Sustainability, the Next Generation Science Standards, and the Education of Future Teachers

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ABSTRACT

The Next Generation Science Standards (NGSS) emphasize how human activities affect the Earth and how Earth processes impact humans, placing the concept of sustainability within the Earth and Space Sciences. We ask: how prepared are future teachers to address sustainability and systems thinking as encoded in the NGSS? And how can geoscientists support them? Most future teachers receive their Earth Science preparation in a single introductory geoscience course, but the content and delivery methods of these courses are not well matched to the NGSS knowledge and skills they will teach. We implemented a nationwide survey in undergraduate courses that addressed sustainability to some extent in order to assess career interests, behaviors, and motivations. Matched pre- and postdata ($n = 1{,}125$) respondents were divided into three groups: those very likely (22%), those somewhat likely (22%), and those not likely (56%) to become teachers. The very likely group resembles the current STEM teacher workforce in gender but is more diverse than the current workforce and the population currently enrolled in teacher preparation programs. The very likely group has higher rates of sustainable behaviors, is motivated by family and friends more than other groups, and is more likely to envision using their knowledge about sustainability in their careers. However, their understanding of key concepts, such as systems thinking, is limited. We suggest that curricular materials that address sustainability through concepts in introductory geoscience courses, such as those presented here, provide a means of reaching this group and better preparing future teachers to teach the NGSS. © *2017 National Association of Geoscience Teachers*. [DOI: 10.5408/16-174.1]

Key words: teacher preparation, introductory geoscience, curriculum development, NGSS, InTeGrate, sustainability

INTRODUCTION

Since the common schools movement began in the 1830s and public education became widespread in the United States, the how, what, and why of teaching and training teachers has changed significantly (Goldstein, 2014). Changing demographics and sociocultural norms in the United States account for some of that change, but deliberate changes to what is taught in the classroom and by whom are typically made at the local and state levels. Widespread reform is inherently challenging, in part because of the sheer size of the teacher corps in the United States: 3.5 million and growing at 6% a year, with more than 200,000 new teachers entering the classroom each year (Bureau of Labor Statistics, 2015; National Center for Education Statistics, 2016). For any attempt at curricular reform to be successful, both new and current teachers need to be prepared to implement the changes, which may involve learning new content and/or teaching techniques, changing the culture of the school or district, or any combination of those.

The Next Generation Science Standards (NGSS) and the accompanying Framework for K–12 Science Education (National Research Council [NRC], 2012) represent one of the most recent efforts at reform. The NGSS significantly shift the emphasis in the Earth Sciences as compared with the previous national standards (NRC, 1996), drawing heavily from a series of literacy documents developed by the scientific communities (University Consortium for Atmospheric Research, 2007; Climate Literacy Network, 2009; Earth Science Literacy Initiative, 2010; Ocean Literacy Network, 2013). As a result, the Earth and Space Science disciplinary core ideas emphasize the ways in which the Earth system is relevant to humans, both how Earth processes impact humans and how human activities impact the Earth—the combination of which lead to the concept of sustainability of human societies. Another component new to these standards is the idea of a three-dimensional framework that interweaves disciplinary core ideas with science and engineering practices and crosscutting concepts (NRC, 2012). While the practices have appeared in different forms in other standards, the incorporation of crosscutting concepts, or those ways of thinking that play a significant role in all disciplines is new. Taken together, the crosscutting concepts describe a more holistic, or systems-oriented, approach to science.

The NGSS embody a significant change in both the how and the what of Earth Science teaching (Wysession, 2014), prompting two questions: first, how prepared are future teachers to address the aspects of sustainability and systems thinking that are encoded in the Next Generation Science Standards? Second, how can we as geoscience educators support these future teachers? Answering these questions requires determining how the expectations for teachers as presented in the NGSS differ from what they experience in their current preparation programs, learning more about the knowledge and motivations of future teachers, and providing strategies for undergraduate geoscience educators to reach this group.

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TABLE I: Percentages of practicing teachers who have taken at least one college course in various scientific disciplines with uncertainty shown in italics (after Banilower et al., 2013).

