a single scientific discipline is taught during a specific school year (i.e. earth science in grade 6, life science in grade 7). Schools are required or encouraged to adopt this organization plan.
Spiraled	The state organizes the framework by grade level so that a specific mixture of scientific disciplines and content are taught during any given year. Schools are required or encouraged to adopt this organization plan.
Flexible	The state organizes the framework by discipline or as a grade band (e.g. grades 6 to 8) but does not define a specific scope or sequence by grade level. Control over sequence in the curriculum is retained by schools.

If the state articulated its frameworks by grade levels that included only a single discipline (e.g. earth science in grade 6, life science in grade 7, etc.), it was coded as “single discipline” to indicate that the format was mandatory and that schools/districts did not have flexibility to alter this organizational scheme. Any available front matter related to the framework’s organization was also read to identify information relevant to the state’s requirements for curriculum presentation by schools and districts. If relevant language was found, it was quoted in the database.

Where a state organized the framework by grade level but included a mixture of scientific disciplines and content (i.e. a blend of earth science, life science, physical science), and the format was presented as mandatory, the framework was rated as "spiraled." Again, a search for relevant supporting language was conducted and appropriate quotes were added to the database where available.

The final category designation was "flexible." This indicated that the state organized its framework by discipline or grade band but did not specify the individual grade level at which it was to be taught. In this instance, schools and districts retain authority to sequence standards to meet their specific needs and circumstances. As before, front matter in the framework was searched for relevant language supporting this conclusion and documented where available. Also, states identified as having a "flexible" framework organization were searched to identify at least two schools or districts within the state that published sequences which differed from one another. Links to these were added to the spreadsheet database to provide further support of this designation. This data is available at https://www.sspec.org (click "data" tab, passphrase: sustainability study).

Estimating the Potential Impact on Students

This specific aim and was tied to research question number four: how many middle school students could potentially receive sustainability education within the public-school science frameworks currently established in the United States? To answer this question, it was necessary to integrate public school enrollment information with the results of the framework analysis. Further, it was apparent the alignment and overlap of individual PEXEs with the eight SPs three SIs varied widely so the results were totaled by individual SP and SI to better capture nuances in the national picture.

Public school enrollment data by grade level for the entire U.S. 2014 school year was located at the National Center for Education Statistics. State level total enrollments were available for years spanning 1990 to 2014 (National Center for Education Statistics [NCES], 2015). These data were used to estimate enrollment in the middle school grades (6 through 8) for each state in 2014. The number of students enrolled in middle school was divided by the total U.S. enrollment to determine a percentage and this was multiplied by individual state level enrollment data. This method assumes the percentage of middle school students in each state is similar to the national average (Table 7).

Table 7. Public school enrollment by State, grades 6 - 8 (NCES, 2015).

State	Middle School Enrollment (est.)	State	Middle School Enrollment (est.)	State	Middle School Enrollment (est.)
AK	29,138	KY	152,968	NY	608,900
AL	165,301	LA	159,223	OH	383,132
AR	109,048	MA	212,322	OK	152,939
AZ	246,941	MD	194,256	OR	133,571
CA	1,402,122	ME	40,532	PA	387,209
CO	197,475	MI	341,619	RI	31,533
CT	120,545	MN	190,418	SC	168,047
DC	17,983	MO	203,868	SD	29,552
DE	29,775	MS	109,048	TN	221,125
FL	612,401	MT	32,105	TX	1,162,577
GA	387,492	NC	344,056	UT	141,181
HI	40,513	ND	23,676	VA	284,411
IA	112,245	NE	69,446	VT	19,394
ID	64,614	NH	41,021	WA	238,487
IL	455,420	NJ	311,111	WI	193,571
IN	232,408	NM	75,605	WV	62,265
KS	110,460	NV	102,000	WY	20,895

A spreadsheet table was constructed with the summary data for all state frameworks from the combined (CO) category that captured the "core" and "opportunity" data together and integrated with state middle school enrollment numbers (Figure 14).

State	Enrollment (thousands)	Avg. Total CO	SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SI1	SI2	SI3
MO	135,832	8.8%	5.6%	0.0%	7.4%	9.3%	11.1%	18.5%	16.7%	7.4%	3.7%	9.3%	7.4%
TN	147,330	8.2%	12.9%	0.0%	4.3%	7.1%	14.3%	21.4%	14.3%	2.9%	4.3%	4.3%	4.3%
WY	13,922	8.2%	5.2%	0.0%	6.9%	8.6%	10.3%	17.2%	15.5%	6.9%	3.4%	8.6%	6.9%
AR	72,656	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
CA	934,200	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
CT	80,316	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
DC	11,982	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
DE	19,838	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
HI	26,993	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
IA	74,786	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
IL	303,435	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
KS	73,597	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
KY	101,919	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
MD	129,428	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
MI	227,612	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
NH	27,331	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
NJ	207,286	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
NV	67,960	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
OR	88,995	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
RI	21,010	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
VT	12,922	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
WA	158,898	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
LA	106,086	7.9%	5.6%	0.0%	5.6%	7.4%	11.1%	18.5%	14.8%	5.6%	3.7%	9.3%	5.6%
Al	110,136	7.7%	7.5%	0.0%	3.8%	5.7%	9.4%	22.6%	11.3%	5.7%	3.8%	7.5%	7.5%
NY	405,695	7.6%	4.8%	0.0%	6.5%	8.1%	9.7%	16.1%	14.5%	6.5%	3.2%	8.1%	6.5%
SD	19,690	7.5%	5.8%	0.0%	5.8%	5.8%	9.6%	21.2%	13.5%	5.8%	1.9%	5.8%	7.7%
CO	131,573	7.5%	9.9%	0.0%	1.0%	5.0%	10.9%	20.8%	11.9%	1.0%	8.9%	5.9%	6.9%
WV	41,486	7.5%	6.0%	0.0%	9.0%	10.4%	7.5%	14.9%	13.4%	9.0%	3.0%	3.0%	6.0%
ID	43,051	7.4%	5.7%	0.0%	5.7%	5.7%	9.4%	18.9%	13.2%	5.7%	1.9%	9.4%	5.7%
MT	21,391	7.3%	5.8%	1.9%	5.8%	7.7%	9.6%	17.3%	13.5%	5.8%	1.9%	3.8%	7.7%
OK	101,900	7.2%	5.6%	0.0%	5.6%	5.6%	9.3%	16.7%	13.0%	5.6%	1.9%	11.1%	5.6%
NC	229,236	7.0%	9.4%	3.1%	0.0%	7.8%	7.8%	10.9%	10.9%	4.7%	7.8%	4.7%	9.4%
UT	94,065	6.6%	5.1%	0.0%	3.4%	8.5%	6.8%	20.3%	13.6%	3.4%	3.4%	3.4%	5.1%
NE	46,270	6.6%	4.9%	0.0%	4.9%	4.9%	8.2%	16.4%	13.1%	4.9%	3.3%	4.9%	6.6%
VA	189,496	5.8%	9.8%	1.8%	2.4%	5.5%	9.1%	9.8%	9.8%	4.3%	3.7%	3.0%	4.3%
MS	72,656	5.3%	4.6%	0.9%	4.6%	3.7%	7.3%	12.8%	11.0%	2.8%	3.7%	4.6%	1.8%
MA	141,465	5.1%	2.8%	0.0%	4.2%	6.9%	4.2%	12.5%	8.3%	5.6%	2.8%	4.2%	4.2%
WI	128,972	4.8%	6.3%	0.0%	6.3%	4.8%	6.3%	7.9%	6.3%	6.3%	3.2%	0.0%	4.8%
IN	154,848	4.5%	3.4%	0.0%	0.0%	5.2%	6.9%	12.1%	6.9%	1.7%	6.9%	3.4%	3.4%
GA	258,177	4.3%	6.1%	0.0%	1.5%	6.1%	6.1%	12.1%	4.5%	1.5%	4.5%	1.5%	3.0%
AZ	164,531	3.9%	3.6%	1.8%	3.0%	3.6%	4.8%	7.2%	6.6%	4.2%	1.8%	1.8%	4.2%
ME	27,006	3.2%	6.3%	2.5%	0.0%	0.0%	2.5%	16.5%	3.8%	0.0%	1.3%	0.0%	2.5%
MN	126,871	3.1%	5.1%	1.0%	0.0%	5.1%	3.1%	8.2%	6.1%	0.0%	3.1%	2.0%	0.0%
ND	15,775	3.0%	1.4%	0.0%	1.4%	2.7%	4.1%	11.0%	8.2%	2.7%	0.0%	0.0%	1.4%
TX	774,597	2.6%	3.1%	0.0%	0.8%	2.4%	3.1%	7.9%	3.1%	1.6%	3.1%	2.4%	1.6%
SC	111,965	2.6%	2.5%	0.0%	1.7%	1.7%	3.3%	8.3%	5.0%	1.7%	2.5%	1.7%	0.8%
NM	50,374	2.4%	1.4%	0.7%	0.0%	1.4%	2.9%	6.5%	3.6%	1.4%	4.3%	2.9%	0.7%
PA	257,988	2.3%	2.1%	1.4%	0.0%	0.7%	3.4%	8.9%	4.8%	0.7%	2.7%	0.7%	0.0%
AK	19,414	2.0%	1.1%	0.0%	3.2%	5.3%	1.1%	7.4%	2.1%	1.1%	0.0%	0.0%	1.1%
OH	255,272	1.8%	0.0%	0.0%	0.0%	1.6%	1.6%	9.7%	3.2%	0.0%	1.6%	1.6%	0.0%
FL	408,028	1.8%	0.9%	0.0%	1.8%	0.9%	1.8%	6.4%	3.7%	0.0%	0.9%	1.8%	0.9%
Population Weighted Average		5.9%	4.8%	0.3%	4.0%	5.9%	7.5%	13.7%	10.5%	4.3%	3.4%	5.4%	4.7%

Figure 15. Summary spreadsheet of average State support for SE.

The format of this tool was designed to facilitate using data enrollment and CO levels to understand nuance in the "national picture" of support for SE. State data were color coded to represent NGSS states (green), NGSS hybrids (blue), and states that wrote their own frameworks with no apparent connection to the NGSS (yellow). Weighted averages were calculated for each individual SP and SI as well as a population weighted composite score which averaged all SPs and SIs together on an equal basis. Mathematical methods for accomplishing this are described in the Discussion chapter.

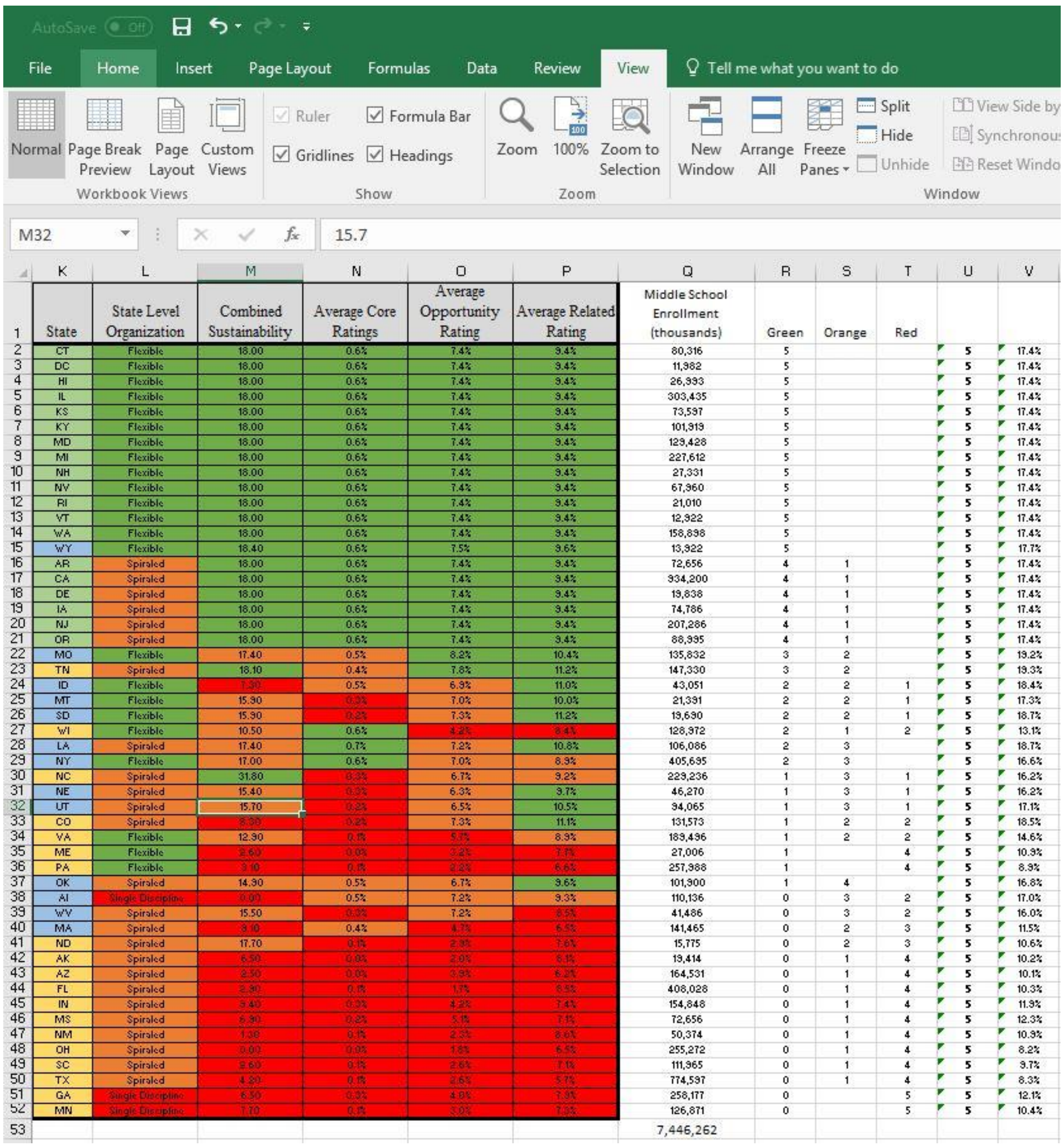
Comparing the Potential for SE between the States

This specific aim seeks to develop a system for "ranking different aspects of support for sustainability education within state frameworks" leading to an "overall assessment that permits comparison between states." The investigation developed three separate lines of evidence that are relevant to this objective. First, examining standards for evidence that sustainability was either explicitly required or implicitly invited by the PEXE's in use by the various states. Second, an assessment of individual PEXE's against the eight SPs and three SIs using the five-dimension CORBNR rating scale. Third, an assessment of whether the state framework organization was flexible and permitted local control over curricular sequencing, or the grade level sequence was specified with control retained by the state. Integrating these three elements into a single measure is the goal of this aim.

Ranking different measures of support for SE into tertiles. To attain this aim, a table was developed on a spreadsheet platform to permit sorting and related calculation. First, the overall percentage of occurrence for the "core," "opportunity," and "related" ratings of the CORBNR were calculated for each state and sorted from highest to lowest, with high representing the condition most favorable for SE and low representing the conditional least favorable. Cohorts were formed by counting the top one third (17) states and coloring the data cells green. The bottom one third were colored red, and the middle third colored orange. In cases where the 17-state cutoff landed on a value that was shared by states beyond the cutoff point, all states with the same value were included in the red or green cohort. For this reason, the middle third group (orange) captured the remaining values and was generally not a full third of the entire population of values.

A similar approach was used for coding the occurrence of standards explicitly requiring or implicitly inviting SE in the curriculum. The two values were combined into a single total and again sorted from highest to lowest. The same color coding scheme was used here as well. Finally, state level organization of the framework was coded with flexible assigned green to indicate that this permitted an individual school or district to arrange curriculum according to local judgment. Next, spiraled was coded orange to indicate the framework was in a format that mixed different disciplines into a single year but that it was specified by the state. And finally, single discipline was coded red to indicate that the state required the delivery of a single science discipline in a specific year with no integration. These cohort color designations were chosen to reflect the presumed relative support to SE that each would offer (green = most support, red = least).

Developing an overall ranking tool. This produced five columns of information relevant to determining a state's overall level of potential support for sustainability education that were color-coded using green to represent the highest tertile of potential support, red to indicate the lowest tertile of support, and orange to indicate the intermediate tertile. These were integrated into a single table that was then sorted to produce a gradient that placed the states with all five of the data categories coded green at the top of the list, transitioning to states with all five of the data categories coded red at the bottom. The two letter state abbreviations were coded (as with other tables) for the origin of the framework with green indicating an NGSS state, yellow indicating an independent state framework, and blue indicating a state publishing a hybrid version of the NGSS (Figure 15).



	K	L	M	N	O	P	Q	R	S	T	U	V
1	State	State Level Organization	Combined Sustainability	Average Core Ratings	Average Opportunity Rating	Average Related Rating	Middle School Enrollment (thousands)	Green	Orange	Red		
2	CT	Flexible	18.00	0.6%	7.4%	9.4%	80,316	5			5	17.4%
3	DC	Flexible	18.00	0.6%	7.4%	9.4%	11,982	5			5	17.4%
4	HI	Flexible	18.00	0.6%	7.4%	9.4%	26,993	5			5	17.4%
5	IL	Flexible	18.00	0.6%	7.4%	9.4%	303,435	5			5	17.4%
6	KS	Flexible	18.00	0.6%	7.4%	9.4%	73,597	5			5	17.4%
7	KY	Flexible	18.00	0.6%	7.4%	9.4%	101,919	5			5	17.4%
8	MD	Flexible	18.00	0.6%	7.4%	9.4%	129,428	5			5	17.4%
9	MI	Flexible	18.00	0.6%	7.4%	9.4%	227,612	5			5	17.4%
10	NH	Flexible	18.00	0.6%	7.4%	9.4%	27,331	5			5	17.4%
11	NV	Flexible	18.00	0.6%	7.4%	9.4%	67,960	5			5	17.4%
12	RI	Flexible	18.00	0.6%	7.4%	9.4%	21,010	5			5	17.4%
13	VT	Flexible	18.00	0.6%	7.4%	9.4%	12,922	5			5	17.4%
14	WA	Flexible	18.00	0.6%	7.4%	9.4%	158,898	5			5	17.4%
15	WY	Flexible	18.40	0.6%	7.5%	9.6%	13,922	5			5	17.7%
16	AR	Spiraled	18.00	0.6%	7.4%	9.4%	72,656	4	1		5	17.4%
17	CA	Spiraled	18.00	0.6%	7.4%	9.4%	934,200	4	1		5	17.4%
18	DE	Spiraled	18.00	0.6%	7.4%	9.4%	19,838	4	1		5	17.4%
19	IA	Spiraled	18.00	0.6%	7.4%	9.4%	74,786	4	1		5	17.4%
20	NJ	Spiraled	18.00	0.6%	7.4%	9.4%	207,286	4	1		5	17.4%
21	OR	Spiraled	18.00	0.6%	7.4%	9.4%	88,995	4	1		5	17.4%
22	MO	Flexible	17.40	0.5%	8.2%	10.4%	135,832	3	2		5	19.2%
23	TN	Spiraled	18.10	0.4%	7.8%	11.2%	147,330	3	2		5	19.3%
24	ID	Flexible	7.30	0.5%	6.9%	11.0%	43,051	2	2	1	5	18.4%
25	MT	Flexible	15.90	0.3%	7.0%	10.0%	21,391	2	2	1	5	17.3%
26	SD	Flexible	15.90	0.2%	7.3%	11.2%	19,690	2	2	1	5	18.7%
27	WI	Flexible	10.50	0.6%	4.2%	8.4%	128,972	2	1	2	5	13.1%
28	LA	Spiraled	17.40	0.7%	7.2%	10.8%	106,086	2	3		5	18.7%
29	NY	Flexible	17.00	0.6%	7.0%	8.9%	405,695	2	3		5	16.6%
30	NC	Spiraled	31.80	0.3%	6.7%	9.2%	229,236	1	3	1	5	16.2%
31	NE	Spiraled	15.40	0.3%	6.3%	9.7%	46,270	1	3	1	5	16.2%
32	UT	Spiraled	15.70	0.2%	6.5%	10.5%	94,065	1	3	1	5	17.1%
33	CO	Spiraled	8.30	0.2%	7.3%	11.1%	131,573	1	2	2	5	18.5%
34	VA	Flexible	12.90	0.1%	5.7%	8.9%	189,496	1	2	2	5	14.6%
35	ME	Flexible	2.60	0.0%	3.2%	7.7%	27,006	1		4	5	10.9%
36	PA	Flexible	3.10	0.1%	2.2%	6.6%	257,988	1		4	5	8.9%
37	OK	Spiraled	14.90	0.5%	6.7%	9.6%	101,900	1	4		5	16.8%
38	AI	Single Discipline	0.00	0.5%	7.2%	9.3%	110,136	0	3	2	5	17.0%
39	WV	Spiraled	15.50	0.3%	7.2%	8.5%	41,486	0	3	2	5	16.0%
40	MA	Spiraled	3.10	0.4%	4.7%	6.5%	141,465	0	2	3	5	11.5%
41	ND	Spiraled	17.70	0.1%	2.9%	7.6%	15,775	0	2	3	5	10.6%
42	AK	Spiraled	6.50	0.0%	2.0%	6.1%	19,414	0	1	4	5	10.2%
43	AZ	Spiraled	2.50	0.0%	3.9%	6.2%	164,531	0	1	4	5	10.1%
44	FL	Spiraled	2.90	0.1%	1.7%	6.5%	408,028	0	1	4	5	10.3%
45	IN	Spiraled	5.40	0.3%	4.2%	7.4%	154,848	0	1	4	5	11.9%
46	MS	Spiraled	6.90	0.2%	5.1%	7.1%	72,656	0	1	4	5	12.3%
47	NM	Spiraled	1.30	0.1%	2.3%	8.6%	50,374	0	1	4	5	10.9%
48	OH	Spiraled	0.00	0.0%	1.8%	6.5%	255,272	0	1	4	5	8.2%
49	SC	Spiraled	9.60	0.1%	2.6%	7.1%	111,965	0	1	4	5	9.7%
50	TX	Spiraled	4.20	0.1%	2.6%	5.7%	774,597	0	1	4	5	8.3%
51	GA	Single Discipline	6.50	0.3%	4.8%	7.3%	258,177	0		5	5	12.1%
52	MN	Single Discipline	7.70	0.1%	3.0%	7.3%	126,871	0		5	5	10.4%
53							7,446,262					

Figure 16. Spreadsheet design for sorting State support for SE into Tertiles.

Chapter III

Results

This investigation focused upon four research questions (Table 8) and examined the middle school science frameworks of all 50 states plus the District of Columbia including the reading and evaluation of over 49,000 performance expectation equivalents (PEXE's).

Table 8. Research questions.

Number	Research Question
1	How frequently is teaching sustainability either explicitly required or implicitly invited by the existing public middle school science learning standards in the United States?
2	Where content standards do not explicitly require or implicitly invite teaching sustainability, to what degree do they incorporate key concepts that are embodied within sustainability education?
3	To what degree do state science frameworks allow for integration of required science content from different domains of science into flexible presentations that best support sustainability education?
4	How many middle school students could potentially receive sustainability education within the public-school science frameworks established in the United States?

Each framework was examined to determine its overall structure and any state level constraints placed upon its organization and delivery. Further, each individual PEXE was read and coded with respect to whether it explicitly required or implicitly invited teaching sustainability and its alignment with eight sustainability principles (SPs) and three sustainability issues (SIs) on the five-dimension CORBNR rating scale. The data thus gathered was organized in a series of state specific spreadsheets that were developed to capture the coding information and permit statistical analysis. The raw data is available for viewing at https://www.sspec.org (click "data" tab, passphrase: sustainability study).

Standards Explicitly Requiring Sustainability Education

First, I present results on the rate of occurrence of PEXEs that explicitly required the teaching of sustainability. Only four states included standards that explicitly required teaching of sustainability (Table 9). Notably, these were all state frameworks that had no connection to the Next Generation Science Standards (NGSS) which was found to make no explicit mention of sustainability in the PEXE's at the middle school level.

Table 9. States explicitly requiring sustainability education.

State	Percent of Standards Explicitly Requiring some Element of Sustainability Education
Maine	2.6%
North Carolina	1.6%
Tennessee	1.4%
Texas	0.8%
DC & All Other States	0.0%

Standards Implicitly Inviting Sustainability Education

It was anticipated that some PEXEs might invite teaching sustainability implicitly without the explicit mention of the term. For this reason, data were collected on the percentage of standards that implicitly invite SE for all 50 states plus the District of

Columbia (Table 10). The results show substantial variation between the 50 states and the District of Columbia with a low of 0.0% (Alabama, Ohio, and Maine) ranging to a high of 15.5% (Wyoming). NGSS states were found to rate at 15.3% of standards implicitly inviting sustainability education (SE) with just one state (Wyoming) scoring higher.

Table 10. Percentage of PEXEs implicitly inviting SE by State.

State	Standards Implicitly Inviting Sustainability Education	State	Standards Implicitly Inviting Sustainability Education	State	Standards Implicitly Inviting Sustainability Education
AK	4.2%	KY	15.3%	NY	14.5%
AL	9.4%	LA	14.8%	OH	0.0%
AR	15.3%	MA	8.3%	OK	13.0%
AZ	4.8%	MD	15.3%	OR	15.3%
CA	15.3%	ME	0.0%	PA	5.5%
CO	12.9%	MI	15.3%	RI	15.3%
CT	15.3%	MN	7.1%	SC	3.3%
DC	15.3%	MO	14.8%	SD	13.5%
DE	15.3%	MS	11.0%	TN	14.3%
FL	2.8%	MT	13.5%	TX	3.9%
GA	6.1%	NC	12.5%	UT	13.6%
HI	15.3%	ND	15.1%	VA	9.8%
IA	15.3%	NE	13.1%	VT	15.3%
ID	13.2%	NH	15.3%	WA	15.3%
IL	15.3%	NJ	15.3%	WI	9.5%
IN	8.6%	NM	15.3%	WV	13.4%
KS	15.3%	NV	15.3%	WY	15.5%

Framework origin color key: green: NGSS; blue: NGSS highbred; yellow: state specific

Ratings of Individual Standards on CORBNR Scale

The next element of the investigation was to rate individual PEXEs on the CORBNR rating scale. Data were collated and averaged by state to produce tables showing overall rating levels for "core" (Table 11), "opportunity" (Table 12), "related"

(Table 13), “barrier” (Table 14), and “not related” (Table 15) ratings across all eight SPs and three SIs. Table 11 presents overall results for PXE’s there were rated as core for each of the individual SPs and SIs on a state-by-state basis. Notably, there is almost no core support for any SP except for number eight. Similarly, Table 12 presents the average results for all SP’s and SIs that were rated as “opportunity”, also listed by state. These results show a much greater degree of overall support, with relative strength noted for SPs 5, 6, and 7, but a near absence of any support for SP 2.

Table 13 organizes data for PEXEs rated “related” in a similar manner. Here, much broader overlap is noted since a PEXE need not align with the SP or SI, but must only require attainment of content, knowledge, or skills that may be useful for developing it. This is followed by Table 14 which presents data for PEXE’s rated as “barrier.” It is apparent here that very few barriers were noted in the language of PEXEs; only SP4 showed any evidence at all and only at very low levels. Finally, Table 15 presents the state by state average for PEXEs judged “not related” to each SP or SI. In each of these tables, state names are color coded to indicate the origin of their framework.

Table 11. Overall average core alignment of PEXEs with SPs and SIs.

State	SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SI1	SI2	SI3
AK	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Al	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%	1.9%	0.0%	1.9%
AR	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%
AZ	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%
CO	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	0.0%	0.0%
CT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%
DC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%
DE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%
FL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.9%	0.0%
GA	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.5%	0.0%	0.0%
HI	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%
IA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%
ID	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%	0.0%	1.9%	1.9%
IL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%
IN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	0.0%
KS	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%
KY	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%
LA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%	1.9%	1.9%	1.9%
MA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.4%	1.4%	0.0%	1.4%
MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%
ME	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
MI	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%
MN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	0.0%
MO	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%	1.9%	0.0%	1.9%
MS	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.9%	0.0%	0.0%	0.0%	0.9%
MT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%	0.0%	1.9%
NC	1.6%	0.0%	0.0%	0.0%	4.7%	0.0%	0.0%	0.0%	0.0%	1.6%	0.0%
ND	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.4%
NE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.6%	0.0%	1.6%
NH	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%
NJ	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%
NM	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%
NV	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%
NY	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.6%	1.6%	1.6%	1.6%
OH	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
OK	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%	0.0%	1.9%	1.9%
OR	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%
PA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%	0.0%
RI	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%
SC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%	0.0%
SD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%
TN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.4%	1.4%	1.4%	0.0%
TX	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%	0.0%
UT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%
VA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.6%	0.0%	0.6%	0.0%
VT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%
WA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%
WI	1.6%	0.0%	1.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.2%
WV	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.5%	0.0%	1.5%
WY	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%

Framework origin color key: green: NGSS; blue: NGSS highbred; yellow: state specific

Table 12. Overall average opportunity alignment of PEXEs with SPs and SIs.

State	SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SI1	SI2	SI3
AK	1.1%	0.0%	3.2%	5.3%	1.1%	7.4%	2.1%	1.1%	0.0%	0.0%	1.1%
Al	7.5%	0.0%	3.8%	5.7%	9.4%	22.6%	11.3%	3.8%	1.9%	7.5%	5.7%
AR	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%
AZ	3.6%	1.8%	3.0%	3.6%	4.8%	7.2%	6.6%	4.2%	1.8%	1.8%	4.2%
CA	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%
CO	9.9%	0.0%	1.0%	5.0%	10.9%	20.8%	11.9%	1.0%	6.9%	5.9%	6.9%
CT	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%
DC	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%
DE	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%
FL	0.9%	0.0%	1.8%	0.9%	1.8%	6.4%	3.7%	0.0%	0.9%	0.9%	0.9%
GA	4.5%	0.0%	1.5%	6.1%	6.1%	12.1%	4.5%	1.5%	3.0%	1.5%	3.0%
HI	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%
IA	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%
ID	5.7%	0.0%	5.7%	5.7%	9.4%	18.9%	13.2%	3.8%	1.9%	7.5%	3.8%
IL	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%
IN	3.4%	0.0%	0.0%	5.2%	6.9%	12.1%	6.9%	1.7%	5.2%	1.7%	3.4%
KS	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%
KY	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%
LA	5.6%	0.0%	5.6%	7.4%	11.1%	18.5%	14.8%	3.7%	1.9%	7.4%	3.7%
MA	2.8%	0.0%	4.2%	6.9%	4.2%	12.5%	8.3%	4.2%	1.4%	4.2%	2.8%
MD	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%
ME	6.3%	2.5%	0.0%	0.0%	2.5%	16.5%	3.8%	0.0%	1.3%	0.0%	2.5%
MI	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%
MN	5.1%	1.0%	0.0%	5.1%	3.1%	8.2%	6.1%	0.0%	3.1%	1.0%	0.0%
MO	5.6%	0.0%	7.4%	9.3%	11.1%	18.5%	16.7%	5.6%	1.9%	9.3%	5.6%
MS	4.6%	0.9%	4.6%	3.7%	7.3%	12.8%	10.1%	2.8%	3.7%	4.6%	0.9%
MT	5.8%	1.9%	5.8%	7.7%	9.6%	17.3%	13.5%	5.8%	0.0%	3.8%	5.8%
NC	7.8%	3.1%	0.0%	7.8%	3.1%	10.9%	10.9%	4.7%	7.8%	3.1%	9.4%
ND	1.4%	0.0%	1.4%	2.7%	4.1%	11.0%	8.2%	2.7%	0.0%	0.0%	0.0%
NE	4.9%	0.0%	4.9%	4.9%	8.2%	16.4%	13.1%	4.9%	1.6%	4.9%	4.9%
NH	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%
NJ	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%
NM	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%
NV	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%
NY	4.8%	0.0%	6.5%	8.1%	9.7%	16.1%	14.5%	4.8%	1.6%	6.5%	4.8%
OH	0.0%	0.0%	0.0%	1.6%	1.6%	9.7%	3.2%	0.0%	1.6%	1.6%	0.0%
OK	5.6%	0.0%	5.6%	5.6%	9.3%	16.7%	13.0%	3.7%	1.9%	9.3%	3.7%
OR	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%
PA	2.1%	1.4%	0.0%	0.7%	3.4%	8.9%	4.8%	0.7%	2.7%	0.0%	0.0%
RI	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%
SC	2.5%	0.0%	1.7%	1.7%	3.3%	8.3%	5.0%	1.7%	2.5%	0.8%	0.8%
SD	5.8%	0.0%	5.8%	5.8%	9.6%	21.2%	13.5%	5.8%	1.9%	5.8%	5.8%
TN	12.9%	0.0%	4.3%	7.1%	14.3%	21.4%	14.3%	1.4%	2.9%	2.9%	4.3%
TX	3.1%	0.0%	0.8%	2.4%	3.1%	7.9%	3.1%	1.6%	3.1%	1.6%	1.6%
UT	5.1%	0.0%	3.4%	8.5%	6.8%	20.3%	13.6%	1.7%	3.4%	3.4%	5.1%
VA	9.8%	1.8%	2.4%	5.5%	9.1%	9.8%	9.8%	3.7%	3.7%	2.4%	4.3%
VT	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%
WA	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%
WI	4.8%	0.0%	4.8%	4.8%	6.3%	7.9%	6.3%	6.3%	3.2%	0.0%	1.6%
WV	6.0%	0.0%	9.0%	10.4%	7.5%	14.9%	13.4%	9.0%	1.5%	3.0%	4.5%
WY	5.2%	0.0%	6.9%	8.6%	10.3%	17.2%	15.5%	5.2%	1.7%	6.9%	5.2%

Framework origin color key: green: NGSS; blue: NGSS highbred; yellow: state specific

Table 13. Overall average related alignment of PEXEs with SPs and SIs.

State	SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SI1	SI2	SI3
AK	10.5%	1.1%	1.1%	17.9%	17.9%	14.7%	18.9%	4.2%	0.0%	3.2%	0.0%
Al	7.5%	3.8%	9.4%	3.8%	17.0%	13.2%	18.9%	9.4%	9.4%	3.8%	5.7%
AR	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
AZ	6.6%	3.0%	2.4%	15.6%	12.0%	8.4%	7.8%	2.4%	3.6%	4.2%	2.4%
CA	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
CO	9.9%	6.9%	9.9%	5.9%	21.8%	10.9%	22.8%	9.9%	6.9%	8.9%	7.9%
CT	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
DC	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
DE	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
FL	5.5%	0.9%	1.8%	28.4%	13.8%	11.9%	15.6%	4.6%	8.3%	1.8%	0.9%
GA	4.5%	6.1%	6.1%	1.5%	21.2%	12.1%	15.2%	4.5%	7.6%	4.5%	3.0%
HI	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
IA	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
ID	17.0%	5.7%	7.5%	3.8%	18.9%	15.1%	18.9%	9.4%	13.2%	3.8%	7.5%
IL	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
IN	10.3%	1.7%	12.1%	5.2%	12.1%	10.3%	12.1%	10.3%	1.7%	0.0%	5.2%
KS	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
KY	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
LA	14.8%	7.4%	9.3%	3.7%	16.7%	16.7%	16.7%	7.4%	14.8%	3.7%	7.4%
MA	8.3%	4.2%	5.6%	1.4%	13.9%	6.9%	13.9%	5.6%	5.6%	2.8%	2.8%
MD	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
ME	8.9%	1.3%	3.8%	16.5%	15.2%	6.3%	16.5%	3.8%	6.3%	5.1%	1.3%
MI	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
MN	8.2%	1.0%	2.0%	11.2%	16.3%	10.2%	16.3%	4.1%	5.1%	3.1%	3.1%
MO	14.8%	7.4%	9.3%	3.7%	14.8%	16.7%	16.7%	7.4%	13.0%	3.7%	7.4%
MS	9.2%	3.7%	6.4%	3.7%	16.5%	8.3%	14.7%	4.6%	6.4%	2.8%	1.8%
MT	11.5%	5.8%	9.6%	3.8%	17.3%	13.5%	15.4%	7.7%	13.5%	7.7%	3.8%
NC	12.5%	4.7%	9.4%	3.1%	21.9%	12.5%	20.3%	7.8%	1.6%	4.7%	3.1%
ND	4.1%	2.7%	2.7%	15.1%	11.0%	4.1%	20.5%	8.2%	9.6%	4.1%	1.4%
NE	11.5%	6.6%	9.8%	4.9%	16.4%	11.5%	14.8%	6.6%	13.1%	6.6%	4.9%
NH	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
NJ	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
NM	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
NV	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
NY	12.9%	6.5%	8.1%	3.2%	14.5%	11.3%	14.5%	6.5%	11.3%	3.2%	6.5%
OH	11.3%	1.6%	1.6%	0.0%	19.4%	12.9%	14.5%	1.6%	3.2%	3.2%	1.6%
OK	14.8%	5.6%	7.4%	3.7%	16.7%	14.8%	16.7%	5.6%	11.1%	1.9%	7.4%
OR	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
PA	4.1%	4.1%	5.5%	13.7%	8.9%	2.7%	12.3%	8.9%	6.2%	2.1%	4.1%
RI	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
SC	6.6%	0.8%	3.3%	23.1%	11.6%	6.6%	14.0%	2.5%	5.0%	0.8%	3.3%
SD	13.5%	7.7%	9.6%	5.8%	21.2%	11.5%	19.2%	7.7%	13.5%	7.7%	5.8%
TN	11.4%	5.7%	8.6%	2.9%	21.4%	14.3%	21.4%	11.4%	11.4%	7.1%	7.1%
TX	7.1%	2.4%	2.4%	16.5%	10.2%	7.9%	10.2%	1.6%	1.6%	0.0%	2.4%
UT	13.6%	6.8%	10.2%	3.4%	20.3%	8.5%	18.6%	8.5%	11.9%	6.8%	6.8%
VA	10.4%	4.3%	7.3%	19.5%	13.4%	9.8%	13.4%	5.5%	4.9%	4.9%	4.3%
VT	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
WA	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
WI	4.8%	1.6%	1.6%	38.1%	9.5%	4.8%	15.9%	1.6%	6.3%	6.3%	1.6%
WV	11.9%	7.5%	7.5%	3.0%	14.9%	7.5%	14.9%	6.0%	9.0%	7.5%	4.5%
WY	13.8%	6.9%	8.6%	3.4%	15.5%	12.1%	15.5%	6.9%	12.1%	3.4%	6.9%

Framework origin color key: green: NGSS; blue: NGSS highbred; yellow: state specific

Table 14. Overall average barriers to SPs and SIs in PEXEs.

State	SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SI1	SI2	SI3
AK	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Al	0.0%	0.0%	0.0%	1.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AR	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
AZ	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.6%	0.0%
CA	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CO	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CT	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
DC	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
DE	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
FL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
GA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
HI	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
IA	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ID	0.0%	0.0%	0.0%	1.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
IL	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
IN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
KS	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
KY	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
LA	0.0%	0.0%	0.0%	1.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
MA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
MD	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ME	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
MI	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
MN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
MO	0.0%	0.0%	0.0%	1.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
MS	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.8%	0.0%	0.0%
MT	0.0%	0.0%	0.0%	1.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
NC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
ND	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
NE	0.0%	0.0%	0.0%	1.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
NH	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
NJ	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
NM	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
NV	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
NY	0.0%	0.0%	0.0%	1.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
OH	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
OK	0.0%	0.0%	0.0%	1.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
OR	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
RI	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SD	0.0%	0.0%	0.0%	1.9%	0.0%	0.0%	0.0%	0.0%	1.9%	0.0%	0.0%
TN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TX	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
UT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
VA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
VT	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
WA	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
WI	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
WV	0.0%	0.0%	0.0%	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
WY	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Framework origin color key: green: NGSS; blue: NGSS highbred; yellow: state specific

Table 15. Overall average of PEXEs not related to SPs and SIs.

State	SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SI1	SI2	SI3
AK	88.4%	98.9%	95.8%	76.8%	81.1%	77.9%	78.9%	94.7%	100.0%	96.8%	98.9%
Al	84.9%	94.3%	86.8%	88.7%	73.6%	64.2%	69.8%	84.9%	86.8%	88.7%	86.8%
AR	81.4%	93.2%	84.7%	86.4%	74.6%	71.2%	69.5%	86.4%	84.7%	88.1%	86.4%
AZ	89.8%	95.2%	94.6%	80.8%	83.2%	84.4%	85.6%	93.4%	94.6%	93.4%	93.4%
CA	81.4%	93.2%	84.7%	86.4%	74.6%	71.2%	69.5%	86.4%	84.7%	88.1%	86.4%
CO	80.2%	93.1%	89.1%	89.1%	67.3%	68.3%	65.3%	89.1%	84.2%	85.1%	85.1%
CT	81.4%	93.2%	84.7%	86.4%	74.6%	71.2%	69.5%	86.4%	84.7%	88.1%	86.4%
DC	81.4%	93.2%	84.7%	86.4%	74.6%	71.2%	69.5%	86.4%	84.7%	88.1%	86.4%
DE	81.4%	93.2%	84.7%	86.4%	74.6%	71.2%	69.5%	86.4%	84.7%	88.1%	86.4%
FL	93.6%	99.1%	96.3%	70.6%	84.4%	81.7%	80.7%	95.4%	90.8%	96.3%	98.2%
GA	89.4%	93.9%	92.4%	92.4%	72.7%	75.8%	80.3%	93.9%	87.9%	93.9%	93.9%
HI	81.4%	93.2%	84.7%	86.4%	74.6%	71.2%	69.5%	86.4%	84.7%	88.1%	86.4%
IA	81.4%	93.2%	84.7%	86.4%	74.6%	71.2%	69.5%	86.4%	84.7%	88.1%	86.4%
ID	77.4%	94.3%	86.8%	88.7%	71.7%	66.0%	67.9%	84.9%	84.9%	86.8%	86.8%
IL	81.4%	93.2%	84.7%	86.4%	74.6%	71.2%	69.5%	86.4%	84.7%	88.1%	86.4%
IN	86.2%	98.3%	87.9%	89.7%	81.0%	77.6%	81.0%	87.9%	91.4%	96.6%	91.4%
KS	81.4%	93.2%	84.7%	86.4%	74.6%	71.2%	69.5%	86.4%	84.7%	88.1%	86.4%
KY	81.4%	93.2%	84.7%	86.4%	74.6%	71.2%	69.5%	86.4%	84.7%	88.1%	86.4%
LA	79.6%	92.6%	85.2%	87.0%	72.2%	64.8%	68.5%	87.0%	81.5%	87.0%	87.0%
MA	88.9%	95.8%	90.3%	91.7%	81.9%	80.6%	77.8%	88.9%	91.7%	93.1%	93.1%
MD	81.4%	93.2%	84.7%	86.4%	74.6%	71.2%	69.5%	86.4%	84.7%	88.1%	86.4%
ME	84.8%	96.2%	96.2%	83.5%	82.3%	77.2%	79.7%	96.2%	92.4%	94.9%	96.2%
MI	81.4%	93.2%	84.7%	86.4%	74.6%	71.2%	69.5%	86.4%	84.7%	88.1%	86.4%
MN	86.7%	98.0%	98.0%	83.7%	80.6%	81.6%	77.6%	95.9%	91.8%	94.9%	96.9%
MO	79.6%	92.6%	83.3%	85.2%	74.1%	64.8%	66.7%	85.2%	83.3%	87.0%	85.2%
MS	86.2%	95.4%	89.0%	92.7%	76.1%	78.9%	74.3%	92.7%	88.1%	92.7%	96.3%
MT	82.7%	92.3%	84.6%	86.5%	73.1%	69.2%	71.2%	86.5%	84.6%	88.5%	88.5%
NC	78.1%	92.2%	90.6%	89.1%	70.3%	76.6%	68.8%	87.5%	90.6%	90.6%	87.5%
ND	94.5%	97.3%	95.9%	82.2%	84.9%	84.9%	71.2%	89.0%	90.4%	95.9%	97.3%
NE	83.6%	93.4%	85.2%	88.5%	75.4%	72.1%	72.1%	88.5%	83.6%	88.5%	88.5%
NH	81.4%	93.2%	84.7%	86.4%	74.6%	71.2%	69.5%	86.4%	84.7%	88.1%	86.4%
NJ	81.4%	93.2%	84.7%	86.4%	74.6%	71.2%	69.5%	86.4%	84.7%	88.1%	86.4%
NM	81.4%	93.2%	84.7%	86.4%	74.6%	71.2%	69.5%	86.4%	84.7%	88.1%	86.4%
NV	81.4%	93.2%	84.7%	86.4%	74.6%	71.2%	69.5%	86.4%	84.7%	88.1%	86.4%
NY	82.3%	93.5%	85.5%	87.1%	75.8%	72.6%	71.0%	87.1%	85.5%	88.7%	87.1%
OH	88.7%	98.4%	98.4%	98.4%	79.0%	77.4%	82.3%	98.4%	95.2%	95.2%	98.4%
OK	79.6%	94.4%	87.0%	88.9%	74.1%	68.5%	70.4%	88.9%	87.0%	87.0%	87.0%
OR	81.4%	93.2%	84.7%	86.4%	74.6%	71.2%	69.5%	86.4%	84.7%	88.1%	86.4%
PA	93.8%	94.5%	94.5%	85.6%	87.7%	88.4%	82.9%	90.4%	91.1%	97.3%	95.9%
RI	81.4%	93.2%	84.7%	86.4%	74.6%	71.2%	69.5%	86.4%	84.7%	88.1%	86.4%
SC	90.9%	99.2%	95.0%	75.2%	85.1%	85.1%	81.0%	95.9%	92.6%	97.5%	95.9%
SD	80.8%	92.3%	84.6%	86.5%	69.2%	67.3%	67.3%	86.5%	82.7%	86.5%	86.5%
TN	75.7%	94.3%	87.1%	90.0%	64.3%	64.3%	64.3%	85.7%	84.3%	88.6%	88.6%
TX	89.8%	97.6%	96.9%	81.1%	86.6%	84.3%	86.6%	96.9%	95.3%	97.6%	96.1%
UT	81.4%	93.2%	86.4%	88.1%	72.9%	71.2%	67.8%	88.1%	84.7%	89.8%	88.1%
VA	79.9%	93.9%	90.2%	75.0%	77.4%	80.5%	76.8%	90.2%	91.5%	92.1%	91.5%
VT	81.4%	93.2%	84.7%	86.4%	74.6%	71.2%	69.5%	86.4%	84.7%	88.1%	86.4%
WA	81.4%	93.2%	84.7%	86.4%	74.6%	71.2%	69.5%	86.4%	84.7%	88.1%	86.4%
WI	88.9%	98.4%	92.1%	57.1%	84.1%	87.3%	77.8%	92.1%	90.5%	93.7%	93.7%
WV	82.1%	92.5%	83.6%	85.1%	77.6%	77.6%	71.6%	85.1%	88.1%	89.6%	89.6%
WY	81.0%	93.1%	84.5%	86.2%	74.1%	70.7%	69.0%	86.2%	84.5%	87.9%	86.2%

Framework origin color key: green: NGSS; blue: NGSS highbred; yellow: state specific

Structural Barriers to Flexible Curriculum Sequencing

This study also looked for potential barriers to the implementation of SE due to constraints placed upon the sequencing of curriculum permitted by state regulatory agencies. Twenty-two U.S. states plus the District of Columbia were rated as "flexible" indicating individual schools and districts retain local control over curriculum sequence. Three states organize their frameworks in a "single discipline" format and 24 states organize them in a state specified spiraled format (Table 16).

Table 16. Organizational format of middle school science framework, U.S. states.

Organizational Format of Science Curricula		
Flexible	**Single Discipline**	**Spiraled**
Connecticut	Alabama	Alaska
District of Columbia	Georgia	Arizona
Hawaii	Minnesota	Arkansas
Idaho	---	California
Illinois	---	Colorado
Kansas	---	Delaware
Kentucky	---	Florida
Maine	---	Indiana
Maryland	---	Iowa
Michigan	---	Louisiana
Missouri	---	Massachusetts
Montana	---	Mississippi
Nevada	---	Nebraska
New Hampshire	---	New Jersey
New Mexico	---	North Carolina
New York	---	North Dakota
Pennsylvania	---	Ohio
Rhode Island	---	Oklahoma
South Dakota	---	Oregon
Vermont	---	South Carolina
Virginia	---	Tennessee
Washington	---	Texas
Wisconsin	---	Utah
Wyoming	---	West Virginia

Framework origin color key: green: NGSS; blue: NGSS highbred; yellow: state specific

Notably, although the NGSS frameworks are designed with “flexible” sequencing, 13 states that adopted or hybridized them rejected this model, with Alabama requiring a single discipline format and twelve others designing a state-specified spiraled organization plan.

Chapter IV

Discussion

The analysis that follows is organized by research question; broken down by individual hypothesis. After this, a more general discussion is offered with a focus on contextualizing the results into larger patterns that lead to useful recommendations for future efforts to expand sustainability education (SE) in public schools.

It is generally held that whatever the strict requirements of analysis necessary to evaluate each hypothesis, it is also critical to contextualize these results in terms of impact on students. The driving concept behind this project was the need to understand how a greater level of sustainability literacy could be fostered within the United States to meet the challenges of a rising global population interacting with a finite planet. It follows that the level of literacy is a function of both what is known and how many people know it. In education terms, this reduces to how many students can potentially be exposed to SE related concepts; the impact of Hawaii which enrolled 40,513 middle school students in 2014 will be much less than Texas which enrolled 1,162,577 (NCES, 2015).

Each of the data sets analyzed in the section has also been presented in a color-coded format that breaks the range of the data into three cohorts (i.e. top tier, middle tier, and bottom tier). This presentation was designed so that the analyzed data sets could be combined into a single table that would help visualize state rankings necessary for answering research question four.

Research Question One

Research question one asked: how frequently is teaching sustainability either explicitly required or implicitly invited by the existing public middle school science learning standards in the United States? Two hypotheses related to this question were tested:

1. Sustainability is explicitly required by fewer than 3% of the middle school performance expectation equivalents (PEXEs) of all 50 states.
2. Fewer than 5% of middle school PEXEs in the United States implicitly invite teaching sustainability through content that aligns with the goals of sustainability.

Evaluating hypothesis 1. Based on these data, no state has more than 3% of its PEXEs explicitly requiring sustainability and only four states mention it at all in their middle school frameworks. Middle school enrollment data were correlated with each state's results (Table 17), and enrollment data were integrated with the rate of explicit inclusion of sustainability by calculation of a weighted average according to the following method.

$$\frac{\sum_{i=1}^{51}(Se(i)\cdot ENRms(i))}{\sum_{i=1}^{51}ENRms\,(i)}$$

Where: *i = 50 U.S. states and the District of Columbia*

Se(i) = percent of standards explicitly requiring sustainability education in state (i)

ENRms(i) = population of middle school students in state (i)

Using the data in Table 17, the weighted average for the entire U.S. was found to be 0.2%. While four states required some element of SE explicitly in their middle school science frameworks, these represented a minority of students and had a national impact well under the 3% threshold hypothesized. Based upon these results, hypothesis one is accepted.

Table 17. States explicitly requiring sustainability education.