Discipline	Elementary	Middle	High
Earth and/or space science	65 ± *2*	75 ± *2*	61 ± *2*
Environmental science	33 ± *2*	57 ± *3*	56 ± *1*
Life science	90 ± *1*	96 ± *1*	91 ± *1*
Chemistry	47 ± *2*	72 ± *2*	93 ± *1*
Physics	32 ± *2*	61 ± *2*	86 ± *1*

What Future Teachers Learn About Sustainability

Teacher Preparation

Each year, more than 220,000 students complete a teacher preparation program of some sort, which may be a bachelor's degree, master's degree, certification program (often a one-year postbaccalaureate program), or an alternative pathway, such as Teach for America (NRC, 2010; U.S. Department of Education, 2013). A large majority—as much as 88%—complete "traditional" teacher preparation programs, primarily four-year baccalaureate degree programs (U.S. Department of Education, 2013).

Despite (or perhaps because of) these impressive numbers, the only feature shared by traditional teacher preparation programs across the country is variability: requirements for teacher certification vary widely state to state, and not all have content-specific or grade-level–specific requirements (NRC, 2010; U.S. Department of Education, 2013). What does that mean for Earth Science in practice? The 2012 National Survey of Science And Mathematics Education (NSSME) reveals that only 65% of elementary teachers, 75% of middle school science teachers, and 61% of high school science teachers have had at least one college course in Earth and Space Science (Table I; Banilower et al., 2013).

Of current middle and high school science teachers, only 28%–30% went on to take an additional college-level course in Earth or Space Science, with the most common topics of those courses being geology, astronomy, physical geography, meteorology, and oceanography (Banilower et al., 2013). At the high school level, 42% of teachers who teach Earth Science courses have neither a degree in the field nor any courses beyond a single introductory course (Banilower et al., 2013). In other words, the vast majority of practicing teachers have taken either no Earth Science courses or only a single introductory level Earth *or* Space Science course. What do we know about what is taught in these courses?

Current Introductory Courses

Unlike biology and chemistry, there is no standard introductory geoscience curriculum (Macdonald et al., 2005). Typically, geoscience departments offer a broad range of introductory courses that are designed to recruit students into the majors and/or fulfill general education requirements (Macdonald et al., 2005; Tewksbury et al., 2013). Macdonald et al. (2005) found that introductory courses reported by 2,207 geoscience faculty covered at least 25 different topics: the most common were Physical Geology (20%), Earth Science (16%), Environmental Geology (10%), Oceanography, and Historical Geology (both 9%). All of these topics are potential entry points for teaching about human impacts on the Earth system, but it is difficult to assess the extent to which they are being used in that way.

One view into the content of introductory courses is through the textbook market. Table II summarizes information from nine of the most common textbooks, from four different publishers, used in introductory undergraduate

TABLE II: Analysis of chapter titles in common introductory textbooks. Bold numbers in right-hand column indicate that the chapter including human impacts is the final chapter of the book.

Title of Textbook	Publisher	Total Chapters	Chapters w/ Human Impacts	Title of Chapter	Chapter Number
Earth: An Introduction to Physical Geology	Pearson	24	1	Global Climate Change	21
Essentials of Geology	Pearson	20	1	Global Climate Change	**20**
How Does Earth Work?	Pearson	21	1	Global Warming: Real-time Change in the Earth System	**21**
Earth: Portrait of a Planet	Norton	23	1	Global Change In The Earth System	**23**
Essentials of Geology	Norton	21	1	Global Change In The Earth System	**21**
Exploring Geology	McGraw-Hill	19	0	n/a	n/a
The Good Earth	McGraw-Hill	17	1	Global Change	**17**
The Dynamic Earth	Wiley	21	1	Climate and Our Changing Planet	19
Visualizing Geology	Wiley	15	0	n/a	n/a

geology courses in the United States, for which textbook publishers estimate that 275,000 books are sold annually (Martinez and Baker, 2006). Seven of nine have a single chapter that addresses human impacts on the Earth in the context of global change. In five out of those seven, it is the last chapter in the book (Table II). None of the texts have the word "sustainability" as a chapter heading or even as a section heading within a chapter.