State	Standards Explicitly Requiring Some Element of SE	Middle School Enrollment
ME	2.5%	27,006
NC	1.6%	229,236
TN	1.4%	147,330
TX	0.8%	774,597
All Other States & DC	0.0%	9,997,806

Evaluating hypothesis 2. Results in Table 10, Percentage of PEXEs Implicitly Inviting SE by State, were averaged with equal weighting to each state with the finding that 11.9% of state PEXEs implicitly invite SE. To properly contextualize the findings, middle school enrollment data was integrated with these results (Table 18) and a weighted average was calculated as follows:

$$Weighted\ Average\ = \frac{\sum_{i=1}^{51}(S(i) \cdot ENRms(i))}{\sum_{i=1}^{51} ENRms(i)}$$

Where: *i = 51 U.S. states and the District of Columbia*

S(i) = percent of standards implicitly inviting sustainability education in the state

ENRms(i) = population of middle school students in the state

The weighted average was determined to be 10.7%. Both results exceed the 5% threshold hypothesized. In general, the findings support a conclusion that while sustainability has very little explicit mention in middle school science frameworks, they do incorporate concepts that invite SE.

Table 18. Middle school enrollment and standards implicitly inviting SE by state.

State	Standards Implicitly Inviting Sustainability Education	Middle School Enrollment	State	Standards Implicitly Inviting Sustainability Education	Middle School Enrollment
AK	4.2%	29,138	ND	15.1%	23,676
AL	9.4%	165,301	NE	13.1%	69,446
AR	15.3%	109,048	NH	15.3%	41,021
AZ	4.8%	246,941	NJ	15.3%	311,111
CA	15.3%	1,402,122	NM	15.3%	75,605
CO	12.9%	197,475	NV	15.3%	102,000
CT	15.3%	120,545	NY	14.5%	608,900
DC	15.3%	17,983	OH	0.0%	383,132
DE	15.3%	29,775	OK	13.0%	152,939
FL	2.8%	612,401	OR	15.3%	133,571
GA	6.1%	387,492	PA	5.5%	387,209
HI	15.3%	40,513	RI	15.3%	31,533
IA	15.3%	112,245	SC	3.3%	168,047
ID	13.2%	64,614	SD	13.5%	29,552
IL	15.3%	455,420	TN	14.3%	221,125
IN	8.6%	232,408	TX	3.9%	1,162,577
KS	15.3%	110,460	UT	13.6%	141,181
KY	15.3%	152,968	VA	9.8%	284,411
LA	14.8%	159,223	VT	15.3%	19,394
MA	8.3%	212,322	WA	15.3%	238,487
MD	15.3%	194,256	WI	9.5%	193,571
ME	0.0%	40,532	WV	13.4%	62,265
MI	15.3%	341,619	WY	15.5%	20,895
MN	7.1%	190,418	---	**11.9%**	**Average**
MO	14.8%	203,868	---	**15.5%**	**Maximum**
MS	11.0%	109,048	---	**0.0%**	**Minimum**
MT	13.5%	32,105	---	**10.7%**	**Weighted Average**
NC	12.5%	344,056	---	---	---

According to the Pew Research Center, U.S. seventh graders receive an estimated 1,016 hours of instruction per year on average (Pew Research Center, 2014), and a study by the National Center for Education Statistics (NCES) in 1991 determined seventh grade students receive about 3.7 hours of time in formal science instruction per week. Although the data on weekly science instruction is dated, the two values are broadly consistent with one another since the Pew estimate includes all areas of instruction. Based on the NCES data, this equates to 133.5 hours of science instruction per year for an average seventh grade student and about 14 hours of potential time for sustainability education at the middle school level. This estimate was calculated by multiplying estimated science instruction time by the weighted average to best reflect the impact on students. This is a substantial amount of classroom time and greater than the 5% level hypothesized. Hypothesis two is therefore rejected.

In preparation for research question four, these results were also separated into cohorts. Because the level at which standards explicitly require sustainability is so low, the two data sets were combined into a single "explicit or implicit sustainability" table and color-coded. The top cohort cutoff occurred on a state with a value of 15.3% and was expanded to include the remaining states with the same value for a total of 22, shrinking the middle cohort to 13 states. Again, state abbreviations are coded to reflect the origin of the frameworks with green representing Next Generation Science Standards (NGSS) states, blue used for hybrid frameworks, and yellow for state specific origin (Table 19).

This presentation illustrates the strength of the NGSS frameworks in terms of its explicit inclusion and implicit promotion of SE themes. It further demonstrates that

NGSS hybrid states also have generally strong levels of potential SE support, though Alabama and Massachusetts lag this group by four to five percent.

Table 19. Combined explicit or implicit sustainability presented in 3 cohorts.

State	Explicit or Implicit Sustainability	State	Explicit or Implicit Sustainability	State	Explicit or Implicit Sustainability
TN	15.7%	ND	15.1%	CO	12.9%
WY	15.5%	LA	14.8%	MS	11.0%
AR	15.3%	MO	14.8%	VA	9.8%
CA	15.3%	NY	14.5%	WI	9.5%
CT	15.3%	NC	14.1%	AL	9.4%
DC	15.3%	UT	13.6%	IN	8.6%
DE	15.3%	MT	13.5%	MA	8.3%
HI	15.3%	SD	13.5%	MN	7.1%
IA	15.3%	WV	13.4%	GA	6.1%
IL	15.3%	ID	13.2%	PA	5.5%
KS	15.3%	NE	13.1%	AZ	4.8%
KY	15.3%	OK	13.0%	TX	4.7%
MD	15.3%	---	---	AK	4.2%
MI	15.3%	---	---	SC	3.3%
NH	15.3%	---	---	FL	2.8%
NJ	15.3%	---	---	ME	2.5%
NM	15.3%	---	---	OH	0.0%
NV	15.3%	---	---	---	---
OR	15.3%	---	---	---	---
RI	15.3%	---	---	---	---
VT	15.3%	---	---	---	---
WA	15.3%	---	---	---	---

State Framework Origin Color Key: green: NGSS blue: NGSS highbred yellow: state specific

Research Question Two

Research question two asks: where content standards do not explicitly require or implicitly invite teaching sustainability, to what degree do they incorporate key concepts that are embodied within sustainability education? Two hypotheses were tested:

1. Fewer than 10% of middle school PEXEs will specify teaching content and concepts that are aligned with at least one of the key sustainability principles embodied within sustainability education.
2. Fewer than 10% of middle school PEXEs will specify teaching at least one of three a priori sustainability issues used in this study.

Evaluating hypothesis 1. The first hypothesis was initially looked at from the standpoint of PEXEs rated as either “core” or “opportunity.” Tables with enrollment data were constructed and used to calculate unweighted averages for each of these categories (Table 20, Table 21). Based on this analysis, no sustainability principle (SP) is supported at the “core” level by more than a 1.0% of PEXE’s on a nation-wide basis. Support at the “opportunity” level ranges from 0.3% for SP2 up to 15.1% for SP6. Existing middle school science frameworks do not explicitly incorporate principles of SE at a meaningful level anywhere in the nation. However, the findings do show that there is noteworthy overlap between the SPs and PEXE’s as measured by the “opportunity” rating category.

Table 20. Average core alignment of SPS and SIs and enrollment data.

State	SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SI1	SI2	SI3	Middle School Enrollment
AK	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	29,138
Al	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%	1.9%	0.0%	1.9%	165,301
AR	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%	109,048
AZ	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	246,941
CA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%	1,402,122
CO	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	0.0%	0.0%	197,475
CT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%	120,545
DC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%	17,983
DE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%	29,775
FL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.9%	0.0%	612,401
GA	1.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.5%	0.0%	0.0%	387,492
HI	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%	40,513
IA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%	112,245
ID	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%	0.0%	1.9%	1.9%	64,614
IL	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%	455,420
IN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	0.0%	232,408
KS	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%	110,460
KY	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%	152,968
LA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%	1.9%	1.9%	1.9%	159,223
MA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.4%	1.4%	0.0%	1.4%	212,322
MD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%	194,256
ME	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	40,532
MI	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%	341,619
MN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	0.0%	190,418
MO	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%	1.9%	0.0%	1.9%	203,868
MS	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.9%	0.0%	0.0%	0.0%	0.9%	109,048
MT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%	0.0%	1.9%	32,105
NC	1.6%	0.0%	0.0%	0.0%	4.7%	0.0%	0.0%	0.0%	0.0%	1.6%	0.0%	344,056
ND	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.4%	23,676
NE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.6%	0.0%	1.6%	69,446
NH	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%	41,021
NJ	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%	311,111
NM	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%	75,605
NV	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%	102,000
NY	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.6%	1.6%	1.6%	1.6%	608,900
OH	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	383,132
OK	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%	0.0%	1.9%	1.9%	152,939
OR	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%	133,571
PA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%	0.0%	387,209
RI	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%	31,533
SC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%	0.0%	168,047
SD	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%	29,552
TN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.4%	1.4%	1.4%	0.0%	221,125
TX	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%	0.0%	1,162,577
UT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	141,181
VA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.6%	0.0%	0.6%	0.0%	284,411
VT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%	19,394
WA	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%	238,487
WI	1.6%	0.0%	1.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.2%	193,571
WV	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.5%	0.0%	1.5%	62,265
WY	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%	1.7%	1.7%	20,895
---	**0.1%**	**0.0%**	**0.0%**	**0.0%**	**0.1%**	**0.0%**	**0.0%**	**1.0%**	**1.1%**	**1.0%**	**1.2%**	**Average**
---	**1.6%**	**0.0%**	**1.6%**	**0.0%**	**4.7%**	**0.0%**	**0.9%**	**1.9%**	**2.0%**	**1.9%**	**3.2%**	**Maximum**
---	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**Minimum**

Framework origin color key: green: NGSS; blue: NGSS highbred; yellow: state specific

Table 21. Average opportunity alignment of SPS and SIs and enrollment data.

State	SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SI1	SI2	SI3	Middle School Enrollment
AK	1.1%	0.0%	3.2%	5.3%	1.1%	7.4%	2.1%	1.1%	0.0%	0.0%	1.1%	29,138
Al	7.5%	0.0%	3.8%	5.7%	9.4%	22.6%	11.3%	3.8%	1.9%	7.5%	5.7%	165,301
AR	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%	109,048
AZ	3.6%	1.8%	3.0%	3.6%	4.8%	7.2%	6.6%	4.2%	1.8%	1.8%	4.2%	246,941
CA	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%	1,402,122
CO	9.9%	0.0%	1.0%	5.0%	10.9%	20.8%	11.9%	1.0%	6.9%	5.9%	6.9%	197,475
CT	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%	120,545
DC	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%	17,983
DE	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%	29,775
FL	0.9%	0.0%	1.8%	0.9%	1.8%	6.4%	3.7%	0.0%	0.9%	0.9%	0.9%	612,401
GA	4.5%	0.0%	1.5%	6.1%	6.1%	12.1%	4.5%	1.5%	3.0%	1.5%	3.0%	387,492
HI	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%	40,513
IA	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%	112,245
ID	5.7%	0.0%	5.7%	5.7%	9.4%	18.9%	13.2%	3.8%	1.9%	7.5%	3.8%	64,614
IL	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%	455,420
IN	3.4%	0.0%	0.0%	5.2%	6.9%	12.1%	6.9%	1.7%	5.2%	1.7%	3.4%	232,408
KS	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%	110,460
KY	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%	152,968
LA	5.6%	0.0%	5.6%	7.4%	11.1%	18.5%	14.8%	3.7%	1.9%	7.4%	3.7%	159,223
MA	2.8%	0.0%	4.2%	6.9%	4.2%	12.5%	8.3%	4.2%	1.4%	4.2%	2.8%	212,322
MD	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%	194,256
ME	6.3%	2.5%	0.0%	0.0%	2.5%	16.5%	3.8%	0.0%	1.3%	0.0%	2.5%	40,532
MI	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%	341,619
MN	5.1%	1.0%	0.0%	5.1%	3.1%	8.2%	6.1%	0.0%	3.1%	1.0%	0.0%	190,418
MO	5.6%	0.0%	7.4%	9.3%	11.1%	18.5%	16.7%	5.6%	1.9%	9.3%	5.6%	203,868
MS	4.6%	0.9%	4.6%	3.7%	7.3%	12.8%	10.1%	2.8%	3.7%	4.6%	0.9%	109,048
MT	5.8%	1.9%	5.8%	7.7%	9.6%	17.3%	13.5%	5.8%	0.0%	3.8%	5.8%	32,105
NC	7.8%	3.1%	0.0%	7.8%	3.1%	10.9%	10.9%	4.7%	7.8%	3.1%	9.4%	344,056
ND	1.4%	0.0%	1.4%	2.7%	4.1%	11.0%	8.2%	2.7%	0.0%	0.0%	0.0%	23,676
NE	4.9%	0.0%	4.9%	4.9%	8.2%	16.4%	13.1%	4.9%	1.6%	4.9%	4.9%	69,446
NH	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%	41,021
NJ	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%	311,111
NM	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%	75,605
NV	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%	102,000
NY	4.8%	0.0%	6.5%	8.1%	9.7%	16.1%	14.5%	4.8%	1.6%	6.5%	4.8%	608,900
OH	0.0%	0.0%	0.0%	1.6%	1.6%	9.7%	3.2%	0.0%	1.6%	1.6%	0.0%	383,132
OK	5.6%	0.0%	5.6%	5.6%	9.3%	16.7%	13.0%	3.7%	1.9%	9.3%	3.7%	152,939
OR	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%	133,571
PA	2.1%	1.4%	0.0%	0.7%	3.4%	8.9%	4.8%	0.7%	2.7%	0.0%	0.0%	387,209
RI	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%	31,533
SC	2.5%	0.0%	1.7%	1.7%	3.3%	8.3%	5.0%	1.7%	2.5%	0.8%	0.8%	168,047
SD	5.8%	0.0%	5.8%	5.8%	9.6%	21.2%	13.5%	5.8%	1.9%	5.8%	5.8%	29,552
TN	12.9%	0.0%	4.3%	7.1%	14.3%	21.4%	14.3%	1.4%	2.9%	2.9%	4.3%	221,125
TX	3.1%	0.0%	0.8%	2.4%	3.1%	7.9%	3.1%	1.6%	3.1%	1.6%	1.6%	1,162,577
UT	5.1%	0.0%	3.4%	8.5%	6.8%	20.3%	13.6%	1.7%	3.4%	3.4%	5.1%	141,181
VA	9.8%	1.8%	2.4%	5.5%	9.1%	9.8%	9.8%	3.7%	3.7%	2.4%	4.3%	284,411
VT	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%	19,394
WA	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	5.1%	1.7%	6.8%	5.1%	238,487
WI	4.8%	0.0%	4.8%	4.8%	6.3%	7.9%	6.3%	6.3%	3.2%	0.0%	1.6%	193,571
WV	6.0%	0.0%	9.0%	10.4%	7.5%	14.9%	13.4%	9.0%	1.5%	3.0%	4.5%	62,265
WY	5.2%	0.0%	6.9%	8.6%	10.3%	17.2%	15.5%	5.2%	1.7%	6.9%	5.2%	20,895
---	**5.0%**	**0.3%**	**4.7%**	**6.5%**	**8.1%**	**15.1%**	**11.8%**	**3.9%**	**2.2%**	**4.8%**	**4.1%**	**Average**
---	**12.9%**	**3.1%**	**9.0%**	**10.4%**	**14.3%**	**22.6%**	**16.7%**	**9.0%**	**7.8%**	**9.3%**	**9.4%**	**Maximum**
---	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**1.1%**	**6.4%**	**2.1%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**Minimum**

Framework origin color key: green: NGSS; blue: NGSS highbred; yellow: state specific

To gain a better picture of the overall support for SE principles within existing frameworks, data for “core” and “opportunity” were combined into a single table and the results for all eight SPs were averaged by state. The results suggest there is substantial potential for integrating SE despite little explicit inclusion of it in middle school frameworks (Figure 16). Nationwide, 7.0% of all PEXE’s align with at least one SP at either the “core” or “opportunity” level, and thirty-four of 50 states and the District of Columbia exceed this (horizontal green line) indicating a positively skewed distribution. NGSS states provide the foundation of this support with an average 8.7% alignment overall, though Tennessee and Missouri both exceed this by a small margin.

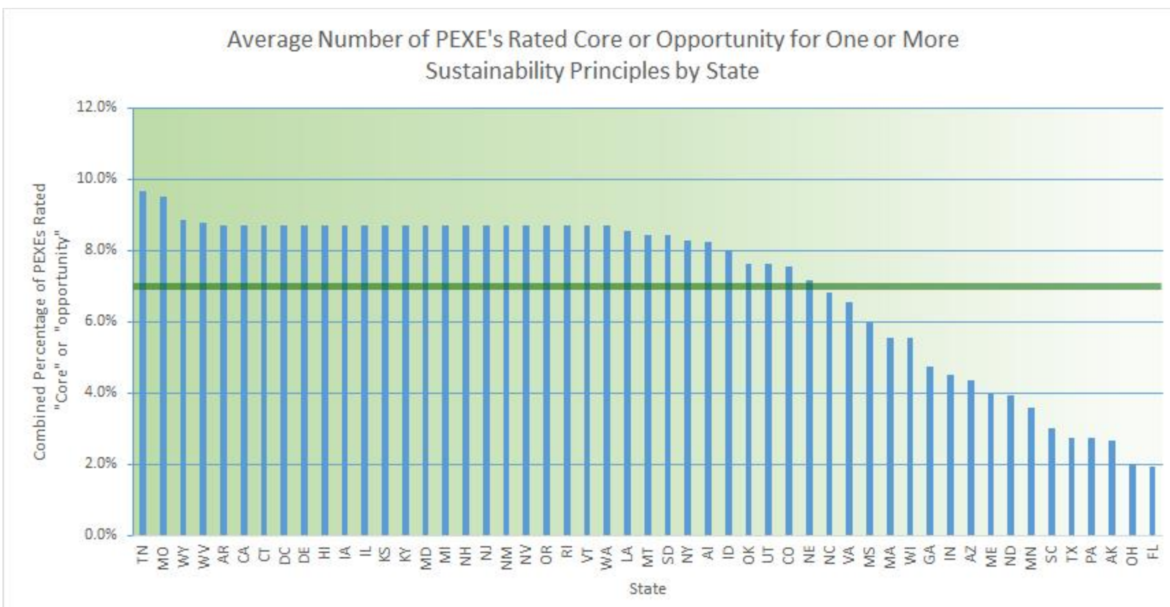


Figure 17. Average PEXE’s rated core or opportunity for SPS by State.

This is still an incomplete picture, however. The hypothesis stipulates a 10% alignment with “*at least one* of the key sustainability principles” (emphasis added). Evaluating this requires looking at each of the SPs individually as presented in Table 22.

Table 22. State support (core and opportunity) for individual sustainability principles.

State	SP1	State	SP2	State	SP3	State	SP4	State	SP5	State	SP6	State	SP7	State	SP8
TN	12.9%	NC	3.1%	WV	9.0%	WV	10.4%	TN	14.3%	Al	22.6%	MO	16.7%	WV	9.0%
CO	9.9%	ME	2.5%	MO	7.4%	MO	9.3%	LA	11.1%	TN	21.4%	WY	15.5%	MO	7.4%
VA	9.8%	MT	1.9%	WY	6.9%	WY	8.6%	MO	11.1%	SD	21.2%	AR	15.3%	WY	6.9%
NC	9.4%	VA	1.8%	AR	6.8%	AR	8.5%	CO	10.9%	CO	20.8%	CA	15.3%	AR	6.8%
Al	7.5%	AZ	1.8%	CA	6.8%	CA	8.5%	WY	10.3%	UT	20.3%	CT	15.3%	CA	6.8%
WI	6.3%	PA	1.4%	CT	6.8%	CT	8.5%	AR	10.2%	ID	18.9%	DC	15.3%	CT	6.8%
ME	6.3%	MN	1.0%	DC	6.8%	DC	8.5%	CA	10.2%	LA	18.5%	DE	15.3%	DC	6.8%
GA	6.1%	MS	0.9%	DE	6.8%	DE	8.5%	CT	10.2%	MO	18.5%	HI	15.3%	DE	6.8%
WV	6.0%	AK	0.0%	HI	6.8%	HI	8.5%	DC	10.2%	MT	17.3%	IA	15.3%	HI	6.8%
MT	5.8%	Al	0.0%	IA	6.8%	IA	8.5%	DE	10.2%	WY	17.2%	IL	15.3%	IA	6.8%
SD	5.8%	AR	0.0%	IL	6.8%	IL	8.5%	HI	10.2%	AR	16.9%	KS	15.3%	IL	6.8%
ID	5.7%	CA	0.0%	KS	6.8%	KS	8.5%	IA	10.2%	CA	16.9%	KY	15.3%	KS	6.8%
LA	5.6%	CO	0.0%	KY	6.8%	KY	8.5%	IL	10.2%	CT	16.9%	MD	15.3%	KY	6.8%
MO	5.6%	CT	0.0%	MD	6.8%	MD	8.5%	KS	10.2%	DC	16.9%	MI	15.3%	MD	6.8%
OK	5.6%	DC	0.0%	MI	6.8%	MI	8.5%	KY	10.2%	DE	16.9%	NH	15.3%	MI	6.8%
WY	5.2%	DE	0.0%	NH	6.8%	NH	8.5%	MD	10.2%	HI	16.9%	NJ	15.3%	NH	6.8%
MN	5.1%	FL	0.0%	NJ	6.8%	NJ	8.5%	MI	10.2%	IA	16.9%	NM	15.3%	NJ	6.8%
AR	5.1%	GA	0.0%	NM	6.8%	NM	8.5%	NH	10.2%	IL	16.9%	NV	15.3%	NM	6.8%
CA	5.1%	HI	0.0%	NV	6.8%	NV	8.5%	NJ	10.2%	KS	16.9%	OR	15.3%	NV	6.8%
CT	5.1%	IA	0.0%	OR	6.8%	OR	8.5%	NM	10.2%	KY	16.9%	RI	15.3%	OR	6.8%
DC	5.1%	ID	0.0%	RI	6.8%	RI	8.5%	NV	10.2%	MD	16.9%	VT	15.3%	RI	6.8%
DE	5.1%	IL	0.0%	VT	6.8%	UT	8.5%	OR	10.2%	MI	16.9%	WA	15.3%	VT	6.8%
HI	5.1%	IN	0.0%	WA	6.8%	VT	8.5%	RI	10.2%	NH	16.9%	LA	14.8%	WA	6.8%
IA	5.1%	KS	0.0%	NY	6.5%	WA	8.5%	VT	10.2%	NJ	16.9%	NY	14.5%	NY	6.5%
IL	5.1%	KY	0.0%	WI	6.3%	NY	8.1%	WA	10.2%	NM	16.9%	TN	14.3%	WI	6.3%
KS	5.1%	LA	0.0%	MT	5.8%	NC	7.8%	NY	9.7%	NV	16.9%	UT	13.6%	MT	5.8%
KY	5.1%	MA	0.0%	SD	5.8%	MT	7.7%	MT	9.6%	OR	16.9%	MT	13.5%	SD	5.8%
MD	5.1%	MD	0.0%	ID	5.7%	LA	7.4%	SD	9.6%	RI	16.9%	SD	13.5%	Al	5.7%
MI	5.1%	MI	0.0%	LA	5.6%	TN	7.1%	Al	9.4%	VT	16.9%	WV	13.4%	ID	5.7%
NH	5.1%	MO	0.0%	OK	5.6%	MA	6.9%	ID	9.4%	WA	16.9%	ID	13.2%	MA	5.6%
NJ	5.1%	ND	0.0%	NE	4.9%	GA	6.1%	OK	9.3%	OK	16.7%	NE	13.1%	LA	5.6%
NM	5.1%	NE	0.0%	MS	4.6%	SD	5.8%	VA	9.1%	ME	16.5%	OK	13.0%	OK	5.6%
NV	5.1%	NH	0.0%	TN	4.3%	Al	5.7%	NE	8.2%	NE	16.4%	CO	11.9%	NE	4.9%
OR	5.1%	NJ	0.0%	MA	4.2%	ID	5.7%	NC	7.8%	NY	16.1%	Al	11.3%	NC	4.7%
RI	5.1%	NM	0.0%	Al	3.8%	OK	5.6%	WV	7.5%	WV	14.9%	MS	11.0%	VA	4.3%
UT	5.1%	NV	0.0%	UT	3.4%	VA	5.5%	MS	7.3%	MS	12.8%	NC	10.9%	AZ	4.2%
VT	5.1%	NY	0.0%	AK	3.2%	AK	5.3%	IN	6.9%	MA	12.5%	VA	9.8%	UT	3.4%
WA	5.1%	OH	0.0%	AZ	3.0%	IN	5.2%	UT	6.8%	GA	12.1%	MA	8.3%	TN	2.9%
NE	4.9%	OK	0.0%	VA	2.4%	MN	5.1%	WI	6.3%	IN	12.1%	ND	8.2%	MS	2.8%
NY	4.8%	OR	0.0%	FL	1.8%	CO	5.0%	GA	6.1%	ND	11.0%	IN	6.9%	ND	2.7%
MS	4.6%	RI	0.0%	SC	1.7%	NE	4.9%	AZ	4.8%	NC	10.9%	AZ	6.6%	IN	1.7%
AZ	3.6%	SC	0.0%	GA	1.5%	WI	4.8%	MA	4.2%	VA	9.8%	WI	6.3%	SC	1.7%
IN	3.4%	SD	0.0%	ND	1.4%	MS	3.7%	ND	4.1%	OH	9.7%	MN	6.1%	TX	1.6%
TX	3.1%	TN	0.0%	CO	1.0%	AZ	3.6%	PA	3.4%	PA	8.9%	SC	5.0%	GA	1.5%
MA	2.8%	TX	0.0%	TX	0.8%	ND	2.7%	SC	3.3%	SC	8.3%	PA	4.8%	AK	1.1%
SC	2.5%	UT	0.0%	IN	0.0%	TX	2.4%	TX	3.1%	MN	8.2%	GA	4.5%	CO	1.0%
PA	2.1%	VT	0.0%	ME	0.0%	SC	1.7%	MN	3.1%	WI	7.9%	ME	3.8%	PA	0.7%
ND	1.4%	WA	0.0%	MN	0.0%	OH	1.6%	ME	2.5%	TX	7.9%	FL	3.7%	FL	0.0%
AK	1.1%	WI	0.0%	NC	0.0%	FL	0.9%	FL	1.8%	AK	7.4%	OH	3.2%	ME	0.0%
FL	0.9%	WV	0.0%	OH	0.0%	PA	0.7%	OH	1.6%	AZ	7.2%	TX	3.1%	MN	0.0%
OH	0.0%	WY	0.0%	PA	0.0%	ME	0.0%	AK	1.1%	FL	6.4%	AK	2.1%	OH	0.0%

Framework origin color key: green: NGSS; blue: NGSS highbred; yellow: state specific

In this presentation, the results for each SP have been sorted by magnitude. Data cells that exceed the 10% threshold for a specific SP are tinted red. In this representation, it is clear most U.S. states have middle school frameworks with the percentage of PEXE's rated either "core" or "opportunity" exceeding the 10% threshold only for SP6 and SP7. To fully contextualize these findings, a weighted average for the combined data was computed using the following method:

$$Average\ CO\ (weighted) = \frac{\sum_{i=1}^{51}(PEXEco(i) \cdot ENRms(i))}{\sum_{i=1}^{51} ENRms(i)}$$

Where: *i = 51 U.S. states and the District of Columbia*

PEXEco(i) = percent of PEXEs rated either core or opportunity for the sustainability principle

ENRms(i) = population of middle school students in the state

Summary statistics and these weighted averages are shown in Table 23. On a population weighted basis, SP6 and SP7 are covered by greater than 10% of the PEXE's in use across the nation. None of the other sustainability principles approach this threshold and SP2 has negligible support in middle school frameworks. Hypothesis one is rejected in this case. From the perspective of a population weighted average, two SPs exceed the 10% threshold for most students and states in the nation.