What about how material is taught? In a 2004 survey, faculty in the geosciences self-reported that traditional lecturing dominates in their introductory classrooms (Macdonald et al., 2005). In an observational study of 26 instructors in introductory geoscience courses spanning multiple institution types, Budd et al. (2013) found that instructors in larger courses ($\geq$72 students) and those at research-intensive institutions are more teacher-centered in their instruction, while instructors in smaller courses are more transitional and/or student-centered. The American Geosciences Institute reports, however, that the average enrollment in introductory physical geology courses across 294 responding departments is 508 (Martinez and Baker, 2006), suggesting that lecture is the dominant mode of conveying geoscience information to the majority of future teachers.

What Future Teachers Will Teach About Sustainability

Sustainability in Standards Pre-NGSS

In the National Science Education Standards (NSES; NRC, 1996), the precursor to the NGSS, Earth and Space Science content standards at the K–4 level focused on making observations of Earth materials and weather, and eventually on observing changes over time. At the middle level, the standards emphasized the hydrologic and rock cycles, along with solar system dynamics. At the high school level, "students focus on matter, energy, crustal dynamics, cycles, geochemical processes, and the expanded time scales necessary to understand events in the [E]arth system" (NRC, 1996, p. 187). None of the Earth and space standards reference human interactions with the Earth—instead, the concepts of hazards, environmental quality, resource availability, and human impacts are included in a separate section, entitled "Science in Personal and Social Perspectives." Their inclusion was important, but their separation from the disciplinary content meant that they were often overlooked. The NSES themselves were not intended to be adopted by states, but they influenced the development and adoption of state-level science standards (Labov, 2006).

A few key analyses of the state standards, mostly developed after the NSES, provide insight into the extent to which human interactions with Earth were, in fact, incorporated. Kastens and Turrin (2006) analyzed states' science standards to assess the extent to which they "directed students' attention and concern to issues of human interactions with the Earth system" (p. 425). They developed a three-category coding scheme that they used to categorize elements of the state standards: (1) Earth and the environment affect humanity, (2) humanity affects Earth and the environment, and (3) individuals affect Earth and the environment. They found wide variation in how state standards addressed these ideas, with overall scores ranging from one instance of inclusion of human interactions with the Earth system to 75 instances. All state standards emphasized how humanity—rather than the individual—interacts with and affects Earth and the environment, effectively disconnecting individual actions and behaviors from knowledge. Overall, the authors felt that the standards were insufficient to influence the behaviors of future citizens towards more sustainable actions.

A 2007 analysis of Earth Science in state standards revealed consistent inclusion of the concept of the Earth as a system, but many other inconsistences and gaps across the country, particularly in including 21st century approaches to data and technology (Hoffman and Barstow, 2007). As with teacher preparation programs, the most consistent feature of Earth Science standards across the 50 states is variability. At the time of the review, the authors evaluated the standards against 35 of the fundamental concepts in the Ocean Literacy document (Ocean Literacy Network, 2013), which was the only one of the four geoscience literacy documents that had been developed. Almost all states include at least a few, but none incorporate more than 20; the mean was 9.6, mostly indirectly addressed. In their review, Hoffman and Barstow (2007) suggest that this gap could be partially addressed by better articulation of the role of the oceans in the Earth system, since the systems approach was already integrated into the curriculum. The review also addressed environmental literacy, which the authors define as follows:

> *An environmentally informed citizen knows that: Earth has finite resources; humanity utilizes Earth resources and causes both short-term and long-term impacts to Earth's systems; space-age and other 21st century technologies can be used to study and model environmental changes; and it is important that people make scientifically informed and responsible decisions regarding the management of Earth's resources and systems. (p. 37)*

The authors found that 20 states addressed environmental literacy concepts directly, 14 states did so indirectly, and 16 states did not address them at all.

Sustainability in the NGSS

In the NGSS, Human Impacts on Earth Systems is one of 12 disciplinary core ideas (DCIs) in Earth and Space Science (NGSS Lead States, 2013). As shown in Table III, the elements of the learning progression within this DCI are closely aligned with both the coding of Kastens and Turrin (2006) and the environmental literacy concepts of Hoffman and Barstow (2007). As of this writing, the NGSS have been adopted by 16 states, five of which were reviewed as failing the environmental literacy concepts (California, Hawaii, Kentucky, New Jersey, and Rhode Island; Hoffman and Barstow, 2007), and five of which had fewer than nine elements of human/environment interactions in their state standards (California, Hawaii, Kentucky, Nevada, and Oregon; Kastens and Turrin, 2006).

As students move from elementary school through middle and high school, their expected understanding of this DCI increases in sophistication. The word "sustainability" first appears at the high school level (Table III). The topic of Human Sustainability is situated solely within the Earth and Space Sciences within the NGSS, despite widespread agreement that sustainability (and even sustainability science) is necessarily inter- and/or transdisciplinary (McMichael et al., 2003; Komiyama and Takeuchi, 2006; Kurland et al., 2010). Feldman and Nation (2015) provide an excellent summary of the variety of ways that the concept of

TABLE III: Learning progression from the NGSS aligned with coding schemes.

Grade band	NGSS DCI: Human Impacts on Earth Systems	Kastens and Turrin (2006)	Hoffman and Barstow (2007)
K–2	Things that people do to live comfortably can affect the world around them. But they can make choices that reduce their impacts on the land, water, air, and other living things.	I→ E[1]	Humanity utilizes Earth resources and causes both short-term and long-term impacts to Earth's systems.
3–5	Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments.	H→ E[2]	Humanity utilizes Earth resources and causes both short-term and long-term impacts to Earth's systems. It is important that people make scientifically informed and responsible decisions regarding the management of Earth's resources and systems.
Middle school	Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things.	H→ E[2]	Humanity utilizes Earth resources and causes both short-term and long-term impacts to Earth's systems.
	Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.	E→ H[3] H→ E[2]	Earth has finite resources; humanity utilizes Earth resources and causes both short-term and long-term impacts to Earth's systems
High school	The **sustainability** of human societies and the biodiversity that supports them requires responsible management of natural resources.	E→ H[3] H→ E[2]	It is important that people make scientifically informed and responsible decisions regarding the management of Earth's resources and systems
	Scientists and engineers can make major contributions by developing technologies that produce less pollution and waste and that preclude ecosystem degradation.	H→ E[2]	Space-age and other 21st century technologies can be used to study and model environmental changes

[1]Standard states or implies that the actions of individuals influence/affect/change the Earth or environment.
[2]Standard states or implies that human society influences/affects/changes the Earth or environment.
[3]Standard states or implies that Earth and environment influence or affect humanity OR standard states or implies that humanity is dependent on natural systems.

sustainability has been envisioned within education. Focusing specifically on sustainability within science classes, they note two broad categories of approaches: those that emphasize science learning, in which sustainability concepts add real-world context to science topics, and those that emphasize sustainability itself across the curriculum. As a set of national standards, the NGSS lean toward the science learning approach, or education *about* sustainability (Sterling, 2003), rather than education *for* sustainability (Santone et al., 2014). This is perhaps most evident in the performance expectations within this topic area, which has also become increasingly sophisticated, such that by high school, students are expected to be able to "create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity" (NGSS Lead States, 2013, 125–127). In this case, the focus is on the skill and the knowledge, not the decision-making or implications that arise from this simulation.

Overall, Earth and Human Activity (the section of the NGSS that includes Human Impacts on Earth Systems) represents fully one-third of the DCIs and performance expectations in the Earth and Space Sciences at the middle and high school levels in the NGSS. On the basis of our analysis, this is a fundamental shift from previous national and state standards as well as from the current content emphasized in introductory geoscience courses in which most future teachers enroll. Given what we know about the science content preparation of current teachers nationwide, it would appear that few teachers have received significant background in sustainability, as it in included in the NGSS, through college coursework.

Our Nationwide Survey About Sustainability Motivations and Behaviors

Motivation

Textbook chapters and course enrollments provide a framework for understanding the content that future

TABLE IV: Postinstruction essay questions and scoring rubrics.