Table 23. Population weighted core and opportunity support for individual SPs.

SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SI1	SI2	SI3	Analysis
5.1%	0.3%	4.7%	6.5%	8.2%	15.1%	11.8%	4.9%	3.2%	5.8%	5.3%	Average
12.9%	3.1%	9.0%	10.4%	14.3%	22.6%	16.7%	9.0%	8.9%	11.1%	9.4%	Maximum
0.0%	0.0%	0.0%	0.0%	1.1%	6.4%	2.1%	0.0%	0.0%	0.0%	0.0%	Minimum
4.8%	0.3%	4.1%	6.0%	7.5%	13.7%	10.6%	4.3%	3.4%	5.4%	4.7%	Weighted Average

The two sustainability principles in question relate to the function of systems and interactions between human and natural systems.

SP6: Sustainable systems are characterized by diversity, recycle matter continuously, and rely on renewable or inexhaustible energy sources. Disruption of these beyond limits can cause the system to become unsustainable.

SP7: Human social and economic systems are highly interconnected with Earth's physical and biological systems. Changes to any system produces effects on others.

The strong nationwide emphasis relevant to SP6 and SP7 is largely due to the NGSS and states that have hybridized it. Overall, 16.9% of NGSS performance expectations align with principle six at either the "core" or "opportunity" level while 15.3% align with principle seven. Because this block includes 19 states and the District of Columbia, many of which have high enrollment, it exerts a strong influence on the national picture.

What is equally evident is that other principles are more weakly represented in the public-school standards of grades six through eight across the nation. The concepts of intergenerational equity (SP1), inclusive decision making (SP3), and integrating broad perspectives (SP4) into sustainability related decisions about humans and the environment all rate around 5% of PEXEs on a nationwide basis. Sustainability principle two, which expresses the principle that human use of resources should produce broad and equitable benefits across all peoples is virtually nonexistent (0.3%).

The concept of human dependency on the environment (SP5) does better at almost 7.5% while the concept that economic development must be balanced with environmental protection (SP8) rates 4.3%. The picture that emerges is that science frameworks in the United States at the middle school level are relatively robust with concepts related to the function and human interactions with Earth's natural systems. To a lesser degree, standards include concepts of protecting resources and natural systems for the future, that humans rely upon these, and that their management requires inclusive decision-making processes that incorporate multiple perspectives. There is little if any recognition that human use of natural resources and systems should produce broad and equitable benefits across peoples and cultures here and now.

Evaluating hypothesis 2. The second hypothesis stipulates that "fewer than 10% of PEXE's will *specify* (emphasis added) teaching at least one of three a priori sustainability issues." In this case, the word "specify" is interpreted to mean an explicit requirement to teach the SI is included in the standard. For this reason, it is necessary to focus on "core" alignment. The phrase "at least one of three a priori sustainability issues" means that summing the results for all three SIs by state into a single combined score is necessary. The three SIs organized by state are shown in Table 24, with a column for the combined scores, summary statistics, and the population weighted average, computed as follows:

$$Population\ Weighted\ Average\ = \frac{\sum_{i=1}^{51}(SIco(i) \cdot ENRms(i))}{\sum_{i=1}^{51} ENRms(i)}$$

Where: *i = 51 U.S. states and the District of Columbia*
SIco(i) = combined percentage of PEXEs rated either core or opportunity for all three SIs
ENRms(i) = middle school enrollment students in the state

Table 24. Core alignment with three SIs by state.

State	SI1	SI2	SI3	Combined	M.S. Enrollment
LA	1.9%	1.9%	1.9%	5.6%	159,223
WY	1.7%	1.7%	1.7%	5.2%	20,895
AR	1.7%	1.7%	1.7%	5.1%	109,048
CA	1.7%	1.7%	1.7%	5.1%	1,402,122
CT	1.7%	1.7%	1.7%	5.1%	120,545
DC	1.7%	1.7%	1.7%	5.1%	17,983
DE	1.7%	1.7%	1.7%	5.1%	29,775
HI	1.7%	1.7%	1.7%	5.1%	40,513
IA	1.7%	1.7%	1.7%	5.1%	112,245
IL	1.7%	1.7%	1.7%	5.1%	455,420
KS	1.7%	1.7%	1.7%	5.1%	110,460
KY	1.7%	1.7%	1.7%	5.1%	152,968
MD	1.7%	1.7%	1.7%	5.1%	194,256
MI	1.7%	1.7%	1.7%	5.1%	341,619
NH	1.7%	1.7%	1.7%	5.1%	41,021
NJ	1.7%	1.7%	1.7%	5.1%	311,111
NM	1.7%	1.7%	1.7%	5.1%	75,605
NV	1.7%	1.7%	1.7%	5.1%	102,000
OR	1.7%	1.7%	1.7%	5.1%	133,571
RI	1.7%	1.7%	1.7%	5.1%	31,533
VT	1.7%	1.7%	1.7%	5.1%	19,394
WA	1.7%	1.7%	1.7%	5.1%	238,487
NY	1.6%	1.6%	1.6%	4.8%	608,900
MT	1.9%	0.0%	1.9%	3.8%	32,105
Al	1.9%	0.0%	1.9%	3.8%	165,301
ID	0.0%	1.9%	1.9%	3.8%	64,614
MO	1.9%	0.0%	1.9%	3.7%	203,868
OK	0.0%	1.9%	1.9%	3.7%	152,939
IN	1.7%	1.7%	0.0%	3.4%	232,408
NE	1.6%	0.0%	1.6%	3.3%	69,446
WI	0.0%	0.0%	3.2%	3.2%	193,571
WV	1.5%	0.0%	1.5%	3.0%	62,265
MA	1.4%	0.0%	1.4%	2.8%	212,322
TN	1.4%	1.4%	0.0%	2.8%	221,125
CO	2.0%	0.0%	0.0%	2.0%	197,475
SD	0.0%	0.0%	1.9%	1.9%	29,552
NC	0.0%	1.6%	0.0%	1.6%	344,056
GA	1.5%	0.0%	0.0%	1.5%	387,492
ND	0.0%	0.0%	1.4%	1.4%	23,676
MN	0.0%	1.0%	0.0%	1.0%	190,418
FL	0.0%	0.9%	0.0%	0.9%	612,401
MS	0.0%	0.0%	0.9%	0.9%	109,048
SC	0.0%	0.8%	0.0%	0.8%	168,047
TX	0.0%	0.8%	0.0%	0.8%	1,162,577
PA	0.0%	0.7%	0.0%	0.7%	387,209
VA	0.0%	0.6%	0.0%	0.6%	284,411
AK	0.0%	0.0%	0.0%	0.0%	29,138
AZ	0.0%	0.0%	0.0%	0.0%	246,941
ME	0.0%	0.0%	0.0%	0.0%	40,532
OH	0.0%	0.0%	0.0%	0.0%	383,132
UT	0.0%	0.0%	0.0%	0.0%	141,181
---	1.1%	1.0%	1.2%	3.3%	Average
---	2.0%	1.9%	3.2%	5.6%	Maximum
---	0.0%	0.0%	0.0%	0.0%	Minimum
---	1.0%	1.1%	1.0%	3.0%	Weighted Average

Framework origin color key: green: NGSS; blue: NGSS highbred; yellow: state specific

The results show that sustainability issues enjoy higher and more consistent "core" ratings than the sustainability principles did. Here, the averages ranged between 1.0% and 1.2% with all three SIs garnering about equal support in middle school science frameworks on a nationwide basis. The combined score however shows that the maximum support is 5.6% (Louisiana) and NGSS states supporting 5.1% core alignment. No state approaches the 10% stipulated, therefore hypothesis two is accepted.

Finally, in preparation for research question four, the combined results for all SPs and SIs are presented. Table 25 presents the overall average for "core" ratings and

Table 25. Combined average core ratings of SPS and SIs by State in three cohorts.

State	Average Core Ratings	State	Average Core Ratings	State	Average Core Ratings
NC	0.7%	Al	0.5%		
LA	0.7%	ID	0.5%	MT	0.3%
WY	0.6%	MO	0.5%	IN	0.3%
AR	0.6%	OK	0.5%	NE	0.3%
CA	0.6%	MA	0.4%	GA	0.3%
CT	0.6%	TN	0.4%	WV	0.3%
DC	0.6%	---	---	CO	0.2%
DE	0.6%	---	---	SD	0.2%
HI	0.6%	---	---	MS	0.2%
IA	0.6%	---	---	UT	0.2%
IL	0.6%	---	---	ND	0.1%
KS	0.6%	---	---	VA	0.1%
KY	0.6%	---	---	MN	0.1%
MD	0.6%	---	---	FL	0.1%
MI	0.6%	---	---	SC	0.1%
NH	0.6%	---	---	TX	0.1%
NJ	0.6%	---	---	PA	0.1%
NM	0.6%	---	---	AK	0.0%
NV	0.6%	---	---	AZ	0.0%
OR	0.6%	---	---	ME	0.0%
RI	0.6%	---	---	OH	0.0%
VT	0.6%	---	---	---	---
WA	0.6%	---	---	---	---
NY	0.6%	---	---	---	---
WI	0.6%	---	---	---	---

Framework origin color key: green: NGSS; blue: NGSS highbred; yellow: state specific

Table 26 presents results for the overall average of "opportunity" ratings with the top, middle, and bottom cohorts color coded. Again, the influence of the NGSS on national

Table 26. Average opportunity ratings of SPS and SIs by State in three cohorts.

State	Average Opportunity Rating	State	Average Opportunity Rating	State	Average Opportunity Rating
MO	8.2%	SD	7.3%	NC	6.2%
TN	7.8%	CO	7.3%	VA	5.7%
WY	7.5%	LA	7.2%	MS	5.1%
AR	7.4%	Al	7.2%	MA	4.7%
CA	7.4%	WV	7.2%	IN	4.2%
CT	7.4%	NY	7.0%	WI	4.2%
DC	7.4%	MT	7.0%	GA	4.0%
DE	7.4%	ID	6.9%	AZ	3.9%
HI	7.4%	OK	6.7%	ME	3.2%
IA	7.4%	UT	6.5%	MN	3.0%
IL	7.4%	NE	6.3%	ND	2.9%
KS	7.4%			TX	2.6%
KY	7.4%			SC	2.6%
MD	7.4%			PA	2.2%
MI	7.4%			AK	2.0%
NH	7.4%			OH	1.8%
NJ	7.4%			FL	1.7%
NM	7.4%				
NV	7.4%				
OR	7.4%				
RI	7.4%				
VT	7.4%				
WA	7.4%				

Framework origin color key: green: NGSS; blue: NGSS highbred; yellow: state specific

results for both "core and "opportunity" ratings are evident. Not only do NGSS states comprise almost the entire top (green) cohort for both "core" and "opportunity" ratings, NGSS hybrid states dominate the middle (orange) cohort as well. Only a few states that have developed frameworks independent of the NGSS offer substantial support for SE as measured by these, metrics; notably Tennessee and Colorado rate well in the "opportunity" category, and North Carolina tops the nation for average "core" ratings with Wisconsin earning a very respectable score as well. Despite this, both Tennessee and Colorado are weaker in the "core" rating and North Carolina and Wisconsin lag in the "opportunity" category suggesting they lack broad overall support for SE.

Research Question Three:

To what degree do state science frameworks allow for integration of required science content from different domains of science into flexible presentations that best support sustainability education? One hypothesis was tested.

1. Most state published public school science frameworks will include elements of structure that create potential barriers to constructing flexible, integrated presentations of content which best support sustainability education.

This hypothesis was investigated by analyzing documentation published by state level departments of education pertaining to curriculum organizational format. Overall, 24 states were identified as having a "flexible" framework. Out of these, investigation of five failed to turn up further corroborating evidence in the form of example schools or districts that published differing curriculum sequences. Some mitigating circumstances may explain this. For example, New Mexico adopted the NGSS in October 2017 and has not yet begun the transition to the new framework. Similarly, Wyoming is in the first year of implementation of the NGSS and thus is unlikely to have local curriculum developed by individual schools or districts yet. The other three, Nevada, Hawaii, and the District of Columbia were searched, and all schools/districts that could be identified pointed directly to NGSS documents but offered no further guidance or structure for sequencing. In these five cases, I have assigned a designation of "flexible" to the states as this is the default mode of the NGSS frameworks and no contrary evidence could be located. Conversely, three states were solidly identified as single discipline (Alabama, Georgia, and Minnesota) with state documents specifying earth science, life science, physical science taught specific grade levels. Finally, 24 states were identified with frameworks that require spiraled curriculum organization according to a specific sequence published by the controlling state agency.

Based upon raw numbers, 27 states place constraints upon science frameworks that would limit a school or educator's flexibility in constructing interdisciplinary sustainability themed units. In order to understand the impact across the population of students in middle school classrooms, enrollment data were integrated with the state classifications (Table 27).

Based on these data, 34% of public school students in grades six through eight are educated in science classrooms that retain the flexible local control over curriculum sequence that is most conducive to supporting sustainability education. Conversely, 6.7% of students nationwide are educated in single discipline classrooms and 59.3% take science in a spiraled format that is structured in specified at the state level. Whatever the organizing principles behind these various spiraled formats, there is no evidence that they are structured around SE principles. For this reason, it is concluded that approximately two thirds (66%) of U.S. public school students in grades six through eight are educated in classrooms that have important structural barriers to implementing sustainability education within existing science frameworks.

Table 27. Middle school enrollment versus curriculum organizational format (by author).

Flexible	Population	Single Discipline	Population	Spiraled	Population
Total	**3,807,463**	**Total**	**743,211**	**Total**	**6,625,271**
Connecticut	120,545	Alabama	165,301	Alaska	29,138
District of Columbia	17,983	Georgia	387,492	Arizona	246,941
Hawaii	40,513	Minnesota	190,418	Arkansas	109,048
Idaho	64,614	---		California	1,402,122
Illinois	455,420	---		Colorado	197,475
Kansas	110,460	---		Delaware	29,775
Kentucky	152,968	---		Florida	612,401
Maine	40,532	---		Indiana	232,408
Maryland	194,256	---		Iowa	112,245
Michigan	341,619	---		Louisiana	159,223
Missouri	203,868	---		Massachusetts	212,322
Montana	32,105	---		Mississippi	109,048
Nevada	102,000	---		Nebraska	23,676
New Hampshire	41,021	---		New Jersey	311,111
New Mexico	75,605	---		North Carolina	69,446
New York	608,900	---		North Dakota	344,056
Pennsylvania	387,209	---		Ohio	383,132
Rhode Island	31,533	---		Oklahoma	152,939
South Dakota	29,552	---		Oregon	133,571
Vermont	19,394	---		South Carolina	168,047
Virginia	284,411	---		Tennessee	221,125
Washington	238,487	---		Texas	1,162,577
Wisconsin	193,571	---		Utah	141,181
Wyoming	20,895	---		West Virginia	62,265

Individual state PEXEs were also examined for potential barriers to SE across all eight SPs and three SIs using the “barrier” classification on the CORBNR rating scale. Findings indicate that the actual language of standards across the nation is almost entirely devoid of potential barriers to sustainability education (Table 28).

Table 28. National average occurrence of “barriers” to sustainability education.

SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SI1	SI2	SI3
0.0%	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%

No barriers were detected for seven of eight SPs. The finding of a barrier to SP4 at a level of 1% was based upon a single NGSS standard (ESS3-3):

> Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment. * [Clarification Statement: Examples of the design process include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact. Examples of human impacts can include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as of the air, water, or land).] (NGSS Lead States, 2013)

The barrier rating is due to the stipulation imposed by the word "scientific" on the directive to apply principles to design a method for monitoring and minimizing human impact on the environment. SP4 is based upon the principle of integrating broad perspectives into decision-making processes related to sustainability issues. It states:

> Decisions about sustainability issues must include social, cultural, economic, political and ethical perspectives as well as scientific knowledge.

By adding the proviso of "scientific principles" the standard directs educators away from integrating other perspectives in the attainment of this performance expectation. While the language does not exclude the relevance of other perspectives, it conspicuously omits them. This is consistent with the thematic element of scientism identified in the NGSS by Feinstein and Kirchglaser (2014); the idea that quantitative analysis and management of systems is key to increasing sustainability. Despite this, five other performance expectations within the NGSS were judged to present "opportunities" for the inclusion of SP4 in a sustainability themed unit. For this reason, it is believed that this possible barrier is unlikely to be important in the overall context of potential support for SP4 within NGSS.

Among the sustainability issues, a very low-level occurrence (0.1%) of barrier was identified to SI1, the issue of climate change. This barrier traces to standards identified in two different states. One of these is South Dakota, a NGSS hybrid states which includes an edited version of NGSS performance expectation MS-ESS3-5 which reads:

> Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century. [Clarification Statement: Examples of factors include human activities (such as fossil fuel combustion, cement production, and agricultural activity) and natural processes (such as changes in incoming solar radiation or volcanic activity). Examples of evidence can include tables, graphs, and maps of global and regional temperatures, atmospheric levels of gases such as carbon dioxide and methane, and the rates of human activities. Emphasis is on the major role that human activities play in causing the rise in global temperatures.] (NGSS Lead States, 2013)

Notably, this performance expectation proceeds from the assumption that global temperatures are rising and further clarifies that human factors in this change are to be considered alongside natural processes. Specific examples provided in the performance expectation point towards human activity is playing a "major role" and climate change.

The South Dakota Science Standards (South Dakota Department of Education, 2015) adds a qualification to this performance expectation and removes the language contained within the clarification statement and examples.

> Ask questions to clarify evidence of the factors that may have caused a change in global temperatures over the past century. (SEP: 1; DCI: ESS3.D; CCC: Stability/Change) (p. 26)

The state's inclusion of the word "may" orients the standard towards skepticism about the cause of climate change and the removal of the clarification statement and examples eliminates all cues to examine human interactions with the climate system.

The other state introducing a possible barrier to teaching climate change as a sustainability issue is Mississippi (Mississippi Department of Education, 2017) which includes PEXE E7.9B3.

> Engage in scientific argument based on current evidence to determine whether climate change happens naturally or is being accelerated through the influence of man. (p. 5)

This performance expectation explicitly fosters debate over whether or not humans are influencing the climate system and is at odds with an overwhelming preponderance of scientific evidence on the subject.

Overall, the potential effects of these two barriers are small. In the case of South Dakota, the language is relatively ambiguous. Mississippi's language is potentially pejorative against the idea that humans are influencing the climate, but the two states represent just 1.2% of the nation's public-school enrollment in grades six through eight.

Based on the evidence, potential structural barriers to flexibly organizing curriculum around sustainability education themes are substantial and meet the stipulation in the hypothesis that "most states…will include elements of structure that create potential barriers." Although the specific language of PEXE currently in use across the United States is essentially free of barriers to SE, the structural barriers are sufficient to meet the criteria of the hypothesis. The hypothesis is accepted.

Because the language of individual PEXEs is effectively free of barriers it is not judged to be of much potential significance with respect to understanding the larger issue of how much support exists for SE within established standards and frameworks. But, the finding of substantial structural barriers supports the conclusion that these need to be factored in to understanding this larger picture. For this reason, state data for curriculum organization was sorted by designation with flexible deemed the optimal condition for SE and coded green. Spiraled was assigned orange as an intermediate condition because it did open the door to interdisciplinary work though the flexibility to sequence curriculum to optimize for an SE themed unit was lacking. Finally, single discipline was coded red as it restricted both interdisciplinary units and the flexibility to adjust sequence to meet the needs of SE (Table 29).

Table 29. Organizational format of State frameworks color coded by cohort.

Organizational Format of Middle School Science Curricula		
Flexible	**Spiraled**	**Single Discipline**
Connecticut	Alaska	Alabama
District of Columbia	Arizona	Georgia
Hawaii	Arkansas	Minnesota
Idaho	California	---
Illinois	Colorado	---
Kansas	Delaware	---
Kentucky	Florida	---
Maine	Indiana	---
Maryland	Iowa	---
Michigan	Louisiana	---
Missouri	Massachusetts	---
Montana	Mississippi	---
Nevada	Nebraska	---
New Hampshire	New Jersey	---
New Mexico	North Carolina	---
New York	North Dakota	---
Pennsylvania	Ohio	---
Rhode Island	Oklahoma	---
South Dakota	Oregon	---
Vermont	South Carolina	---
Virginia	Tennessee	---
Washington	Texas	---
Wisconsin	Utah	---
Wyoming	West Virginia	---

Framework origin color key: green: NGSS; blue: NGSS highbred; yellow: state specific

Research Question Four

How many middle school students could potentially receive sustainability education within the public-school science frameworks currently established in the United States?

This research question focused on a single hypothesis:

1. The majority of students in the United States public schools are subject to middle school frameworks that presents significant challenges to integrating sustainability education into their science classes.

This research question was investigated from a couple of different perspectives. The first of these was an examination of the large-scale alignment of PEXEs currently in use across the nation with the eight sustainability principles and three sustainability issues. That data from Table 11 (p. 86) and Table 12 (p. 87) were combined into a single summative "CO" value by adding the "core" and "opportunity" ratings for individual SPs and SIs on a state by state basis (Table 30). The data were matched with middle school enrollment data and an overall national average "CO" value was calculated as follows.

$$National\ Average\ Total\ CO = \frac{\sum_1^8 SP(i) + \sum_1^3 SI(i)}{11}$$

Where: i = number of SPs or SIs

SPi: combined state average sustainability principle (i) for "core" and "opportunity"

SIi: combined state average sustainability issue (i) for "core" and "opportunity"

Summary statistics (maxima, minima, and unweighted average) were computed for this composite table and an enrollment weighted average was developed as follows:

$$Population\ Weighted\ Average = \frac{\sum_{i=1}^{51}(PEXEco(i) \cdot ENRms(i))}{\sum_{i=1}^{51} ENRms(i)}$$

Where: i = 51 U.S. states and the District of Columbia

PEXEco(i) = percent of PEXEs rated either core or opportunity (for SP, SI, or CO National Average)

ENRms(i) = middle school enrollment students in the state

Table 30. CO composite data and statistics for eight SPS and three SIs.