Topic	Interdisciplinary Problem Solving	Systems Thinking
Prompt	Knowledge of Earth system interactions can influence how people make decisions about global challenges. Identify and describe a global challenge that society will likely face in the next 50 years. Explain how the science related to that challenge informs economic, social, and/or political decision-making related to the global challenge you described.	A systems thinker can identify a system (a natural system, a human system, a linked human/environment system), understand how that system can be divided into interacting parts, and recognize that changes in one part of the system will affect other parts of the system. 1. Give an example of a real-world system and describe its parts. 2. Explain how parts of the system interact. Use systems concepts in your explanation (e.g., positive and negative feedbacks, equilibrium, rates). 3. Using your example system, discuss how an effect in one part of that system can be influenced by multiple causal factors.
Rubric	• 1 pt: Student correctly states and suitably describes a global challenge. • 1 pt: Student correctly identifies and explains one or more scientific implications related to the problem. • 1 pt: Student appropriately connects the science to economic, social and/or political decisions. • 1 pt: Student response is constructed in a coherent and logical manner.	• 1 pt : Student correctly identifies and describes a real-world system including its parts. • 1 pt: Student correctly describes how a change in one part of the system, in turn, alters other parts of the system. • 1 pt: Student correctly explains how parts of the system interact using systems concepts such as feedbacks, equilibrium, rates, etc. • 1 pt: Student describes how an effect can be influenced by multiple causal factors.

teachers encounter in college. To get more insight into preparedness to teach sustainability concepts in the NGSS, however, we employed a nationwide survey of undergraduates that addressed students' career interests and their behaviors and motivations to contribute to solving grand challenges of environmental sustainability.

The survey is part of InTeGrate (http://serc.carleton.edu/integrate), a community-driven project to incorporate learning about Earth in the context of societal issues across the undergraduate curriculum. One of InTeGrate's primary goals was to develop curricula that will (1) increase Earth literacy of all undergraduate students, including the large majority that do not major in the geosciences such as future K–12 teachers; (2) increase students' interest in majoring in the geosciences and in pursuing a career that makes use of geoscience knowledge; and (3) improve students' ability and motivation to contribute to solving grand challenges of resources and environmental sustainability. The project envisions developing a citzenry better positioned to make sustainable decisions in their lives and as part of the broader society—and, in the case of future teachers, incorporate those skills into their teaching in their own classrooms. To assess progress on these goals, InTeGrate developed the InTeGrate Attitudinal Instrument (IAI), which asks questions about student motivations toward sustainability and sustainable behaviors, as well as career and demographic questions. A description of the development and testing of the IAI along with the survey itself is available at http://serc.carleton.edu/integrate/about/iai.html.

METHODS

The IAI was deployed pre- and postinstruction in courses in which InTeGrate materials were being tested; these courses, therefore, addressed sustainability issues to some extent (for details about how the survey was administered, see http://serc.carleton.edu/integrate/about/iai.html). The IAI asks about reason(s) for taking the course (one question, preinstruction only), college major (one question pre- and postinstruction), career interest (two questions pre- and postinstruction, plus one additional question postinstruction), concern about various potential environmental issues (one question, pre- and postinstruction), frequency of engaging in each of several listed behaviors that contribute to environmental sustainability (pre- and postinstruction) and motivations for doing so (postinstruction only), and whether they can envision using what they have learned in this course to help overcome environmental/resource problems (postinstruction only, open response). In addition, the preinstruction survey asks for demographic information (gender, ethnicity, race, year in college, age). Students were also asked to respond to two essay questions meant to probe their interdisciplinary problem-solving and systems-thinking skills (postinstruction only); the prompts for these questions and the scoring rubrics are shown in Table IV.

The IAI was administered by 61 instructors who taught using InTeGrate materials in 68 courses at 46 institutions between fall of 2012 and summer of 2015 (Table V). Responses were anonymized so that pre- and postinstruction surveys were matched with each other but not with the students' identities. Of the 2,160 students who were taught in 68 courses, 1,125 (52.1%) had matched pre- and post-IAI responses (Table V).

We divided the total matched responses into three groups: those very likely to become future teachers, those somewhat interested in becoming future teachers, and those not interested in teaching. The criteria used to define these mutually exclusive groups were:

- **Very likely** future teachers ($n = 245$) fulfilled one of the following criteria:
  - They were enrolled in a course designated as a teacher preparation course (starred in Table V); or
  - They selected "very interested" for "Science teacher in primary or secondary school" on the career question of the IAI (postinstruction); or

TABLE V: InTeGrate modules and courses included in this study, the types of courses where they were pilot-tested, and the number of matched pre- and postinstruction IAI responses for each.