State	M.S. Enrollment (thousands)	National Avg. Total CO	SP1 CO	SP2 CO	SP3 CO	SP4 CO	SP5 CO	SP6 CO	SP7 CO	SP8 CO	SI1 CO	SI2 CO	SI3 CO
MO	203,868	8.8%	5.6%	0.0%	7.4%	9.3%	11.1%	18.5%	16.7%	7.4%	3.7%	9.3%	7.4%
TN	221,125	8.2%	12.9%	0.0%	4.3%	7.1%	14.3%	21.4%	14.3%	2.9%	4.3%	4.3%	4.3%
WY	20,895	8.2%	5.2%	0.0%	6.9%	8.6%	10.3%	17.2%	15.5%	6.9%	3.4%	8.6%	6.9%
AR	109,048	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
CA	1,402,122	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
CT	120,545	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
DC	17,983	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
DE	29,775	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
HI	40,513	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
IA	112,245	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
IL	455,420	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
KS	110,460	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
KY	152,968	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
MD	194,256	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
MI	341,619	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
NH	41,021	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
NJ	311,111	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
NM	75,605	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
NV	102,000	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
OR	133,571	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
RI	31,533	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
VT	19,394	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
WA	238,487	8.0%	5.1%	0.0%	6.8%	8.5%	10.2%	16.9%	15.3%	6.8%	3.4%	8.5%	6.8%
LA	159,223	7.9%	5.6%	0.0%	5.6%	7.4%	11.1%	18.5%	14.8%	5.6%	3.7%	9.3%	5.6%
Al	165,301	7.7%	7.5%	0.0%	3.8%	5.7%	9.4%	22.6%	11.3%	5.7%	3.8%	7.5%	7.5%
NY	608,900	7.6%	4.8%	0.0%	6.5%	8.1%	9.7%	16.1%	14.5%	6.5%	3.2%	8.1%	6.5%
SD	29,552	7.5%	5.8%	0.0%	5.8%	5.8%	9.6%	21.2%	13.5%	5.8%	1.9%	5.8%	7.7%
CO	197,475	7.5%	9.9%	0.0%	1.0%	5.0%	10.9%	20.8%	11.9%	1.0%	8.9%	5.9%	6.9%
WV	62,265	7.5%	6.0%	0.0%	9.0%	10.4%	7.5%	14.9%	13.4%	9.0%	3.0%	3.0%	6.0%
ID	64,614	7.4%	5.7%	0.0%	5.7%	5.7%	9.4%	18.9%	13.2%	5.7%	1.9%	9.4%	5.7%
MT	32,105	7.3%	5.8%	1.9%	5.8%	7.7%	9.6%	17.3%	13.5%	5.8%	1.9%	3.8%	7.7%
OK	152,939	7.2%	5.6%	0.0%	5.6%	5.6%	9.3%	16.7%	13.0%	5.6%	1.9%	11.1%	5.6%
NC	344,056	7.0%	9.4%	3.1%	0.0%	7.8%	7.8%	10.9%	10.9%	4.7%	7.8%	4.7%	9.4%
UT	141,181	6.6%	5.1%	0.0%	3.4%	8.5%	6.8%	20.3%	13.6%	3.4%	3.4%	3.4%	5.1%
NE	69,446	6.6%	4.9%	0.0%	4.9%	4.9%	8.2%	16.4%	13.1%	4.9%	3.3%	4.9%	6.6%
VA	284,411	5.8%	9.8%	1.8%	2.4%	5.5%	9.1%	9.8%	9.8%	4.3%	3.7%	3.0%	4.3%
MS	109,048	5.3%	4.6%	0.9%	4.6%	3.7%	7.3%	12.8%	11.0%	2.8%	3.7%	4.6%	1.8%
MA	212,322	5.1%	2.8%	0.0%	4.2%	6.9%	4.2%	12.5%	8.3%	5.6%	2.8%	4.2%	4.2%
WI	193,571	4.8%	6.3%	0.0%	6.3%	4.8%	6.3%	7.9%	6.3%	6.3%	3.2%	0.0%	4.8%
IN	232,408	4.5%	3.4%	0.0%	0.0%	5.2%	6.9%	12.1%	6.9%	1.7%	6.9%	3.4%	3.4%
GA	387,492	4.3%	6.1%	0.0%	1.5%	6.1%	6.1%	12.1%	4.5%	1.5%	4.5%	1.5%	3.0%
AZ	246,941	3.9%	3.6%	1.8%	3.0%	3.6%	4.8%	7.2%	6.6%	4.2%	1.8%	1.8%	4.2%
ME	40,532	3.2%	6.3%	2.5%	0.0%	0.0%	2.5%	16.5%	3.8%	0.0%	1.3%	0.0%	2.5%
MN	190,418	3.1%	5.1%	1.0%	0.0%	5.1%	3.1%	8.2%	6.1%	0.0%	3.1%	2.0%	0.0%
ND	23,676	3.0%	1.4%	0.0%	1.4%	2.7%	4.1%	11.0%	8.2%	2.7%	0.0%	0.0%	1.4%
TX	1,162,577	2.6%	3.1%	0.0%	0.8%	2.4%	3.1%	7.9%	3.1%	1.6%	3.1%	2.4%	1.6%
SC	168,047	2.6%	2.5%	0.0%	1.7%	1.7%	3.3%	8.3%	5.0%	1.7%	2.5%	1.7%	0.8%
PA	387,209	2.3%	2.1%	1.4%	0.0%	0.7%	3.4%	8.9%	4.8%	0.7%	2.7%	0.7%	0.0%
AK	29,138	2.0%	1.1%	0.0%	3.2%	5.3%	1.1%	7.4%	2.1%	1.1%	0.0%	0.0%	1.1%
OH	383,132	1.8%	0.0%	0.0%	0.0%	1.6%	1.6%	9.7%	3.2%	0.0%	1.6%	1.6%	0.0%
FL	612,401	1.8%	0.9%	0.0%	1.8%	0.9%	1.8%	6.4%	3.7%	0.0%	0.9%	1.8%	0.9%
	Maximum	8.8%	12.9%	3.1%	9.0%	10.4%	14.3%	22.6%	16.7%	9.0%	8.9%	11.1%	9.4%
	Minimum	1.8%	0.0%	0.0%	0.0%	0.0%	1.1%	6.4%	2.1%	0.0%	0.0%	0.0%	0.0%
	Unweighted Average	6.5%	5.1%	0.3%	4.7%	6.5%	8.2%	15.1%	11.8%	4.9%	3.2%	5.8%	5.3%
	Population Weighted Average	6.4%	4.8%	0.3%	4.1%	6.0%	7.5%	13.7%	10.6%	4.3%	3.4%	5.4%	4.7%

Framework origin color key: green: NGSS; blue: NGSS highbred; yellow: state specific

Support for SE at the national scale. On a prima facie basis, all states include elements within their frameworks that can support some aspects of SE. Although averaged total alignment ranges from 1.8% to 8.8% of PEXEs, no state has zero. The population weighted average reveals that overall 6.4% of PEXEs in current use align with the SPs and SIs identified in this investigation, while individual SPs and SIs were found to have alignment at the national level ranging from 0.3% to 13.7%. Moreover, NGSS and NGSS hybrid states have standards that align with the investigation SPs and SIs at a level ranging from 5.1% (Massachusetts) up to 8.8% (Missouri) with five states that publish independent frameworks falling within this range. Collectively, these states represent 63% of U.S. public school enrollment in grades six through eight. This represents a significant opportunity for integrating SE within the established frameworks governing the science curricula of a sizable fraction of U.S. public school students.

Yet, this representation is incomplete. Public schools are mandated to cover all standards, as opposed to focusing on a subset of “key” ones. Frameworks with a higher proportion of “related” standards that provide enabling knowledge to SE topics can more easily accommodate sustainability education while serving the overarching goal of teaching the frameworks as they are written. Data for PEXEs rated as “related” were tabulated, integrated with enrollment data, and summed to produce an overall average of the SPs and SIs by state (Table 31) to provide a means of examining this aspect of support for SE within a state science framework. Again, an overall national average value and enrollment weighted averages were calculated.

$$National\ Average\ Related\ = \frac{\sum_1^8 SP(i) +\ \sum_1^3 SI(i)}{11}$$

Where: $i = number\ of\ SPs\ or\ SIs$

SPi: state average sustainability principle (i) for "related"

SIi: state average sustainability issue (i) for "related"

$$Population\ Weighted\ Average\ = \frac{\sum_{i=1}^{51}(PEXErel(i) \cdot ENRms(i))}{\sum_{i=1}^{51} ENRms\ (i)}$$

Where: *i = 51 U.S. states and the District of Columbia*

PEXErel(i) = percent of PEXEs rated either core or opportunity (for SP, SI, or CO National Average) in the state

ENRms(i) = middle school enrollment students in the state

There is a patchwork of potential support for integrating SE into curricula on a state-by-state basis (Table 31). While overall state averages (both weighted and unweighted) show that a sizable proportion of standards are related to each SP and SI, there is a substantial range. SP7 for example is 15.7% of PEXEs rated as "related" across the nation while SP2 is roughly 1/3 that value at 5.3%. Importantly, an examination of minimum values demonstrate that some states have little or no "related" support for SE for many of the sustainability principles and issues.

Combining these data with results for "core and "opportunity" alignment (Table 32) establishes that a sizable proportion (15.4%) of the standards currently in place within state science frameworks in the United States provide the infrastructure for building SE based curricula. In this view, standards that are rated as "related" are foundation knowledge that can be taught leading into an SE themed unit with the "core" and "opportunity" standards being the focal endpoints.

Table 31. Related rating alignment of SPs and SIs with enrollment data.

State	M.S. Enrollment	Overall Average Related	SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SI1	SI2	SI3
AK	29,138	8.1%	10.5%	1.1%	1.1%	17.9%	17.9%	14.7%	18.9%	4.2%	0.0%	3.2%	0.0%
Al	165,301	9.3%	7.5%	3.8%	9.4%	3.8%	17.0%	13.2%	18.9%	9.4%	9.4%	3.8%	5.7%
AR	109,048	9.4%	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
AZ	246,941	6.2%	6.6%	3.0%	2.4%	15.6%	12.0%	8.4%	7.8%	2.4%	3.6%	4.2%	2.4%
CA	1,402,122	9.4%	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
CO	197,475	11.1%	9.9%	6.9%	9.9%	5.9%	21.8%	10.9%	22.8%	9.9%	6.9%	8.9%	7.9%
CT	120,545	9.4%	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
DC	17,983	9.4%	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
DE	29,775	9.4%	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
FL	612,401	8.5%	5.5%	0.9%	1.8%	28.4%	13.8%	11.9%	15.6%	4.6%	8.3%	1.8%	0.9%
GA	387,492	7.9%	4.5%	6.1%	6.1%	1.5%	21.2%	12.1%	15.2%	4.5%	7.6%	4.5%	3.0%
HI	40,513	9.4%	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
IA	112,245	9.4%	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
ID	64,614	11.0%	17.0%	5.7%	7.5%	3.8%	18.9%	15.1%	18.9%	9.4%	13.2%	3.8%	7.5%
IL	455,420	9.4%	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
IN	232,408	7.4%	10.3%	1.7%	12.1%	5.2%	12.1%	10.3%	12.1%	10.3%	1.7%	0.0%	5.2%
KS	110,460	9.4%	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
KY	152,968	9.4%	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
LA	159,223	10.8%	14.8%	7.4%	9.3%	3.7%	16.7%	16.7%	16.7%	7.4%	14.8%	3.7%	7.4%
MA	212,322	6.5%	8.3%	4.2%	5.6%	1.4%	13.9%	6.9%	13.9%	5.6%	5.6%	2.8%	2.8%
MD	194,256	9.4%	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
ME	40,532	7.7%	8.9%	1.3%	3.8%	16.5%	15.2%	6.3%	16.5%	3.8%	6.3%	5.1%	1.3%
MI	341,619	9.4%	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
MN	190,418	7.3%	8.2%	1.0%	2.0%	11.2%	16.3%	10.2%	16.3%	4.1%	5.1%	3.1%	3.1%
MO	203,868	10.4%	14.8%	7.4%	9.3%	3.7%	14.8%	16.7%	16.7%	7.4%	13.0%	3.7%	7.4%
MS	109,048	7.1%	9.2%	3.7%	6.4%	3.7%	16.5%	8.3%	14.7%	4.6%	6.4%	2.8%	1.8%
MT	32,105	10.0%	11.5%	5.8%	9.6%	3.8%	17.3%	13.5%	15.4%	7.7%	13.5%	7.7%	3.8%
NC	344,056	9.2%	12.5%	4.7%	9.4%	3.1%	21.9%	12.5%	20.3%	7.8%	1.6%	4.7%	3.1%
ND	23,676	7.6%	4.1%	2.7%	2.7%	15.1%	11.0%	4.1%	20.5%	8.2%	9.6%	4.1%	1.4%
NE	69,446	9.7%	11.5%	6.6%	9.8%	4.9%	16.4%	11.5%	14.8%	6.6%	13.1%	6.6%	4.9%
NH	41,021	9.4%	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
NJ	311,111	9.4%	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
NM	75,605	9.4%	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
NV	102,000	9.4%	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
NY	608,900	8.9%	12.9%	6.5%	8.1%	3.2%	14.5%	11.3%	14.5%	6.5%	11.3%	3.2%	6.5%
OH	383,132	6.5%	11.3%	1.6%	1.6%	0.0%	19.4%	12.9%	14.5%	1.6%	3.2%	3.2%	1.6%
OK	152,939	9.6%	14.8%	5.6%	7.4%	3.7%	16.7%	14.8%	16.7%	5.6%	11.1%	1.9%	7.4%
OR	133,571	9.4%	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
PA	387,209	6.6%	4.1%	4.1%	5.5%	13.7%	8.9%	2.7%	12.3%	8.9%	6.2%	2.1%	4.1%
RI	31,533	9.4%	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
SC	168,047	7.1%	6.6%	0.8%	3.3%	23.1%	11.6%	6.6%	14.0%	2.5%	5.0%	0.8%	3.3%
SD	29,552	11.2%	13.5%	7.7%	9.6%	5.8%	21.2%	11.5%	19.2%	7.7%	13.5%	7.7%	5.8%
TN	221,125	11.2%	11.4%	5.7%	8.6%	2.9%	21.4%	14.3%	21.4%	11.4%	11.4%	7.1%	7.1%
TX	1,162,577	5.7%	7.1%	2.4%	2.4%	16.5%	10.2%	7.9%	10.2%	1.6%	1.6%	0.0%	2.4%
UT	141,181	10.5%	13.6%	6.8%	10.2%	3.4%	20.3%	8.5%	18.6%	8.5%	11.9%	6.8%	6.8%
VA	284,411	8.9%	10.4%	4.3%	7.3%	19.5%	13.4%	9.8%	13.4%	5.5%	4.9%	4.9%	4.3%
VT	19,394	9.4%	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
WA	238,487	9.4%	13.6%	6.8%	8.5%	3.4%	15.3%	11.9%	15.3%	6.8%	11.9%	3.4%	6.8%
WI	193,571	8.4%	4.8%	1.6%	1.6%	38.1%	9.5%	4.8%	15.9%	1.6%	6.3%	6.3%	1.6%
WV	62,265	8.5%	11.9%	7.5%	7.5%	3.0%	14.9%	7.5%	14.9%	6.0%	9.0%	7.5%	4.5%
WY	20,895	9.6%	13.8%	6.9%	8.6%	3.4%	15.5%	12.1%	15.5%	6.9%	12.1%	3.4%	6.9%
	Maximum	11.2%	17.0%	7.7%	12.1%	38.1%	21.9%	16.7%	22.8%	11.4%	14.8%	8.9%	7.9%
	Minimum	5.7%	4.1%	0.8%	1.1%	0.0%	8.9%	2.7%	7.8%	1.6%	0.0%	0.0%	0.0%
	Unweighted average	8.9%	11.4%	5.3%	7.2%	6.9%	15.6%	11.1%	15.7%	6.4%	9.5%	3.9%	5.2%
	Weighted Average	8.5%	10.7%	4.9%	6.6%	8.2%	15.0%	10.8%	14.9%	5.9%	8.4%	3.2%	4.9%

Framework origin color key: green: NGSS; blue: NGSS highbred; yellow: state specific

Table 32. Combined COR support for SE.

State	Average Core Ratings	Average Opportunity Rating	Average Related Rating	Combined: Core, Opportunity, and Related	Middle School Enrollment	Cumulative Percentage of U.S. Enrollment
TN	0.4%	7.8%	11.2%	19.3%	221,125	2.0%
MO	0.5%	8.2%	10.4%	19.2%	203,868	3.8%
SD	0.2%	7.3%	11.2%	18.7%	29,552	4.1%
LA	0.7%	7.2%	10.8%	18.7%	159,223	5.5%
CO	0.2%	7.3%	11.1%	18.5%	197,475	7.3%
ID	0.5%	6.9%	11.0%	18.4%	64,614	7.8%
WY	0.6%	7.5%	9.6%	17.7%	20,895	8.0%
AR	0.6%	7.4%	9.4%	17.4%	109,048	9.0%
CA	0.6%	7.4%	9.4%	17.4%	1,402,122	21.5%
CT	0.6%	7.4%	9.4%	17.4%	120,545	22.6%
DC	0.6%	7.4%	9.4%	17.4%	17,983	22.8%
DE	0.6%	7.4%	9.4%	17.4%	29,775	23.1%
HI	0.6%	7.4%	9.4%	17.4%	40,513	23.4%
IA	0.6%	7.4%	9.4%	17.4%	112,245	24.4%
IL	0.6%	7.4%	9.4%	17.4%	455,420	28.5%
KS	0.6%	7.4%	9.4%	17.4%	110,460	29.5%
KY	0.6%	7.4%	9.4%	17.4%	152,968	30.9%
MD	0.6%	7.4%	9.4%	17.4%	194,256	32.6%
MI	0.6%	7.4%	9.4%	17.4%	341,619	35.6%
NH	0.6%	7.4%	9.4%	17.4%	41,021	36.0%
NJ	0.6%	7.4%	9.4%	17.4%	311,111	38.8%
NM	0.6%	7.4%	9.4%	17.4%	75,605	39.5%
NV	0.6%	7.4%	9.4%	17.4%	102,000	40.4%
OR	0.6%	7.4%	9.4%	17.4%	133,571	41.6%
RI	0.6%	7.4%	9.4%	17.4%	31,533	41.9%
VT	0.6%	7.4%	9.4%	17.4%	19,394	42.0%
WA	0.6%	7.4%	9.4%	17.4%	238,487	44.2%
MT	0.3%	7.0%	10.0%	17.3%	32,105	44.5%
UT	0.2%	6.5%	10.5%	17.1%	141,181	45.7%
AL	0.5%	7.2%	9.3%	17.0%	165,301	47.2%
OK	0.5%	6.7%	9.6%	16.8%	152,939	48.6%
NY	0.6%	7.0%	8.9%	16.6%	608,900	54.0%
NE	0.3%	6.3%	9.7%	16.2%	69,446	54.6%
NC	0.7%	6.2%	9.2%	16.1%	344,056	57.7%
WV	0.3%	7.2%	8.5%	16.0%	62,265	58.3%
VA	0.1%	5.7%	8.9%	14.6%	284,411	60.8%
WI	0.6%	4.2%	8.4%	13.1%	193,571	62.6%
MS	0.2%	5.1%	7.1%	12.3%	109,048	63.5%
GA	0.3%	4.0%	7.9%	12.1%	387,492	67.0%
IN	0.3%	4.2%	7.4%	11.9%	232,408	69.1%
MA	0.4%	4.7%	6.5%	11.5%	212,322	71.0%
ME	0.0%	3.2%	7.7%	10.9%	40,532	71.3%
ND	0.1%	2.9%	7.6%	10.6%	23,676	71.5%
MN	0.1%	3.0%	7.3%	10.4%	190,418	73.3%
FL	0.1%	1.7%	8.5%	10.3%	612,401	78.7%
AK	0.0%	2.0%	8.1%	10.2%	29,138	79.0%
AZ	0.0%	3.9%	6.2%	10.1%	246,941	81.2%
SC	0.1%	2.6%	7.1%	9.7%	168,047	82.7%
PA	0.1%	2.2%	6.6%	8.9%	387,209	86.2%
TX	0.1%	2.6%	5.7%	8.3%	1,162,577	96.6%
OH	0.0%	1.8%	6.5%	8.2%	383,132	100.0%
Average	0.4%	6.0%	8.9%	15.4%	---	---
Weighted Average	0.4%	5.5%	8.5%	14.4%	---	---

Framework origin color key: green: NGSS; blue: NGSS highbred; yellow: state specific

To contextualize the findings concerning "related" standards on a nationwide basis, a color-coded table separating national average ratings for "related" on a state-by-state basis was developed with green again representing the top one third cohort, orange the middle cohort, and red the bottom one third cohort (Table 33). This provides a sort of visual ranking of this aspect of existing frameworks and prepares the data for integration with the other results thus far presented into an integrated format that can show the overall picture of support for SE on a nationwide basis.

Table 33. State average related ratings color coded by cohort.

State	Average Related Rating	State	Average Related Rating	State	Average Related Rating
SD	11.2%	Al	9.3%	NY	8.9%
TN	11.2%	NC	9.2%	VA	8.9%
CO	11.1%			WV	8.5%
ID	11.0%			FL	8.5%
LA	10.8%			WI	8.4%
UT	10.5%			AK	8.1%
MO	10.4%			GA	7.9%
MT	10.0%			ME	7.7%
NE	9.7%			ND	7.6%
OK	9.6%			IN	7.4%
WY	9.6%			MN	7.3%
AR	9.4%			MS	7.1%
CA	9.4%			SC	7.1%
CT	9.4%			PA	6.6%
DC	9.4%			MA	6.5%
DE	9.4%			OH	6.5%
HI	9.4%			AZ	6.2%
IA	9.4%			TX	5.7%
IL	9.4%				
KS	9.4%				
KY	9.4%				
MD	9.4%				
MI	9.4%				
NH	9.4%				
NJ	9.4%				
NM	9.4%				
NV	9.4%				
OR	9.4%				
RI	9.4%				
VT	9.4%				
WA	9.4%				

Framework origin color key: green: NGSS; blue: NGSS highbred; yellow: state specific

Cohort analysis and state-level support for SE. Determining how many middle school students could potentially receive sustainability education within science classrooms requires examination at the state level where a subtler picture develops. This investigation was designed around a conceptual framework that posits two conditions must be met for SE to be widely implemented within science classrooms. First, state level framework organization must be flexible enough to support the interdisciplinary nature of SE. Second, the standards must incorporate or direct student learning towards SE related topics and concepts. Because of this, the study design looked at framework organization, the explicit or implicit inclusion of sustainability within its requirements for student learning, and the degree to which individual PEXEs aligned with sustainability principles and sustainability issues on the CORBNR rating scale. Each of these has the capacity to contribute to the ability of a framework to support SE and answering this research question requires building an integrated picture of these separate elements.

Table 34 helps to visualize this large-scale picture formed by looking at these dimensions simultaneously. It incorporates data columns for state level organization, a combined rating for explicit/implicit sustainability inclusion, and averages for the "core," "opportunity," and "related" designations on the CORBNR rating scale using the color-coded presentation separated by high, medium, and low cohorts previously described. As before, shading in the state column shows the origin of the framework with green indicating an NGSS state, yellow indicating states that independently developed their framework, and blue used for states that hybridized the NGSS.

Table 34. State ability to support SE based on 5 metrics shown in cohorts.

State	State Level Organization	Explicit or Implicit Sustainability	Average Core Ratings	Average Opportunity Rating	Average Related Rating
AK	Spiraled	4.2%	0.0%	2.0%	8.1%
Al	Single Discipline	9.4%	0.5%	7.2%	9.3%
AR	Spiraled	15.3%	0.6%	7.4%	9.4%
AZ	Spiraled	4.8%	0.0%	3.9%	6.2%
CA	Spiraled	15.3%	0.6%	7.4%	9.4%
CO	Spiraled	12.9%	0.2%	7.3%	11.1%
CT	Flexible	15.3%	0.6%	7.4%	9.4%
DC	Flexible	15.3%	0.6%	7.4%	9.4%
DE	Spiraled	15.3%	0.6%	7.4%	9.4%
FL	Spiraled	2.8%	0.1%	1.7%	8.5%
GA	Single Discipline	6.1%	0.3%	4.0%	7.9%
HI	Flexible	15.3%	0.6%	7.4%	9.4%
IA	Spiraled	15.3%	0.6%	7.4%	9.4%
ID	Flexible	13.2%	0.5%	6.9%	11.0%
IL	Flexible	15.3%	0.6%	7.4%	9.4%
IN	Spiraled	8.6%	0.3%	4.2%	7.4%
KS	Flexible	15.3%	0.6%	7.4%	9.4%
KY	Flexible	15.3%	0.6%	7.4%	9.4%
LA	Spiraled	14.8%	0.7%	7.2%	10.8%
MA	Spiraled	8.3%	0.4%	4.7%	6.5%
MD	Flexible	15.3%	0.6%	7.4%	9.4%
ME	Flexible	2.5%	0.0%	3.2%	7.7%
MI	Flexible	15.3%	0.6%	7.4%	9.4%
MN	Single Discipline	7.1%	0.1%	3.0%	7.3%
MO	Flexible	14.8%	0.5%	8.2%	10.4%
MS	Spiraled	11.0%	0.2%	5.1%	7.1%
MT	Flexible	13.5%	0.3%	7.0%	10.0%
NC	Spiraled	14.1%	0.7%	6.2%	9.2%
ND	Spiraled	15.1%	0.1%	2.9%	7.6%
NE	Spiraled	13.1%	0.3%	6.3%	9.7%
NH	Flexible	15.3%	0.6%	7.4%	9.4%
NJ	Spiraled	15.3%	0.6%	7.4%	9.4%
NM	Flexible	15.3%	0.6%	7.4%	9.4%
NV	Flexible	15.3%	0.6%	7.4%	9.4%
NY	Flexible	14.5%	0.6%	7.0%	8.9%
OH	Spiraled	0.0%	0.0%	1.8%	6.5%
OK	Spiraled	13.0%	0.5%	6.7%	9.6%
OR	Spiraled	15.3%	0.6%	7.4%	9.4%
PA	Flexible	5.5%	0.1%	2.2%	6.6%
RI	Flexible	15.3%	0.6%	7.4%	9.4%
SC	Spiraled	3.3%	0.1%	2.6%	7.1%
SD	Flexible	13.5%	0.2%	7.3%	11.2%
TN	Spiraled	15.7%	0.4%	7.8%	11.2%
TX	Spiraled	4.7%	0.1%	2.6%	5.7%
UT	Spiraled	13.6%	0.2%	6.5%	10.5%
VA	Flexible	9.8%	0.1%	5.7%	8.9%
VT	Flexible	15.3%	0.6%	7.4%	9.4%
WA	Flexible	15.3%	0.6%	7.4%	9.4%
WI	Flexible	9.5%	0.6%	4.2%	8.4%
WV	Spiraled	13.4%	0.3%	7.2%	8.5%
WY	Flexible	15.5%	0.6%	7.5%	9.6%

Framework origin color key: green: NGSS; blue: NGSS highbred; yellow: state specific

After integrating these into a single presentation, the table was sorted, so states with all five indicators falling within the respective bottom third were organized at the bottom, while those with five indicators falling at the top third located at the top. Next came states with four of the indicators at either the bottom or the top, followed by three, and so on. The resulting table produces a gradient between states where all the study metrics were most favorable for incorporating SE trending toward states where all the metrics were least favorable (Table 35).

The cohort analysis shown in Table 35 grew out of an effort to help visualize and understand the differences between various state frameworks with respect to supporting sustainability education. Early on, it was recognized that answering research question four could take on an arbitrary aspect, despite efforts to quantify differences between state standards. How much support within a state framework is "enough" to make SE feasible is not readily quantified, while it is easier and more practical to show the gradient that exists between states and highlight the differences. For this reason, Table 35 was built around three tiered cohorts across five separate metrics.

Five metrics integrated into a composite rating. The first of these metrics is state level organization, deemed critical because building coherent SE themed units may benefit from integrating disparate standards. Conversely, a rigid curriculum may have all the pieces necessary but locked in a place that makes it impossible to build an intelligible understanding of the sustainability principles.

Table 35. Overall State support for SE based on sorted cohort data.

State	State Level Organization	Explicit or Implicit Sustainability	Average Core Ratings	Average Opportunity Rating	Average Related Rating	
CT	Flexible	15.3%	0.6%	7.4%	9.4%	Group 1
DC	Flexible	15.3%	0.6%	7.4%	9.4%	
HI	Flexible	15.3%	0.6%	7.4%	9.4%	
IL	Flexible	15.3%	0.6%	7.4%	9.4%	
KS	Flexible	15.3%	0.6%	7.4%	9.4%	
KY	Flexible	15.3%	0.6%	7.4%	9.4%	
MD	Flexible	15.3%	0.6%	7.4%	9.4%	
MI	Flexible	15.3%	0.6%	7.4%	9.4%	
NH	Flexible	15.3%	0.6%	7.4%	9.4%	
NM	Flexible	15.3%	0.6%	7.4%	9.4%	
NV	Flexible	15.3%	0.6%	7.4%	9.4%	
RI	Flexible	15.3%	0.6%	7.4%	9.4%	
VT	Flexible	15.3%	0.6%	7.4%	9.4%	
WA	Flexible	15.3%	0.6%	7.4%	9.4%	
WY	Flexible	15.5%	0.6%	7.5%	9.6%	
AR	Spiraled	15.3%	0.6%	7.4%	9.4%	Group 2
CA	Spiraled	15.3%	0.6%	7.4%	9.4%	
DE	Spiraled	15.3%	0.6%	7.4%	9.4%	
IA	Spiraled	15.3%	0.6%	7.4%	9.4%	
NJ	Spiraled	15.3%	0.6%	7.4%	9.4%	
OR	Spiraled	15.3%	0.6%	7.4%	9.4%	
MO	Flexible	14.8%	0.5%	8.2%	10.4%	Group 3
TN	Spiraled	15.7%	0.4%	7.8%	11.2%	
ID	Flexible	13.2%	0.5%	6.9%	11.0%	
LA	Spiraled	14.8%	0.7%	7.2%	10.8%	
OK	Spiraled	13.0%	0.5%	6.7%	9.6%	
MT	Flexible	13.5%	0.3%	7.0%	10.0%	
NY	Flexible	14.5%	0.6%	7.0%	8.9%	
SD	Flexible	13.5%	0.2%	7.3%	11.2%	
NC	Spiraled	14.1%	0.7%	6.2%	9.2%	
NE	Spiraled	13.1%	0.3%	6.3%	9.7%	
UT	Spiraled	13.6%	0.2%	6.5%	10.5%	
CO	Spiraled	12.9%	0.2%	7.3%	11.1%	
Al	Single Discipline	9.4%	0.5%	7.2%	9.3%	
WV	Spiraled	13.4%	0.3%	7.2%	8.5%	
WI	Flexible	9.5%	0.6%	4.2%	8.4%	
MA	Spiraled	8.3%	0.4%	4.7%	6.5%	
ND	Spiraled	15.1%	0.1%	2.9%	7.6%	Group 4
ME	Flexible	2.5%	0.0%	3.2%	7.7%	
PA	Flexible	5.5%	0.1%	2.2%	6.6%	
VA	Flexible	9.8%	0.1%	5.7%	8.9%	
AK	Spiraled	4.2%	0.0%	2.0%	8.1%	
AZ	Spiraled	4.8%	0.0%	3.9%	6.2%	
FL	Spiraled	2.8%	0.1%	1.7%	8.5%	
IN	Spiraled	8.6%	0.3%	4.2%	7.4%	
MS	Spiraled	11.0%	0.2%	5.1%	7.1%	
OH	Spiraled	0.0%	0.0%	1.8%	6.5%	
SC	Spiraled	3.3%	0.1%	2.6%	7.1%	
TX	Spiraled	4.7%	0.1%	2.6%	5.7%	
GA	Single Discipline	6.1%	0.3%	4.0%	7.9%	
MN	Single Discipline	7.1%	0.1%	3.0%	7.3%	

Framework origin color key: green: NGSS; blue: NGSS highbred; yellow: state specific

The second metric was the combined score for the explicit requirement or implicit promotion of sustainability in framework standards. This was designed as a coarse-grained measure of language within the frameworks that broadly overlapped with sustainability related concepts. It was further supported by the third and fourth metrics. These were the average ratings of "core" and "opportunity" support for all standards in the state across all the SPs and SIs. They provide a direct focus on how strongly the state standards supported the sustainability principles and engaged the sustainability issues that could help integrate them. Finally, the average rating for "related" standards was included to represent the enabling knowledge that would make teaching the sustainability principles possible. It is the portion of a state framework that can be directly engaged by an SE themed unit as part of building an understanding in support of each SP.

The cohort analysis represents relative differences between the states with respect to elements within their frameworks that support the inclusion of sustainability education. There is no absolute scale as to what represents sufficient SE support for any of these metrics except for the state level organization where flexible is deemed to be superior to either spiraled or single discipline formats. Based on this analysis, reasonable conclusions may be drawn about which state frameworks have more potential support for SE than others.

Four groups emerge from the cohort analysis. The presentation in table 35 suggests four distinct groups of states emerge from this analysis, based on the pattern of top tier (green), middle tier (orange) or bottom tier (red) cohorts they fell into. These groups have been identified on the table and are discussed individual below.

1. Fifteen states at the top of Table 35 form a group with all five of the metrics coded green, indicating they are part of the top one third cohort. These states have adopted the NGSS except for Wyoming which is in NGSS derivative. The NGSS offers substantial support across all the SPs except for SP2, which no state supported well. When the average "core," "opportunity," and "related" ratings are combined for these states, a total of 17.4% of their standards are potentially engaged by developing SE themed units (Table 32) that are tied to the content concepts and skills required by their frameworks. This and support for local flexibility in sequencing curriculum within the frameworks, represents the most favorable conditions extant within the United States for implementing SE in public schools for grades six through eight.

This is deemed to be substantial potential support for sustainability. Using the previously derived figure of an average 133.5 hours of science instruction in middle school, a student could potentially be expected to participate in 24 hours of SE themed instruction built around existing standards within these state frameworks.

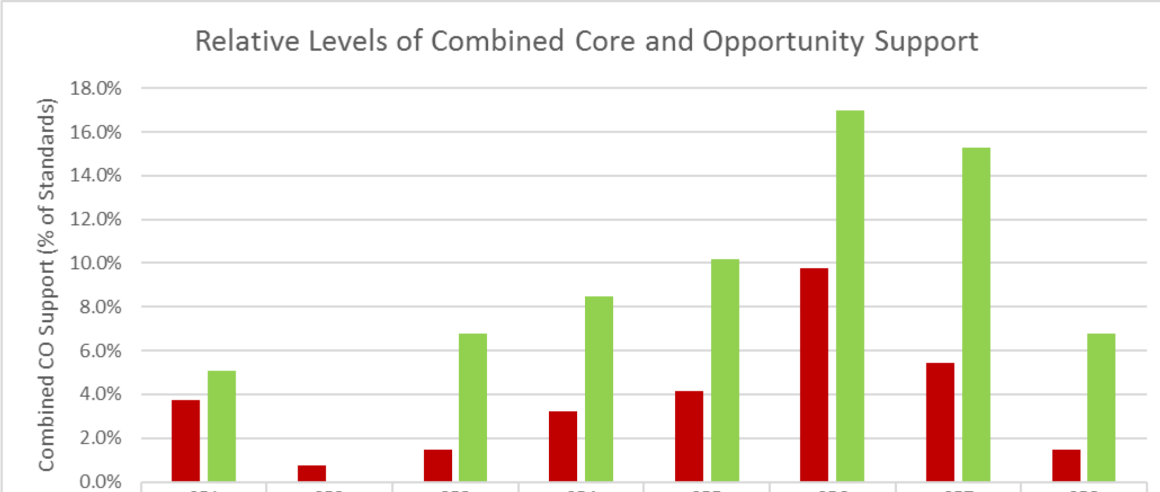
2. Directly below this group lie six states that are also NGSS but do not retain flexible curriculum organization. Each specifies a spiraled curriculum format that restricts local control over sequencing around potential SE themed units. Other than this restriction, the group retains all the characteristics of group 1.

How important is the lack of flexible sequencing? This is not easily answered. Educators may be willing to modify state sequencing for a variety of reasons, including the goal of building SE themed units. Conversely, standardized testing may make this impractical if it rigorously tests certain knowledge within a given school year. At best, it can be concluded this is a potential barrier to building or adopting SE themed units within these states.

3. The middle of the table is populated with states that transition between the top and bottom cohorts. Most have frameworks that are states NGSS derivatives, with a few that are independently developed (Tennessee, North Carolina, Colorado, and Wisconsin). Notably, the average "opportunity" and "related" ratings lie relatively close to those in the top cohort (green) as does the measure of explicit/implicit inclusion of sustainability. Six of these states retain flexible curriculum organization (Missouri, Idaho, Montana, New York, South Dakota, and Wisconsin) and these arguably retain a level of SE potential similar to group 1.

4. The bottom of the table is populated by two states which are in the red cohort for all five metrics and eleven that are in the red for four metrics. Among this group the only variation is in the state level organization of the frameworks. Three of the states qualified as flexible, while eight rated as spiraled and two as single discipline. All are independently developed frameworks with no link to the NGSS.

There is little evidence that this group of 13 states offers much potential support for integrating SE within their existing frameworks. They are characterized by much lower average "core" and "opportunity" ratings when compared to the NGSS frameworks that form the basis for group 1 (Figure 17). For educators in these states, integrating SE that embraced the full range of sustainability principles would likely require going beyond mandated frameworks and expanding their curriculum as a result. For educators trying to meet performance requirements on mandated state tests, this would be problematic.



	SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8
Group 4	3.7%	0.7%	1.5%	3.2%	4.2%	9.8%	5.4%	1.5%
Group 1	5.1%	0.0%	6.8%	8.5%	10.2%	17.0%	15.3%	6.8%

Figure 18. *Comparison of group 4 support for individuals SPs with group 1.*

Hypothesis 1 is accepted. The presentation in Table 35 makes it apparent that a minority of states (15) fall in the top third for all five of these metrics (Group 1) and potentially offer the most fertile ground for delivering robust SE. These states represent 18% of U.S. middle school enrollment. Conversely, nearly an equal number of states (13) score in the bottom third for at least four of the five metrics (Group 4) and thus present substantial hurdles to be overcome if SE is to be integrated. These states represent 35% of U.S. middle school enrollment. In between these extremes lie a mixture of characteristics that offer intermediate levels of support for SE implementation. Further, it is important to note that over half of the states (28) representing 66% of U.S. middle school enrollment either specify single discipline or spiraled curricula that restrict the flexibility for developing interdisciplinary curriculum sequences most favorable to SE themed units.

To integrate the results of these metrics with U.S. middle school enrollment, a weighted average of the number of "green" metrics in the state by middle school enrollment was computed using the following method:

$$Weighted\ Average\ 'Green' = \frac{\sum_{i=1}^{51}(Cg(i) \cdot ENRms(i))}{\sum_{i=1}^{51} ENRms\ (i)}$$

Where: *i = 51 U.S. states and the District of Columbia*

Cg(i) = number of categories rated "green" (top third of all states)

ENRms(i) = middle school enrollment in the state

The population weighted average was 2.1, meaning an "average" U.S. middle school science students is educated in a science classroom guided by state frameworks where 2.1 of these metrics fall in the top one third cohort.

This leads us to a more robust conclusion to research question number four. Although there is significant support for SE based on any one of these five measures, the support is highly variable across the states. The comprehensive view in Table 35 suggests important challenges exist for implementing sustainability education within the existing science frameworks of U.S. science classrooms. NGSS states and their hybrids offer a substantial level of support for SE within their frameworks, and many retain the capacity for flexible curriculum organization that makes sustainability education themed units a truly viable alternative. However, this capacity for across-the-board support based on these criteria is intact in just 15 states and is progressively eroded as you read further down the table. Despite the opportunities that exist, the hypothesis that the "majority of students in the United States public schools are subject to middle school frameworks that present significant challenges to integrating" SE is accepted.

To summarize, group 1 (all green) includes just 18% of all public-school students enrolled in grades six through eight in the United States. If the six states that retain flexible curriculum organization in group 3 are included, this rises to 28%. This is the portion of middle school students learning in schools guided by frameworks that offer high level of support for SE within the language of their standards and retained full flexibility to sequence their curriculum accordingly. While many of the other states in group 3 have similar, if slightly lower, potential support for SE within the language of their standards, only these six retain curriculum sequencing flexibility. This presents a potential leverage point for advocates who would like to promote wider implementation of SE within U.S. public schools. Flipping “spiraled” to “flexible” within groups 2 and 3 would expand this higher level of potential for SE inclusion to near 60% of U.S. students.

Core SE Themes Missing from Public Education Frameworks

Sustainability education principles are not explicitly articulated within existing science standards, as evidenced by the low levels of “core” support identified within U.S. Public school frameworks. The “core” alignment identified with sustainability issues supports the view that a substantial fraction of U.S. frameworks explicitly direct student learning towards issues relevant to sustainability without providing the conceptual context necessary for sustainability education to emerge from the standards. Although there are substantial levels of “opportunity” support for sustainability principles, this indicates general compatibility of the standard with the SP, without explicitly articulating the principle itself. SE is possible in this environment, but without more explicit (core) support within the frameworks, it is unlikely to emerge spontaneously. For advocates of

SE, identifying the key gaps may help focus efforts to integrate sustainability principles more fully into U.S. public education.

To uncover these gaps, an examination of sample standards from the NGSS and a selection of independently developed frameworks was conducted. The goal as to identify language characteristics that were common despite the independent origin of the frameworks.

Intragenerational equity. Certain ideas that are fundamental to sustainability are not explicit within U.S. frameworks. This was most clear in the data for SP2 which expresses the need for promoting intragenerational equity and widespread human well-being.

> Human interactions with the environment, including consumption patterns and use of natural resources should produce widespread well-being and equitable benefits for all peoples.

This goal of using the Earth's natural resources in a manner that is fair to all living humans is virtually nonexistent within state frameworks. No standards were found to rate as "core" (Table 20) and only eight states included a standard that rated as "opportunity" resulting in a nationwide average level of support of just 0.3 percent (Table 21). Notably, this SP is entirely absent within the NGSS and the hybrid frameworks derived from it; all support for SP2 was identified in states that independently develop their frameworks. Several examples help to understand what is missing.

North Carolina expresses relevant concepts, at the "opportunity" level, in standard 7.E.1.6 which states students must "Conclude that the good health of humans requires: monitoring the atmosphere, maintaining air quality and stewardship." (North Carolina Department of Public Instruction). This links human "well-being" to environmental quality and stewardship but lacks the theme of promoting intragenerational equity. Similarly, Maine performance indicator C3.b states "Identify personal choices that can either positively or negatively impact society including population, ecosystem sustainability, personal health, and environmental quality" (Maine Department of Education, 2015). This language also directs student learning toward understand how human activity affects society, as a homogeneous entity, but fails to acknowledge that more than one society exists, or that "society" may be divisible into groups that are not necessarily treated equitably. In sum, evidence indicates that a minority of standards recognize that human environmental impacts affect well-being but do not go so far as to directly address managing resource use in a manner that is fair and equitable to all people.

Addressing inequity has been a stated goal of sustainability since the concept began to emerge from United Nations documents forty-five years ago (United Nations, 1972). While U.S. state science frameworks express a need for environmental protection and stewardship, with an implied goal securing associated benefits for humans in the future, the idea that all living people have a right to share the benefits that come from accessing natural resources is entirely absent.

Human dependency on the environment. In a similar vein key themes about the human relationship with the environment are also poorly expressed within state frameworks. SP5 five focuses on the theme of interdependence; the idea that humanity exists within and as a part of nature versus separate outside of it. The principle reads:

> Humans depend upon Earth's physical and biological systems for environmental services and natural resources. Our collective well-being depends on maintaining and protecting their healthy and stable function.

This is a statement of human dependency upon maintaining healthy, functioning physical and biological systems on the planet. Only North Carolina supported this SP at the "core" level in standard 6.E.2.4:

> Conclude that the good health of humans requires: monitoring the lithosphere, maintaining soil quality and stewardship. (North Carolina Department of Public Instruction)

The state publishes very similar language in standards related to both air and water quality as well. The wording clearly expresses that stewardship of these resources is necessary for human health, which is a reasonable approximation that humans are dependent upon the "healthy and stable function" of earth's systems.

Outside of this, the SP5 garnered 8.1% support at the "opportunity" level. Again, NGSS and its hybrid derivatives for the backbone of this, though the independent frameworks of both Tennessee and Colorado scored higher. In general, this support was tied to thematic elements of protecting or maintaining the environment, benefits humans receive from it, or understanding human impact, while falling short of explicitly articulating the core theme that humans are dependent upon healthy environmental function. NGSS standard MS-ESS3-3 demonstrates this.

> Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.* [Clarification Statement: Examples of the design process include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact. Examples of human impacts can include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the

> removal of wetlands), and pollution (such as of the air, water, or land).] (NGSS Lead States, 2013)

The standard serves to direct student learning toward managing human environmental impact without expressing any connection to human well-being. Similarly, the Tennessee science standard 6.LS4.2 (Tennessee Department of Education, 2017) provides an additional example with the following language:

> Design a possible solution for maintaining biodiversity of ecosystems while still providing necessary human resources without disrupting environmental equilibrium. (p. 47)

This standard includes the thematic elements of environmental stewardship and human benefit from the exploitation of natural resources without quite expressing the theme that humans depend on the environment for maintaining our collective well-being. Both examples illustrate what appears as a pattern among state standards; humans are not explicitly portrayed as existing within nature. In no case were explicit barriers to this SP identified. Rather, the standards remain silent on the specific issue while humans are consistently depicted as needing to protect or maintain the environment as a separate entity.

Interconnectedness with earth systems. In a very similar vein, state standards failed to explicitly recognize that human social and economic systems are directly influenced by the health and function of natural systems. Sustainability principle seven expresses this as follows:

> Human social and economic systems are highly interconnected with Earth's physical and biological systems. Changes to any system produces effects on others.

This principle characterizes human social and economic systems as intertwined in a relationship of bidirectional feedback with Earth's physical and biological systems. All states included support for this principle at the "opportunity" level, and the NGSS had multiple standards that aligned at this level. Only one included a standard that rated as "core." Mississippi College and Career Readiness Standards for Science standard L.7.3.4 (Mississippi Department of Education, 2017) captures SP7 as follows:

> Explain how disruptions in cycles (e.g., water, oxygen, carbon, and nitrogen) affect biodiversity and ecosystem services (e.g., water, food, and medications) which are needed to sustain human life on Earth. (p. 52)

This clearly expresses that disruptions to natural systems have consequences with respect to sustaining human life. Most states were not this clear and incorporated thematic elements of humans impacting the environment, without the reciprocal relationship. Moreover, this unidirectional relationship is equally evident in standard published by the states that had the lowest and highest overall combined average support for the SPs and SIs. The lowest is represented by Florida standard SC.7.E.6.6 which reads:

> Identify the impact that humans have had on Earth, such as deforestation, urbanization, desertification, erosion, air and water quality, changing the flow of water. (Florida State University, 2017)

And, the highest is represented by Tennessee standard 6.ESS2.4. (Tennessee Department of Education, 2017)

> Apply scientific principles to design a method to analyze and interpret the impact of humans and other organisms on the hydrologic cycle. (p. 48)

Both states exemplify what appears to be a consistent bias to recognize human impact on the environment without explicitly acknowledging the feedback that this must consequently have on humans. This orientation is inconsistent with core tenets of sustainability thinking that firmly places humans within nature. While the omission does not qualify as an “barrier” according to the design of this study and the way standards were coded, it does represent an obstacle for SE advocates. The “opportunity” level support that exists within frameworks suggests that the space exists for SE themed units to be designed in such a manner as to incorporate these themes will still adhering to the standards. That said, the cues to direct educators in this direction are not currently present.

Power Standards

During analysis of the results, it was observed that certain individual standards within a state framework seem to exert outsized influence on the level of the “core” and “opportunity” ratings. These standards provided “core” or “opportunity” support across multiple sustainability principles and issues and greatly strengthen the overall potential support for SE within the framework. I have termed them “power standards” (Table 36). I have defined a “power standard” as any PEXE that provides combined “core” or “opportunity” support for at least 70% of SPs and SIs. The 70% threshold was chosen based on analysis of the NGSS which showed a sharp drop off in impact below that cut off; the next closest standard generating only 54% combined support. Reading and analysis of the language within these “power standards” revealed that they fit within two broad groups. The first group consist of standards that directed student learning towards understanding human impact upon the environment (shaded blue). The second group consist of standards that directed student learning towards designing or evaluating solutions to environmental problems (shaded green). Further discussion of both groups will follow.

Table 36. Power standards from NGSS and Independent State frameworks.

Standard	SP1	SP2	SP3	SP4	SP5	SP6	SP7	SP8	SI1	SI2	SI3	Overall CO Support
Arizona 8.3.1.1	O	O	O	O	O	O	O	O	O	R	O	90.9%
Virginia 6.9.d	O	O	O	O	O	O	O	C	O	R	O	90.9%
Arizona 7.3.1.1	O	R	O	O	O	O	O	O	O	R	O	81.8%
Arizona 8.3.1.2	O	O	O	O	O	O	O	O	R	R	O	81.8%
Georgia S6E6.b	C	R	O	O	O	O	O	O	R	O	O	81.8%
Mississippi L.7.3.5	O	NR	O	O	O	O	O	O	R	O	O	81.8%
NGSS MS-ESS3-4	O	R	O	O	O	O	O	O	R	O	C	81.8%
North Carolina 7.E.1.6	O	O	R	O	C	O	O	O	O	NR	O	81.8%
Virginia 6.7.f	O	O	R	O	O	O	O	O	NR	O	O	81.8%
Wisconsin F81	O	NR	O	O	O	O	O	O	O	R	C	81.8%
Alaska 7SD2.1	O	R	O	O	O	O	O	O	NR	NR	O	72.7%
Arizona 7.3.1.2	O	R	O	O	O	O	O	O	NR	B	O	72.7%
Arizona 7.3.1.3	O	R	O	O	O	O	O	O	R	R	O	72.7%
Colorado 6.2.C	O	R	R	O	O	O	O	O	NR	O	O	72.7%
Mississippi E.8.10.2	O	NR	O	O	O	O	O	O	R	R	O	72.7%
Mississippi E.8.10.4	O	R	O	O	O	O	O	O	O	NR	NR	72.7%
NGSS MS-ESS3-3	O	NR	O	B	O	O	O	O	R	O	O	72.7%
NGSS MS-LS2-5	O	NR	O	O	O	O	O	C	NR	R	O	72.7%
North Carolina 6.E.2.4	O	O	R	O	C	O	O	O	NR	NR	O	72.7%
North Carolina 68.E.1.4	O	R	R	O	C	O	O	O	NR	C	O	72.7%
Tennessee 6.ETS.1.1	O	NR	O	O	O	O	O	O	R	R	O	72.7%
Texas 6.7.B	O	R	O	O	O	O	O	O	O	NR	R	72.7%
Texas 7.8.C	O	NR	O	O	O	O	O	O	NR	C	O	72.7%
Virginia 6.5.f	O	R	R	O	O	O	O	O	NR	O	O	72.7%
Virginia 6.6.d	O	R	R	O	O	O	O	O	O	NR	O	72.7%
Virginia 6.9.c	O	R	O	O	O	O	O	O	NR	NR	O	72.7%
Wisconsin E86	C	R	O	O	O	O	O	O	R	R	C	72.7%
Wisconsin H82	O	NR	C	O	O	O	O	O	R	R	O	72.7%

Table 37. shows the impact of power standards on the NGSS and states that independently developed frameworks (hybrid states have been omitted because power standards within those frameworks closely mirror the NGSS). The table lists the number of power standards that occur within the curriculum and the average combined CO

support for the full range of SPs and SIs. The fourth column indicates the percentage of the support the support within the framework that was provided by the power standards.

Table 37. Power standards and their impact on SE potential.

Framework	Number of Power Standards (Total Number of Standards)	Overall Average CO Support for SPs and SIs (%)	Support Provided by Power Standards (%)
Wisconsin	3 (63)	4.76	75.8
Arizona	5 (167)	3.86	62.0
North Carolina	3 (64)	6.96	51.0
NGSS	3 (59)	8.01	48.1
Texas	2 (127)	2.65	43.2
Mississippi	3 (109)	5.25	41.5
Alaska	1 (95)	2.01	38.1
Virginia	5 (164)	5.76	33.7
Georgia	1 (66)	4.27	29.0
Tennessee	1 (70)	8.18	12.7
Colorado	1 (101)	7.47	9.6

For example, the NGSS includes three power standards out of a total of 59 in the framework. The framework provides an overall average CO support of 8.01% for the SPs and SIs and the three power standards accounted for 48.1% of this support. Overall, "power standards" provide an average of 40% of the support for SE found within the various state frameworks though they represent fewer than 5% of the total number of standards.

Data show that the inclusion of even one power can augment the potential support for SE to a significant degree. I argue here that advocates who seek to promote sustainability education in public schools can benefit by understanding the nature of these power standards and encourage wider inclusion of similar language within state frameworks.

Patterns in power standards. Examination of the standards included in this sample shows that they fit within two thematic groups. The first group (blue) consist of standards that explore how human activities create impact upon the environment. Arizona science standard 8.3.1.1 (Arizona Department of Education, 2005) provides an excellent example of this with the following language:

> Analyze the risk factors associated with natural, human induced, and/or biological hazards, including:
> - waste disposal of industrial chemicals
> - greenhouse gases (p. 21)

Similarly, NGSS standard MS–ESS3-4 provides another example:

> Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems. [Clarification Statement: Examples of evidence include grade-appropriate databases on human populations and the rates of consumption of food and natural resources (such as freshwater, mineral, and energy). Examples of impacts can include changes to the appearance, composition, and structure of Earth's systems as well as the rates at which they change. The consequences of increases in human populations and consumption of natural resources are described by science, but science does not make the decisions for the actions society takes.] (NGSS Lead states, 2013)

And a third example is provided by Wisconsin standard E.8.6 (Wisconsin Department of Public Instruction) which reads:

> Describe through investigations the use of the earth's resources by humans in both past and current cultures, particularly how changes in the resources used for the past 100 years are the basis for efforts to conserve and recycle renewable and non-renewable resources.