Module	Number of Instructors	Type of Course	Matched Surveys
Soils, Systems, and Society	3	Elementary science methods	39[1]
Exploring Geoscience Methods	3	Secondary science methods	25[1]
Interactions Between Water, Earth's Surface, and Human Activity	3	Introductory geoscience for preservice teachers	41[1]
Environmental Justice and Freshwater Resources	3	Introductory geoscience/general education	17
Environmental Justice and Freshwater Resources (Spanish version)	1	Spanish language	16
Humans' Dependence on Mineral Resources	4	Introductory geoscience/general education	98
Natural Hazards and Risks: Hurricanes	3	Introductory geoscience/general education	75
Living on the Edge	2	Introductory geoscience/general education	16
Climate of Change	12	Introductory geoscience/general education	493
A Growing Concern	3	Introductory geoscience/general education	27
Carbon, Climate, and Energy Resources	3	Introductory geoscience/general education	51
Cli-Fi: Climate Science in Literary Fiction	3	Multiple (English, general education)	43
Map Your Hazards!	3	Multiple (sociology, general education, volcanology)	56
Mapping the Environment with Sensory Perception	3	Multiple (English, general education, honors)	24
Water Sustainability in Cities	4	Upper-level geoscience and engineering	30
Course	**Number of Instructors**	**Type of Course**	**Matched Surveys**
Coastal Processes, Hazards and Society	3	General education	31
Water, Science, and Society	3	General education	20
Renewable Energy and Environmental Sustainability	2	Introductory interdisciplinary	19
Critical Zone Science	2	Advanced interdisciplinary	4
		Total	**1,125**

[1]Course enrollment restricted to students in teacher preparation programs.

  - They indicated Education as a major that they have already chosen or are very likely to choose on the IAI (postinstruction).
- **Somewhat likely** future teachers ($n = 251$) fulfilled one of the following criteria:
  - They selected "a little bit interested" for "Science teacher in primary or secondary school" on the career question of the IAI postinstruction; or
  - They indicated that Education was a major they "might choose" on the IAI (postinstruction).
- **Not likely** future teachers ($n = 629$) are not in either of the very likely or somewhat likely populations, but also meet the following criteria:
  - They were not enrolled in a teacher preparation course; and
  - They selected "not interested" for "Science teacher in primary or secondary school" on the career question (postinstruction); and
  - They indicated that Education was a major they "will not choose."

We refer to these three groups throughout this paper as the Very, Somewhat, and Not groups.

We use both the career and major questions to acknowledge the fact that students who plan to teach at the elementary level are more likely to major in education, while students who plan to teach at the middle or secondary level more often major in the discipline that they will teach (e.g., biology, physics, history). On the survey questions, we did not distinguish between teaching at the elementary, middle, or secondary levels, so the Very and Somewhat populations include students who are interested in teaching at all levels in the K–12 system.

Numerical and statistical analyses for the rest of the IAI questions were based on these three subpopulations. For numerical Likert-scale questions, pre- and postinstruction