Each of these standards are an exploration of human impact on the environment. While they differ in language, this common theme is a powerful lever for integrating SE.

The second group (green) of "power standards" to lever outsized support for SE, were standards related to designing and/or evaluate solutions for environmental problems or protection. Typically, the standards require students to engage in activities related to environmental protection or mitigation of human impact. NGSS provides an initial example with standard MS-LS2-5:

> Evaluate competing design solutions for maintaining biodiversity and ecosystem services. * [Clarification Statement: Examples of ecosystem services could include water purification, nutrient recycling, and prevention of soil erosion. Examples of design solution constraints could include scientific, economic, and social considerations.] (NGSS Lead States, 2013)

and MS-ESS3-3 which reads:

> Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment. * [Clarification Statement: Examples of the design process include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact. Examples of human impacts can include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as of the air, water, or land).] (NGSS Lead States, 2013)

Both standards engage students with activities related to environmental protection as part of a design process. These types of standards provide rich opportunities for students to learn about the nature of a problem, identify criteria and constraints, and engage in a process of formulating solutions. This is not confined to the NGSS. Similar themes can be identified in the Colorado Academic Standards, Science (Colorado Department of Education, 2009) as shown by standard 6.2.C:

> Identify problems, and propose solutions related to water quality, circulation, and distribution – both locally and worldwide (DOK 1-4). (p. 97)

North Carolina standard (North Carolina Department of Public Instruction) 7.E.1.6,

> Conclude that the good health of humans requires: monitoring the atmosphere, maintaining air quality, and stewardship

Tennessee Academic Standards for Science (Tennessee Department of Education, 2017) standard 6.ETS1.1,

> Evaluate design constraints on solutions for maintaining ecosystems and biodiversity. (p. 48)

and Wisconsin standard H82,

> Present a scientific solution to a problem involving the earth and space, life and environmental, or physical sciences and participate in a consensus-building discussion to arrive at a group decision. (Wisconsin Department of Public Instruction)

In each case, the standard directs student learning toward understanding environmental function and engaging in stewardship related activities. While some standards are considerably more explicit in this regard than others, the core theme is present. Educators could reasonably integrate multiple SPs while pursuing the content that the standards point to in a problem-based learning process.

Summation of Findings

This study began with three basic objectives. The first of these was to "understand the degree to which the content and structure of public school learning standards in the United States can support and promote teaching of sustainability to middle school students." The results obtained demonstrate that sustainability education receives very little explicit direction or support from current U.S. middle school frameworks. Only four states were found to include explicitly requirements related to sustainability within their frameworks and the seven of the eight sustainability principles (SP) are almost entirely unsupported at the "core" level. The one exception was principle eight which expresses that environmental protection must be balanced with economic development. While it is true that the three sustainability issues (SI) used in this study were found to have “core” support in most U.S. states, it must be considered that while these issues serve as nexus points for the SPs in this study, they do not articulate them. To qualify as “core” for a SI, a standard only needed to direct student learning towards exploring the issue. The lack of explicit support for the SPs within the frameworks leaves educators without the guidance necessary to integrate these issues into a full expression of sustainability, even as the “core” support for SIs might provide an impetus to do so.

Despite this, the study has identified a substantial foundation within existing frameworks for building SE into teacher delivered curriculum. Nationally, 11.9% of state standards were found to implicitly invite sustainability education (10.7% enrollment weighted) and combining “opportunity” support with the results for “core” suggest there is substantial overlap between the content and concepts in state frameworks and sustainability principles. Seven of the eight SPs achieve combined CO support levels of 4.7% or higher. Further, significant levels of “related” standards were identified for all the SPs and SIs. The nationally averaged level of “related” standards was 8.9% (8.5% enrollment weighted) and no individual sustainability principle scored lower than 5.3% (4.9% enrollment weighted). When the ratings of “core,” “opportunity,” and “related” were combined a nationally averaged 15.4% (14.4% enrollment weighted) is revealed. This means approximately 1/6 of existing standards can directly bear on developing the principles of sustainability, and the “core” support for the three sustainability issues provide potential focal points to build sustainability themed units around. And, almost no evidence of language within standards that could act as a barrier to incorporating sustainability principles within SE themed units was identified. For advocates seeking to promote sustainability education within public schools, established state frameworks offer substantial infrastructure to build upon. Given the pressure mandated high-stakes testing applies to educators to “stick to the standards,” this is good news.

There are however, caveats. Sustainability is an inherently interdisciplinary endeavor and authentic sustainability education requires integration across science disciplines, and ideally subjects outside of science. Overall, 24 states (including the District of Columbia) were identified as having state-mandated frameworks that supported the flexibility to sequence curriculum at the local level. In these states, educators have the best potential freedom to construct thematic units that still meet the demand for students to attain the objectives and standards. These states however include just 34% of enrolled in middle school students in the nation. The remaining 27 states have state specified restrictions on potential curriculum sequencing that present a potential barrier to constructing thematic units that may fall outside the prescribed sequence. Educators in these states face institutional structures that may not permit them the flexibility to sequence curriculum into coherent SE themed units. Under these conditions, combined with the imperative to drive achievement on state-mandated testing, sustainability education is unlikely to be an attractive option.

The second broad objective was to “develop a data set that permits comparison of individual state standards and allows identification of characteristics that may support higher levels of teaching sustainability.” The design of the spreadsheet tools in this study facilitated the analysis of individual standards for their overall impact on potential support for SE. The results demonstrated that a surprisingly high fraction of the total support within a given framework was often provided by just a few standards. In the Next

Generation Science Standards, 48.1% of the combined “core” and “opportunity” support was provided by just three out of 59 standards. Similar results were evident in other states and analysis of these “power standards” revealed useful patterns.

First, higher levels of support for multiple sustainability principles was rooted in standards that explored anthropogenic impact on the environment. These standards open the door to exploring resource consumption as an interaction between human culture and environmental impact. Second, support across most SPs was identified in standards that engaged students in activities related to designing solutions to environmental problems. These standards took the form of understanding environmental function, threats, and mitigation strategies. Notably, these frequently focused on locally relevant issues that offer high potential for student engagement within the cultural context of their states. These findings are potentially significant because they point towards two thematic elements that occur within many state frameworks which sustainability advocates may seek to promote and see expanded.

The third broad objective of this study was to “identify qualities and components of state science standards that can contribute to establishing meaningful levels of sustainability literacy, in students, in the middle school setting.” The results in this area are decidedly mixed across the various sustainability principles used as metrics in this investigation. The only widespread “core” support for a sustainability principle was identified for SP8; “Economic development and environmental protection must go hand in hand. Both are necessary for human well-being.” The support was largely based in the next generation science standards and may result from the influence of business interests in the development of these frameworks. The remaining sustainability principles contained virtually no “core” support of any kind.

Societal Barriers to Sustainability Education Principles

As noted, certain important sustainability concepts were absent from the frameworks analyzed in this study. Research results identified substantial support at the “opportunity” level spread across seven of the eight sustainability principles. These opportunities represent places where state standards incorporate themes that are consistent with sustainability principles even though they do not expressly articulate them. Well-designed SE themed units could potentially exploit these opportunities and develop the sustainability principles were expressly while integrating the content required by the curriculum. It must be acknowledged however, that this support is often quite generic in nature and lacks specific focus on certain critical sustainability themes.

The theme of intragenerational equity, the idea that all humans should benefit from the use of natural resources and services, is nearly nonexistent across the state standards. Incorporating this idea into science frameworks likely presents a difficult societal challenge in the United States. Its inclusion would be tantamount to acknowledging inequity that exists between various groups of people and making a commitment to reducing or eliminating it. This is an ongoing, and often contentious, topic in U.S. economic and political discourse, and increasing gaps in income equity and ongoing problems with environmental justice suggest this is a “bridge too far” for education at this time.

Despite the relatively strong level of support for systems related themes within the "planet" sphere, the standards supporting sustainability principle five show a nearly universal failure to acknowledge human dependency on healthy and stable earth systems and results for principle seven showed an absence of recognition that disruptions to earth systems produce (potentially negative) feedback on the human systems that are dependent upon them.

This seems to mirror a general cultural bias that humans exist outside of nature and that our technological exploitation and control nature protects our overall well-being. This is an expression of the techno-centrism as identified by Feinstein and Kirchglaser (2014). It is true there is substantial evidence that state science frameworks incorporate principles of environmental health and protection, but these are most frequently framed as a human duty to do right by the environment and not as an imperative for protecting our collective well-being. These gaps are in direct contradiction to core tenets of sustainability; that humans exist within nature and that our collective well-being is inextricably intertwined with the health of the physical and biological planet. Sustainability clearly espouses the view that it is, in fact, one well-being. In sum, middle school science frameworks seem to incorporate a general tendency to prioritize the socio-economic benefits of reasonable resource exploitation and development while maintaining a certain agnostic distance from acknowledging the degree to which our overall welfare is intertwined with maintaining the healthy function of the planet's physical and biological systems.

To be clear, no significant evidence of restriction or prohibition against the core themes of the sustainability principles was noted within middle school frameworks.

While middle school science education in the United States is probably reinforcing existing biases rooted in many centuries of society being based on resource extraction, use, and disposal models, it has also provided many of the tools by which sustainability education may begin to dislodge this paradigm.

Recommendations

This study proceeded from an assumption that state mandated standards exert decisive influence over what is taught in school classrooms. It follows that for sustainability education to take root and grow within this paradigm, it must provide a viable vehicle for driving student understanding towards attaining state standards. This study suggests that the highest levels of this capacity exists in about half of the U.S. states, almost entirely rooted in the next generation science standards, and about a third of the nation's students are taught in schools that have the best prospects. There is significant potential beyond this fraction, if the flexibility to sequence curriculum into SE themed units can be expanded upon. How best to capitalize upon what exists and expand the potential further?

The best prospects for integrating SE within the existing frameworks lie with the Next Generation Science Standards. Collectively, the twenty NGSS states along with the eleven that hybridized it cover about 52% of U.S. middle school students. As a block, they represent some of the strongest and most consistent support for the eight sustainability principles and three sustainability issues examined in this study. Group 1 of the cohort analysis, which is comprised of states that made the top cohort for all five metrics, were all NGSS states except for the hybrid curriculum of Wyoming. Similarly, group 2 was also composed of NGSS states and differed from group 1 only by having a "spiraled" versus "flexible" state specified curriculum organization. Group 3, which made up the mid-tier of support for SE, was dominated by NGSS hybrid states. For any advocacy group with the practical goal of developing and disseminating a sustainability education curriculum that supports student mastery of the knowledge, content, and skills established within state frameworks, the NGSS should be their primary target. Properly designed, such a curriculum could achieve strong scientific literacy as defined by the frameworks while incorporating authentic sustainability education for a potentially large segment of the U.S. population. Indeed, the current phase of the NGSS rollout includes the development and dissemination of curriculum linked to the standards. SE themed units designed around NGSS would fit within this ongoing effort.

For interest groups with more strategic goals, such as increasing the overall level of support for SE into public education frameworks, there are also practical strategies that can be employed. The most clear-cut would be to focus on flipping states that specify a "spiraled" or "single discipline" curriculum organization to "flexible." While one goal for national science standards was to increase consistency of science education in the U.S., NGSS preserves flexibility within the grades 6-8 span. This does not materially undermine that objective of overall consistency while removing unnecessary constraints that could undermine efforts to integrate SE. Advocating for this change is less likely to be more controversial than other steps, such as attempting to get explicit sustainability-based standards adopted into a revised framework. Whereas the study found significant "opportunity" support for integrating SE principles within existing frameworks, this change would help sustainability friendly educators to maximize their ability to capitalize on existing potential within current frameworks.

The second strategy would be to press for expanded integration of the themes identified within power standards as described the study. Two themes drive the majority of support for the sustainability principles within existing frameworks. The first of these themes are standards related to exploring how human activities create impact upon the environment. The value in this focus is that human environmental impact occurs in many scales from local to global and identifying problems relevant to a given state can provide an impetus for crafting standards that support sustainability education without directly confronting politically contentious issues such as climate change. The second theme are standards related to engaging students in problem-based solutions to environmental problems or the mitigation of human impact. Again, example issues abound at scales ranging from local to global that can be focal points for integrating SE themes in a less contentious manner. While some may consider these measures are inadequate compared to the pressing need for widespread sustainability education, I argue here for taking incremental steps in states such as Ohio and Florida which showed extraordinarily low levels of potential support for sustainability education that seems to be rooted in a sociopolitical environment that has been unreceptive in the past. Focusing on improving public education related to widely recognized local issues such as water quality and pollution may be more effective than attempting to lever global issues into revisions of state frameworks.

Limitations

This study has certain limitations that need to be considered as part of contextualizing the results. First, this is a study of potential support for SE that lies within the language of established standards and in no way, speaks to if or how relevant curriculum may have been constructed to capitalize on this potential. Many observers report that SE is largely marginalized within public schools and that significant factors work against it (Aikens et al., 2016; Feinstein, 2009; Læssøe et al., 2009; Rowe, 2007). This study sought to establish whether the goals of sustainability education align sufficiently with current requirements within state frameworks to determine whether or not a mismatch between these presented an insurmountable barrier. It appears they do not, but what can be constructed around this potential is an open question.

Although this study identifies potential components of frameworks that can support SE, it does not look at the question of how they might be assembled into coherent units that effectively cover all the sustainability principles. As such this study defines the potential space within which SE can exist in established frameworks but cannot inform on how or to what degree it might emerge.

Further, the study establishes a model for assessing potential support for SE within state frameworks, but whether this model has predictive power related to current practices is an open question that goes beyond the scope of this research. The NGSS frameworks stood out as providing leading levels of potential support for SE and a minority of states were identified as providing very low levels. This presents an opportunity to compare levels of SE being implemented in the two groups to determine whether the potential support that was identified is already being capitalized upon.

Additionally, this study is confined to the discipline of science and does not specifically address potential integration of frameworks with another subject such as social studies and language arts. All authors on the topic agree; sustainability education is inherently interdisciplinary. Investigation into the support other subject areas or grade bands such as high school might lend is called for and would likely be worthwhile. Their omission is due to size and scope of the existing study being too large to expand further.

Finally, this study does not look at connections between standardized testing and their impact upon classroom practice or curriculum. Substantial research documents the considerable influence standardized testing wields over classroom practice, yet this component of education is even less homogeneous than the frameworks being assessed. Eight states and the District of Columbia will administer the PARCC test, fourteen use the Smarter Balanced Assessment Consortium test, and the remainder use tests that are independently designed in-state (Gewertz, 2015). How frameworks are interpreted by test designers and the way in which they are assessed, influences the choices educators make about what to teach and how to frame it.

Future Directions

This study provides a foundation for expanded research going forward. As noted, an investigation into the predictive power of this model by comparing the level of sustainability education in the NGSS states with those that scored poorly in the study is practical and would be valuable. Such a study can help to validate the potential support for SE identified in the current research and could help reveal existing practices that could further the cause of SE adoption on a wider basis.

This study could be expanded along several different axis'. There is a need to look for potential support that crosses between science and humanities disciplines. Sustainability advocates are in strong agreement that SE must be an interdisciplinary endeavor. The weak performance on the "people" sphere of sustainability principles, especially the absence of support identified for SP2 (intragenerational equity) argues strongly that additional support is needed for this component in any potential program of sustainability education. This could be supplied by humanities-based studies focusing more closely on equity issues that characterize this sphere.

There would also be value in applying this methodology to other grade band such as high school and the science, engineering, and technology classes including AP environmental science taught during those years. While middle school may a prime opportunity for integrating SE, other potential should be identified and capitalized on.

Further, given the relative strength of support for SE found in the NGSS compared to other frameworks, it might be valuable to investigate other patterns that tie this support together. For example, it is possible that certain disciplinary core ideas (DCI's) may be common to a majority of the support identified in this study. While the data to investigate has not been developed here, it could yield a worthwhile avenue of inquiry for future work.

Finally, how standardized testing influences the potential identified in this study should be probed further. Given the broad agreement with an education research that high-stakes testing influences classroom practice, further exploration in this area is essential.

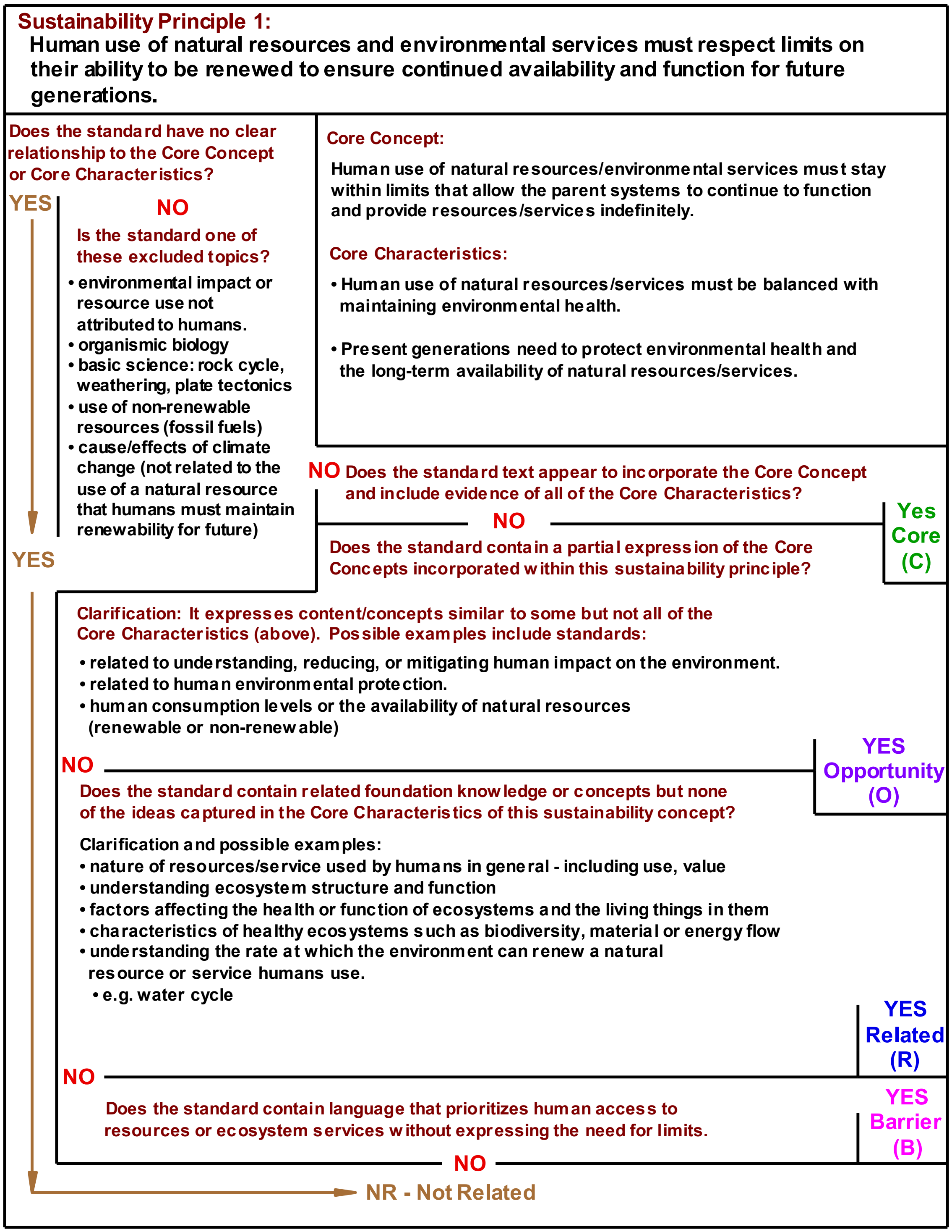
Conclusions

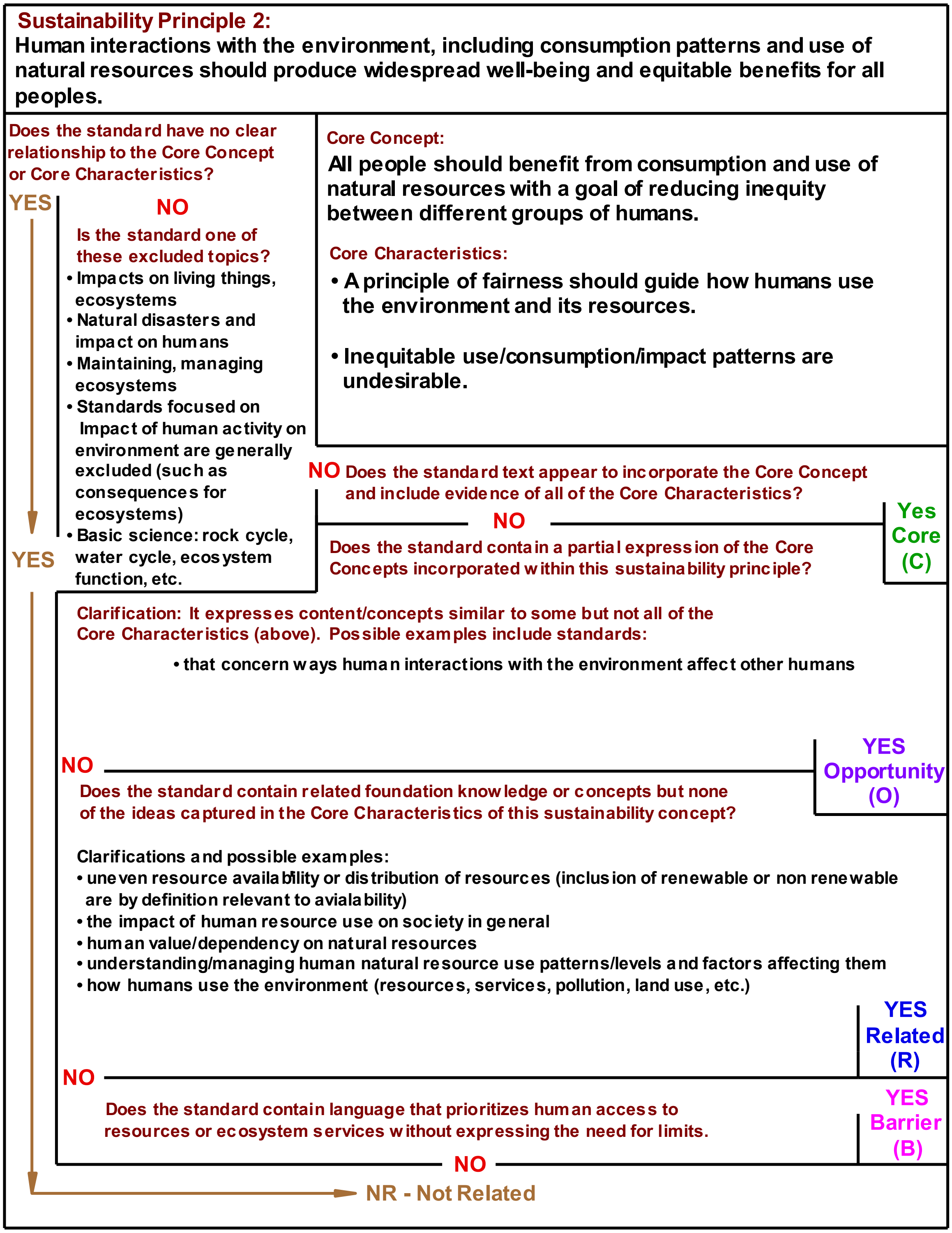
Sustainability education has the capacity to transform middle school science classes and how they are experienced by students. While a subset of students may be innately engaged by learning “hard science” many are not, and education research points out that engaging students with personal connections creates science that is both authentic and relevant to a wider audience. Integrating social, cultural, economic, and political perspectives with the quantified understandings that are strongly established in science frameworks has the capacity to change student experience. This was an original goal of the NGSS development process, and SE is a natural extension and maturation of the vison of engaging students by the application of science in socially relevant ways.

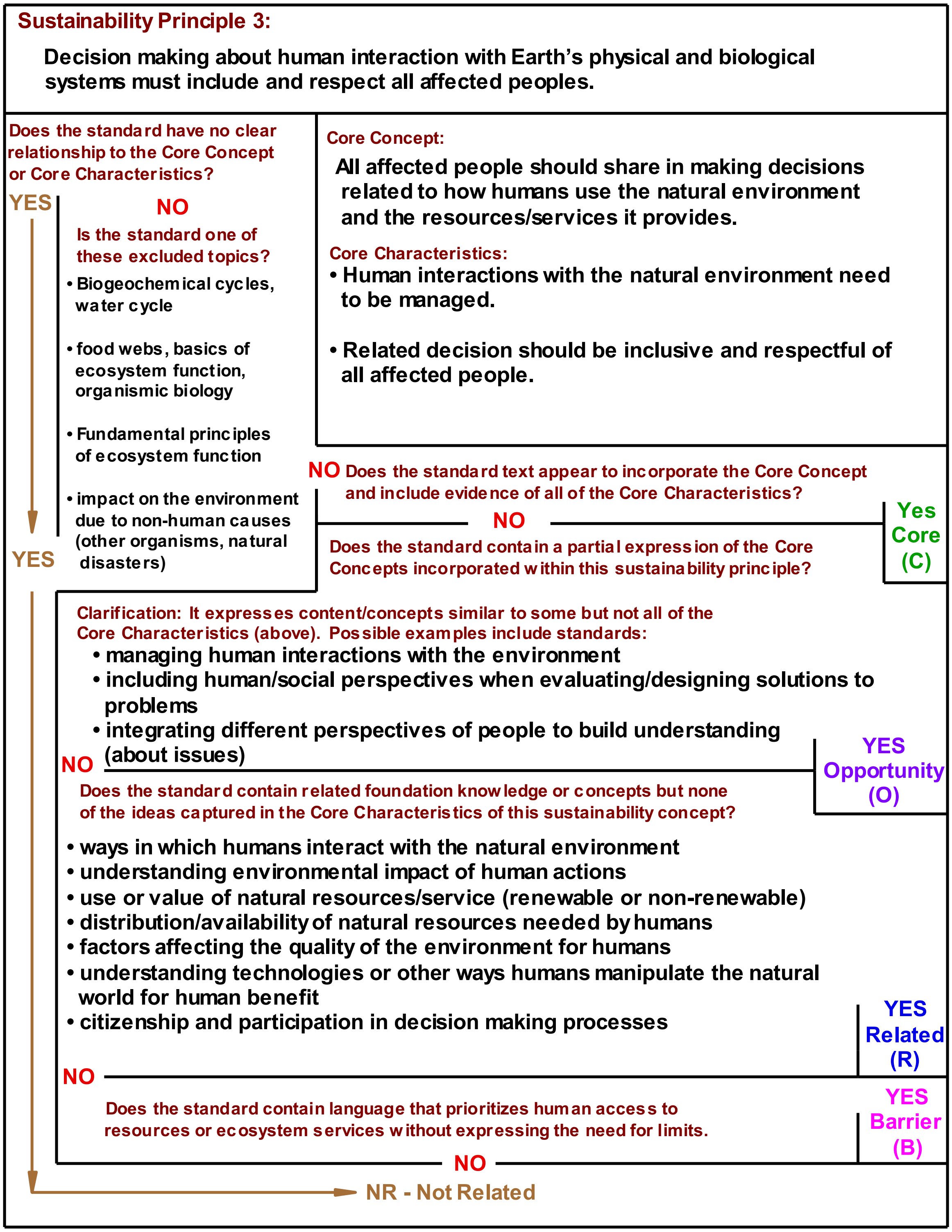
This is really an argument for expanding environmental education and rooting it an interdisciplinary cultural context. Such dramatic changes are difficult to achieve over small timescales in institutions as large as public education in the United States, but persistent and directed pressure towards distant goal can make incremental progress. It is my anecdotal observation that the greatest challenge to motivating students in science is giving it a human face. Humans are social animals and we relate most readily to the issues grounded in our interactions with one another. Most students of this age also have an innate empathy for nature and living things. Sustainability education provides the capacity to teach science through the lenses of human interactions and empathy. By engaging emotional connections with scientific understanding, we can make science classes more innately motivating and lever significant progress towards making a public that has basic literacy in these important challenges that face humanity.

Appendix 1

SP and SI Coding Flowcharts




Sustainability Principle 2:
Human interactions with the environment, including consumption patterns and use of natural resources should produce widespread well-being and equitable benefits for all peoples.
Does the standard have no clear relationship to the Core Concept or Core Characteristics?
YES
NO
Is the standard one of these excluded topics?
• Impacts on living things, ecosystems
• Natural disasters and impact on humans
• Maintaining, managing ecosystems
• Standards focused on Impact of human activity on environment are generally excluded (such as consequences for ecosystems)
• Basic science: rock cycle, water cycle, ecosystem function, etc.
YES
Core Concept:
All people should benefit from consumption and use of natural resources with a goal of reducing inequity between different groups of humans.
Core Characteristics:
• A principle of fairness should guide how humans use the environment and its resources.
• Inequitable use/consumption/impact patterns are undesirable.
NO
Does the standard text appear to incorporate the Core Concept and include evidence of all of the Core Characteristics?
Yes
Core
(C)
NO
Does the standard contain a partial expression of the Core Concepts incorporated within this sustainability principle?
Clarification: It expresses content/concepts similar to some but not all of the Core Characteristics (above). Possible examples include standards:
• that concern ways human interactions with the environment affect other humans
YES
Opportunity
(O)
NO
Does the standard contain related foundation knowledge or concepts but none of the ideas captured in the Core Characteristics of this sustainability concept?
Clarifications and possible examples:
• uneven resource availability or distribution of resources (inclusion of renewable or non renewable are by definition relevant to avialability)
• the impact of human resource use on society in general
• human value/dependency on natural resources
• understanding/managing human natural resource use patterns/levels and factors affecting them
• how humans use the environment (resources, services, pollution, land use, etc.)
YES
Related
(R)
NO
Does the standard contain language that prioritizes human access to resources or ecosystem services without expressing the need for limits.
YES
Barrier
(B)
NO
NR - Not Related


Sustainability Principle 3:
Decision making about human interaction with Earth's physical and biological systems must include and respect all affected peoples.
Does the standard have no clear relationship to the Core Concept or Core Characteristics?
YES
NO
Is the standard one of these excluded topics?
• Biogeochemical cycles, water cycle
• food webs, basics of ecosystem function, organismic biology
• Fundamental principles of ecosystem function
• impact on the environment due to non-human causes (other organisms, natural disasters)
YES
Core Concept:
All affected people should share in making decisions related to how humans use the natural environment and the resources/services it provides.
Core Characteristics:
• Human interactions with the natural environment need to be managed.
• Related decision should be inclusive and respectful of all affected people.
NO
Does the standard text appear to incorporate the Core Concept and include evidence of all of the Core Characteristics?
Yes
Core
(C)
NO
Does the standard contain a partial expression of the Core Concepts incorporated within this sustainability principle?
Clarification: It expresses content/concepts similar to some but not all of the Core Characteristics (above). Possible examples include standards:
• managing human interactions with the environment
• including human/social perspectives when evaluating/designing solutions to problems
• integrating different perspectives of people to build understanding (about issues)
YES
Opportunity
(O)
NO
Does the standard contain related foundation knowledge or concepts but none of the ideas captured in the Core Characteristics of this sustainability concept?
• ways in which humans interact with the natural environment
• understanding environmental impact of human actions
• use or value of natural resources/service (renewable or non-renewable)
• distribution/availability of natural resources needed by humans
• factors affecting the quality of the environment for humans
• understanding technologies or other ways humans manipulate the natural world for human benefit
• citizenship and participation in decision making processes
YES
Related
(R)
NO
Does the standard contain language that prioritizes human access to resources or ecosystem services without expressing the need for limits.
YES
Barrier
(B)
NO
NR - Not Related

Sustainability Principle 4:

Decisions about sustainability issues must include social, cultural, economic, political and ethical perspectives as well as scientific knowledge.

Does the standard have no clear relationship to the Core Concept or Core Characteristics?

YES

NO

Is the standard one of these excluded topics?

- understanding the science of environmental function but lacking language connecting human • interactions with it.

YES

Core Concept:

Sustainability issues are complex and decisions about them need to incorporate diverse perspectives and types of knowledge.

Core Characteristics:

- Science is one of many ways of understanding sustainability issues.
- Decisions about sustainability issues must consider a broad range of perspectives (social, cultural, economic, political and ethical).

NO Does the standard text appear to incorporate the Core Concept and include evidence of all of the Core Characteristics?

Yes Core (C)

NO

Does the standard contain a partial expression of the Core Concepts incorporated within this sustainability principle?

Clarification: It expresses content/concepts similar to some but not all of the Core Characteristics (above). Possible examples include standards:

- including expanded human, social, political, or economic perspectives to develop knowledge or solutions to problems
- understanding factors affecting distribution, use, or availability of natural resources (renewable or non-renewable) or services
- understanding and mitigating human environmental impacts
- understanding/mitigating factors affecting levels of human consumption or resource use
- understanding the scientific nature of sustainability issues
  - climate change and mitigation
  - use of renewable vs non-renewable resources
  - soil conservation in agriculture
  - consumption levels or patterns
  - population growth
  - water quality and use
  - deforestation/land use

YES Opportunity (O)

NO

Does the standard contain related foundation knowledge or concepts but none of the ideas captured in the Core Characteristics of this sustainability concept?

- understanding technologies or other ways humans modify the natural world for their benefit
- understanding benefits humans derive from the natural environment.
- understanding the nature of human impact on the environment (no mitigation)
- understanding the nature of scientific knowledge, how it is developed, or its limitations
- citizenship and participation in decision making processes in general

YES Related (R)

NO

Does the standard contain language that prioritizes human access to resources or ecosystem services without expressing the need for limits.

YES Barrier (B)

NO

NR - Not Related

Sustainability Principle 5:
Humans depend upon Earth's physical and biological systems for environmental services and natural resources. Our collective well-being depends on maintaining and protecting their healthy and stable function.

Does the standard have no clear relationship to the Core Concept or Core Characteristics?

YES

NO

Is the standard one of these excluded topics?
- -states of matter
- -nature of matter
- -the structure and function of living things
- - metabolisms other than photsynthesis
- -Nat. disasters, geologic hazards
- -evidence of continental drift (not process)

YES

Core Concept:
Humanity is dependent upon the Earth to provide resources and environmental services that support our collective well-being.

Core Characteristics:
- All humans use and depend upon the Earth as a source of resources and environmental services.
- The healthy and stable function of natural systems providing these is necessary for human well-being.
- Environmental protection is necessary for humanity's well-being

NO Does the standard text appear to incorporate the Core Concept and include evidence of all of the Core Characteristics?

Yes Core (C)

NO

Does the standard contain a partial expression of the Core Concepts incorporated within this sustainability principle?

Clarification: It expresses content/concepts similar to some but not all of the Core Characteristics (above). Possible examples include standards:
- benefits humans derive from the natural environment
- human use of natural resources/services
- human protection, maintenance, or impact on Earth's natural resources/services
- designing/evaluating (human) solutions to environmental issues (problems)
- understanding human impact on the environment and/or its consequences environmental quality and its impact on humans (not natural disasters or geologic hazards)

YES Opportunity (O)

NO

Does the standard contain related foundation knowledge or concepts but none of the ideas captured in the Core Characteristics of this sustainability concept?
- nature & function of Earth's physical or biological systems (ex. ecosystem function, plate tectonics, rock cycle, biogeochemical cycles, water cycle, weather, climate, atmosphere, etc.)
- the flow of energy and matter through the biosphere
- the function of natural systems that provide resources or environmental services for humans (weathering > soils)
- processes that support the ability of natural systems to provide resources or environmental services for humans
  - Photosynthesis

YES Related (R)

NO

Does the standard contain language that prioritizes human access to resources or ecosystem services without expressing the need for limits.

YES Barrier (B)

NO

NR - Not Related

Sustainability Principle 6:
Sustainable systems are characterized by diversity, recycle matter continuously, and rely on renewable or inexhaustible energy sources. Disruption of these beyond limits can cause the system to become unsustainable.

Core Concept:

Sustainable systems share certain characteristics.

Core Characteristics:

- Sustainable systems are able to maintain stable function indefinitely.
- Sustainable systems are typically diverse in makeup, continuously recycle matter, & rely on renewable/inexhaustible energy sources.
- If diversity in the system, or the flow of matter or energy are disrupted beyond certain limits, the system will become unstable and may become unsustainable.

Does the standard have no clear relationship to the Core Concept or Core Characteristics?

YES → NR - Not Related

NO

Is the standard one of these excluded topics?

- physical systems or processes not subject to human impacts (e.g. orbits, seasons)
- basic science related to motion, chemistry, conservation of mass & energy, physical laws.
- geologic hazards and natural disasters
- weather, differentiating between cell types, Earth's structure, heredity, evolution, genetics

YES → NR - Not Related

NO

Does the standard text appear to incorporate the Core Concept and include evidence of all of the Core Characteristics?

Yes → Core (C)

NO

Does the standard contain a partial expression of the Core Concepts incorporated within this sustainability principle?

Clarification: It expresses content/concepts similar to some but not all of the Core Characteristics (above). Possible examples include standards that concern:

- general system science/theory (structure, function, concepts)
- tendency toward biodiversity in ecosystems (niches filled)
- destabilizing factors/influences on Earth systems
- cycling/circulation of matter in systems (ecosystems, rock cycle, plate tectonics, gen. atmospheric circulation)
- flow of energy in systems
- maintaining ecosystem diversity/function/services/capacity
- understanding/monitoring/minimizing/mitigating human environmental impacts

YES → Opportunity (O)

NO

Does the standard contain related foundation knowledge or concepts but none of the ideas captured in the Core Characteristics of this sustainability concept?

- processes contributing to cycles (photosynthesis, respiration, convection)
- structure & function of cells and organism as systems
- ecosystem structure (components, ecological relationships)
- human resource use (without environmental impact)
- renewable vs. non-renewable resources
- structure and evidence supporting understanding cyclical systems (plate tectonic, rock cycle)

YES → Related (R)

NO

Does the standard contain language that prioritizes human access to resources or ecosystem services without expressing the need for limits.

YES → Barrier (B)

NO → NR - Not Related

Sustainability Principle 7:

Human social and economic systems are highly interconnected with Earth's physical and biological systems. Changes to any system produces effects on others.

Core Concept: **Human systems and the Earth's systems are interconnected and affect one another.**

Core Characteristics:

- **Human systems are inter-dependent with the Earth's natural systems.**
- **Changes to any system produces effects on other connected systems.**

Does the standard have no clear relationship to the Core Concept or Core Characteristics?

YES → (go to NR - Not Related)

NO

Is the standard one of these excluded topics?

small scale systems & individual processes that function within systems
e.g. human body systems
organism biology
photosynthesis

processes not subject to significant change (tides seasons)

system science/theory disturbance

YES → (go to NR - Not Related)

NO Does the standard text appear to incorporate the Core Concept and include evidence of all of the Core Characteristics?

Yes → Core (C)

NO

Does the standard contain a partial expression of the Core Concepts incorporated within this sustainability principle?

Clarification: It expresses content/concepts similar to some but not all of the Core Characteristics (above). Possible examples include standards:

- use or benefits humans derive from natural resources/services
- human interaction with the environment (ex. recreation, resource exploitation, land use, pollution, gene manipulation, etc.)
- human actions to understand or mitigate impact and/or protect the environment
- how the environment impacts humans (ex. natural disasters, climate change)
- integrating human and environmental criteria/constraints in design problems
- how scientific discoveries impact society and/or the environment

YES → Opportunity (O)

NO

Does the standard contain related foundation knowledge or concepts but none of the ideas captured in the Core Characteristics of this sustainability concept?

- normal functioning of large scale natural systems humans frequently interact with (e.g. climate, ecosystems, biogeochemical cycles, plate tectonics, weather, etc.)
- large scale processes that produce resources/services humans use
- understanding conditions that produce change within a system (either generally or specific example).
- connections between 2 human systems or between 2 natural systems. e.g. How policy affects society or weather and the crust, causes of mass extinctions

YES → Related (R)

NO

Does the standard contain language that prioritizes human access to resources or ecosystem services without expressing the need for limits.

YES → Barrier (B)

NO → NR - Not Related

Sustainability Principle 8:

Economic development and environmental protection must go hand in hand. Both are necessary for human well-being.

Does the standard have no clear relationship to the Core Concept or Core Characteristics?

YES

NO

Is the standard one of these excluded topics?

normal environmental function
plate tectonics, rock cycle, photosynthesis, respiration, organismic biology, weather

YES

Core Concept:

Humanity has equal need for a healthy economy and a healthy environment.

Core Characteristics:

- Economic development benefits people.
- Environmental protection benefits people.
- Economic development and environmental protection should be coequal goals.

If a standard requires the application of economic constraints into environmental protection or environmental constraints to economic activity, it should be considered core. The implication is that both have benefits explicitly indicating a need to balance both considerations.

NO Does the standard text appear to incorporate the Core Concept and include evidence of all of the Core Characteristics?

Yes Core (C)

NO

Does the standard contain a partial expression of the Core Concepts incorporated within this sustainability principle?

Clarification: It expresses content/concepts similar to some but not all of the Core Characteristics (above). Possible examples include standards:
intersections of economic and environmental concern without expressing that both are necessary for human well-being

- protecting the environment within economic constraints
- managing resources, resource use
- minimizing or mitigating human impact on the environment
- impact of consumption levels on environment
- integrating human and environmental criteria/constraints in (general/non-environmental) design problems
- understanding impact of environmental problems on human well-being
- human well-being requires environmental protection

YES Opportunity (O)

NO

Does the standard contain related foundation knowledge or concepts but none of the ideas captured in the Core Characteristics of this sustainability concept?

- ways environment benefits humans (including resources provided)
- ways environment supports economics
- understanding factors that impact economics
- understanding ways in which humans impact the environment
- impact development/economics on environment
- impact of environmental protection on economics
- impact of new science/technology, discoveries, etc.
- distribution, availability, nature of resources/services humans use

YES Related (R)

NO

Does the standard contain language that prioritizes human access to resources or ecosystem services without expressing the need for limits.

YES Barrier (B)

NO

NR - Not Related

Sustainability Issue 1:
The standard concerns understanding how humans have contributed to a rise in global temperatures over the last century and the consequences of this for humans and other living things.

Does the standard have no clear relationship to the Core Concept or Core Characteristics?

YES → NR - Not Related

NO

Is the standard one of these excluded topics?

Basic science related to molecules, their structure, or properties.

YES → NR - Not Related

Core Concept:

Human activites are contributing to climate changes that will impact all living things.

Core Characteristics:

- Earth's climate is changing at least partly as a result of human actions.
- Change to Earth's climate impacts humans and other living things.

NO

Does the standard text appear to incorporate the Core Concept and include evidence of all of the Core Characteristics?

Yes → Core (C)

NO

Does the standard contain a partial expression of the Core Concepts incorporated within this sustainability principle?

Clarification: It expresses content/concepts similar to some but not all of the Core Characteristics (above). Possible examples include standards:

- understanding ways humans impact the environment in general (mechanism or impact not specified)
- how changes to temperature (OR abiotic factors) produce change in earth's physical or biological systems
- understanding the "greenhouse effect" or the carbon cycle (biogeochemical cycles included)
- learning about potential changes to atmospheric composition (climate change not mentioned)
- advantages/disadvantages/impact of different energy resources

YES → Opportunity (O)

NO

Does the standard contain related foundation knowledge or concepts but none of the ideas captured in the Core Characteristics of this sustainability concept?

- atmospheric composition and/or normal function of earth's climate system
- general benefits or unintended impacts of technology on society or earth
- how climate, weather, sea level, or other climate linked aspects of Earth affect humans (climate change not included)
- understanding the distribution, nature, or availability of fossil fuel resources
- properties of electromagnetic radiation (visble vs. IR, absorption, transmission)
- How electricity is generated (no discussion of impact)
- evaluating renewable vs. nonrenewable resources in general
- Factors related to human resource consumption patterns
- related to mitigating human impact or protecting earth's systems in general

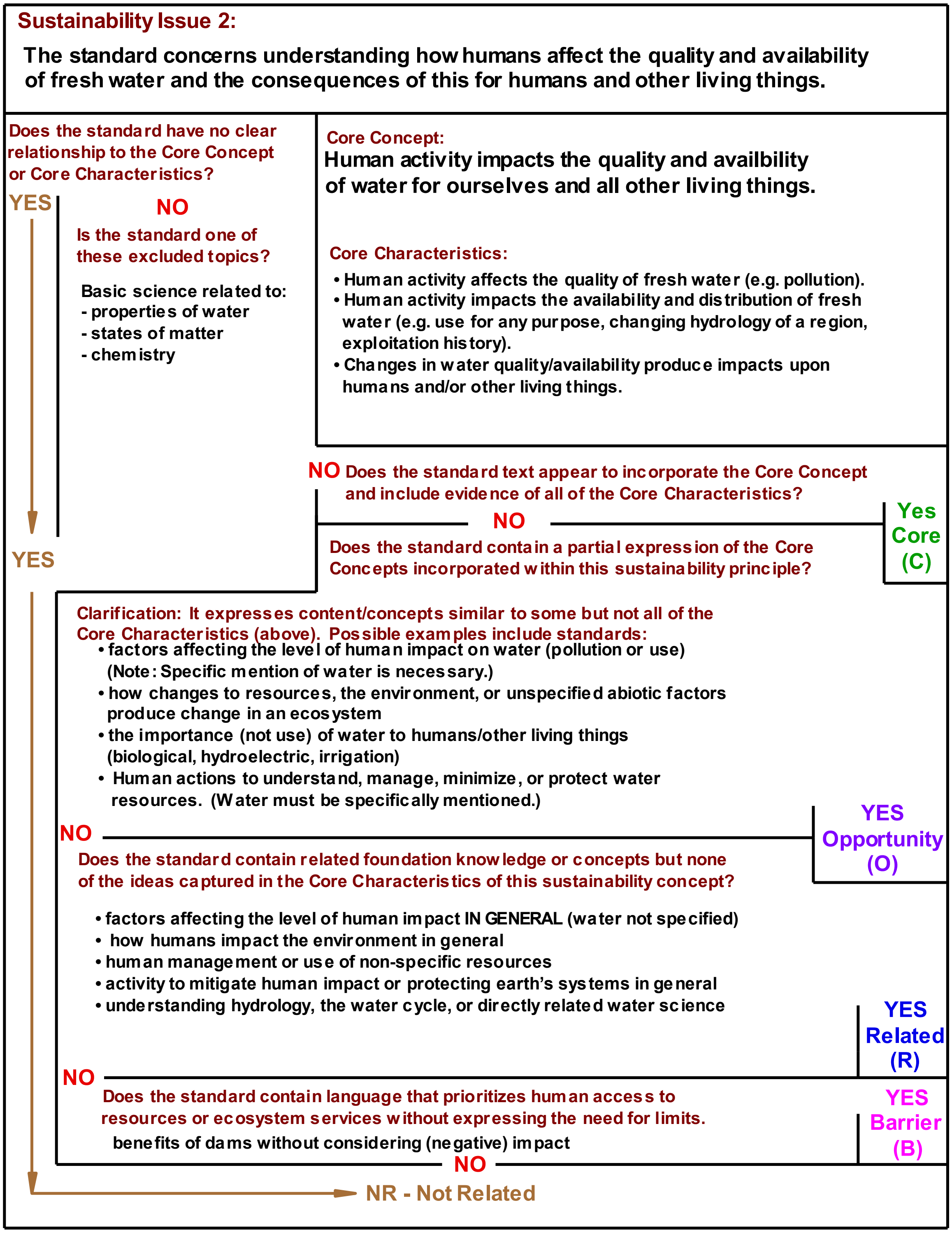
YES → Related (R)

NO

Does the standard contain language that prioritizes human access to resources or ecosystem services without expressing the need for limits.

YES → Barrier (B)

NO → NR - Not Related


Sustainability Issue 2:
The standard concerns understanding how humans affect the quality and availability of fresh water and the consequences of this for humans and other living things.
Does the standard have no clear relationship to the Core Concept or Core Characteristics?
YES
NO
Is the standard one of these excluded topics?
Basic science related to:
- properties of water
- states of matter
- chemistry
Core Concept:
Human activity impacts the quality and availbility of water for ourselves and all other living things.
Core Characteristics:
• Human activity affects the quality of fresh water (e.g. pollution).
• Human activity impacts the availability and distribution of fresh water (e.g. use for any purpose, changing hydrology of a region, exploitation history).
• Changes in water quality/availability produce impacts upon humans and/or other living things.
NO Does the standard text appear to incorporate the Core Concept and include evidence of all of the Core Characteristics?
Yes Core (C)
NO
Does the standard contain a partial expression of the Core Concepts incorporated within this sustainability principle?
YES
Clarification: It expresses content/concepts similar to some but not all of the Core Characteristics (above). Possible examples include standards:
• factors affecting the level of human impact on water (pollution or use) (Note: Specific mention of water is necessary.)
• how changes to resources, the environment, or unspecified abiotic factors produce change in an ecosystem
• the importance (not use) of water to humans/other living things (biological, hydroelectric, irrigation)
• Human actions to understand, manage, minimize, or protect water resources. (Water must be specifically mentioned.)
YES Opportunity (O)
NO
Does the standard contain related foundation knowledge or concepts but none of the ideas captured in the Core Characteristics of this sustainability concept?
• factors affecting the level of human impact IN GENERAL (water not specified)
• how humans impact the environment in general
• human management or use of non-specific resources
• activity to mitigate human impact or protecting earth's systems in general
• understanding hydrology, the water cycle, or directly related water science
YES Related (R)
NO
Does the standard contain language that prioritizes human access to resources or ecosystem services without expressing the need for limits.
benefits of dams without considering (negative) impact
YES Barrier (B)
NO
NR - Not Related

Sustainability Issue 3:

The standard concerns understanding factors that affect the level of human impact on the environment and/or our consumption of natural resources.

Does the standard have no clear relationship to the Core Concept or Core Characteristics?

YES

NO

Is the standard one of these excluded topics?

Standards with a focus on how the environment functions such as how it maintains, cycles, or renews resources are generally considered to be not related.

YES

Core Concept:

The level of human use of resources and impact on the environment is affected by many factors.

Core Characteristics:

- Different groups of humans impact the environment at different levels.
- Some groups use resources at a higher rate than other groups
- Population level can also affect the degree of impact or consumption.
- High levels of resource consumption lead to greater environmental impact.

NO Does the standard text appear to incorporate the Core Concept and include evidence of all of the Core Characteristics?

Yes Core (C)

NO

Does the standard contain a partial expression of the Core Concepts incorporated within this sustainability principle?

Clarification: It expresses content/concepts similar to some but not all of the Core Characteristics (above). Possible examples include standards:

- The standard concerns understanding or mitigating human impact on the environment (causes of climate change, land use, water use/quality, etc.)

YES Opportunity (O)

NO

Does the standard contain related foundation knowledge or concepts but none of the ideas captured in the Core Characteristics of this sustainability concept?

- The standard concerns benefits humans derive from natural resources.
- The standard concerns human use of natural resources in general.
- The standard concerns how changes to resources (biotic or abiotic) in an ecosystem can produce change in its function or structure.

YES Related (R)

NO

Does the standard contain language that prioritizes human access to resources or ecosystem services without expressing the need for limits.

YES Barrier (B)

NO

NR - Not Related

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