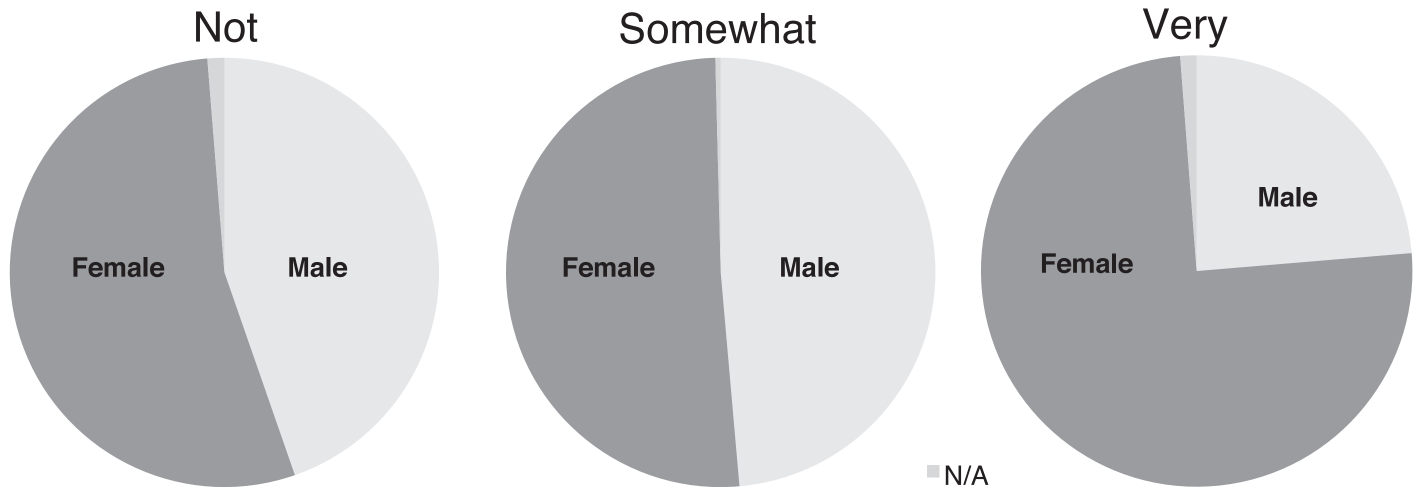

FIGURE 1: Pie charts showing the gender of respondents in the Very, Somewhat, and Not populations.

means were calculated for the three populations; a *t* test was used to determine if there was a statistically significant difference between the pre- and postinstruction means and a one-way ANOVA was used to determine if there was a statistically significant difference between the populations. Answers to the single open-ended response question on the IAI were coded; we analyzed responses from those who had responded Yes and No to the initial question separately. The rest of the coding scheme was developed through a grounded theory inductive approach, in which the researcher examines the responses for patterns and trends that emerge from the data and then categorizes these according to codes or concept indicators (Chi, 1997; Feig, 2011). As is typical in such work, the coding scheme passed through multiple iterations involving two researchers comparing, reconciling, and revising. When the coding scheme had stabilized, a third researcher recoded 22% of the responses to test for interrater consistency. Although the consistency was adequate, the scheme was found to be difficult to apply and yielded too many lightly populated categories. We therefore developed a simplified scheme by merging several categories and clarifying the description of other categories.

For the two essay questions probing systems thinking and interdisciplinary problem solving, a selection of responses from the Very group were scored against a rubric (Table IV) and explored qualitatively for emerging themes. Only responses from students in the elementary and secondary science methods courses (Table V) were examined in order to probe more deeply into the interdisciplinary problem-solving and systems-thinking capabilities of the most likely future teachers who are also closest to being in their own classroom, as these two courses are typically taken by students in their third or fourth years of college.

RESULTS

Demographics

A primary demographic result is that 496 out 1,125 students for whom we have matched pre- and postinstruction data (44%) are potential future teachers, and 22% are very likely to enter the classroom. The total sampled population was 58% female, 41% male, and 1% preferred not to say. When broken down into our three subpopulations, however, the gender distribution varied (Fig. 1). Students who are very interested in becoming teachers are overwhelming female: 75% ($n = 184/245$).

The total sampled population was 58% white or Asian and 36% underrepresented minority (including Hispanic, black, Alaskan Native, Pacific Islander, American Indian), and 6% did not respond or responded "Other," which could include two or more races. As with gender, the three subpopulations look somewhat different from the entire population (Fig. 2). Of the students very interested in becoming teachers, a higher percentage is white or Asian (65%) than our total sampled population (58%).

The IAI asked students for their year in college on the preinstruction survey; the total sampled population was dominated by students in their second year of college (33%), with around 20% for first-, third-, and fourth-year students and less than 2% graduate students or other. The Somewhat and Not groups mirror this trend, but the Very group looks quite a bit different (Fig. 3). Thirty-six percent of the very interested population is in their fourth year in college, a full two years more advanced than the other subpopulations.

Sustainable behaviors

On both the pre- and postinstruction surveys, students were asked about how often they:

- Turned off the water while brushing teeth;
- Recycled paper, glass or aluminum;
- Washed clothes in cold water;
- Unplugged appliances to eliminate "ghost" power use;
- Walked or biked instead of using car;
- Turned off light when leaving a room;
- Used public transportation instead of a car;
- Used a power saver scheme for a computer;
- Purchased locally grown food;
- Brought a reusable bag to the grocery store.

From their responses, we calculated a sustainable behaviors index by assigning one point for each sustainability behavior that the respondent reported engaging in within the preceding week.

Figure 4 shows the distribution of sustainable behaviors index score by teacher-interest groups. On both the

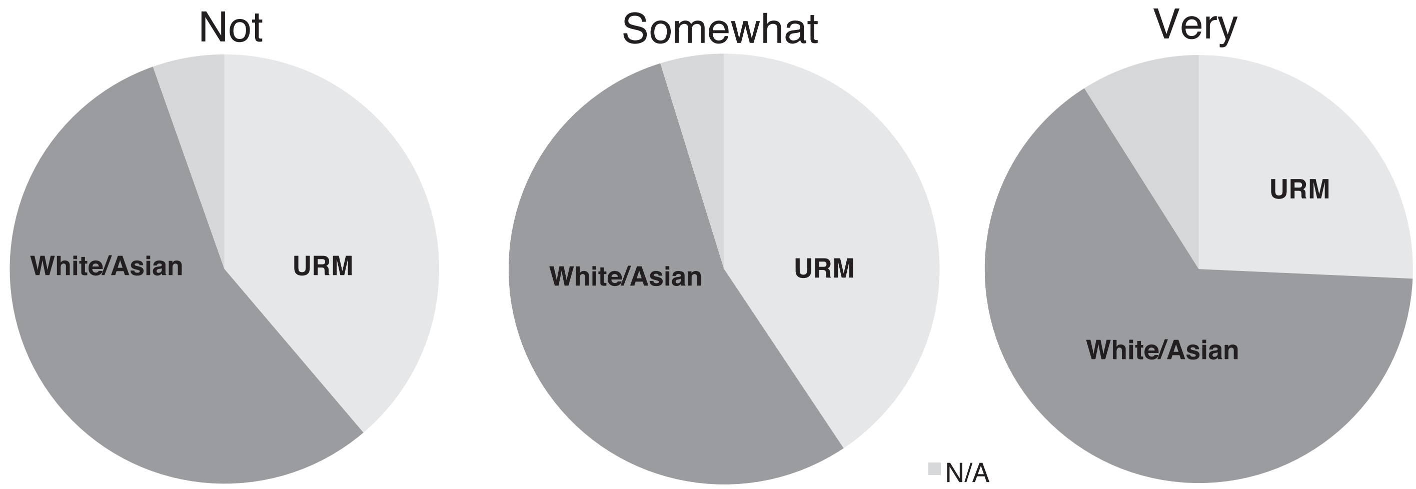

FIGURE 2: Pie charts showing the ethnicity of respondents in the Very, Somewhat, and Not populations.

preinstruction and postinstruction survey, the Very group has the highest mean sustainable behaviors index (Fig. 4). The Very group and the Not group showed a small, but statistically significant, increase in mean sustainable behavior index across instruction, while the Somewhat group did not.

As follow-up, the postinstruction survey also asked, "When you engage in behaviors such as those listed in the previous question, what factors or sources of information influence your decision to do so?" Respondents were asked to mark all that apply from a provided list. For all three groups, the most commonly selected reason for engaging in sustainable behaviors was "Desire to save money," followed by "Concern about pollution" (Fig. 5). However, the Very group differed from the others in being more likely to be influenced by family and friends (Fig. 5). For the entire sample, "This course or module" was chosen more often than "Other college courses"; however, this was less true for the Very group than for the other two groups (Fig. 5).

Envisioning the Future

On the postinstruction IAI only, students were asked, "As you think about your future, can you envision using what you have learned in this course to help society overcome problems of environmental degradation, natural resources limitations, or other environmental issues?" After the yes/no selection, students could fill in one of two open response fields, labeled "If yes, how?" and "If not, why not?" In other words, the student was asked to consider if they could see themselves transitioning from the role of a learner, where they collected information about environmental issues, into the role of a teacher, leader, or doer, where they will share their knowledge to help society resolve or overcome environmental issues.

Overall, students were five times as likely to envision themselves in this new active role than not (Table VI), and only 19 out of 1,125 students (<2%) declined to answer the question; these proportions were consistent across all three subpopulations. The vast majority added further explanation to support their response giving additional insight into their thinking, and these responses were coded (Table VI). Because the results from the Not and Somewhat groups mirror those of the entire population, here we simplify our presentation to compare coding results from the Very group with the entire population (Figs. 6 and 7).

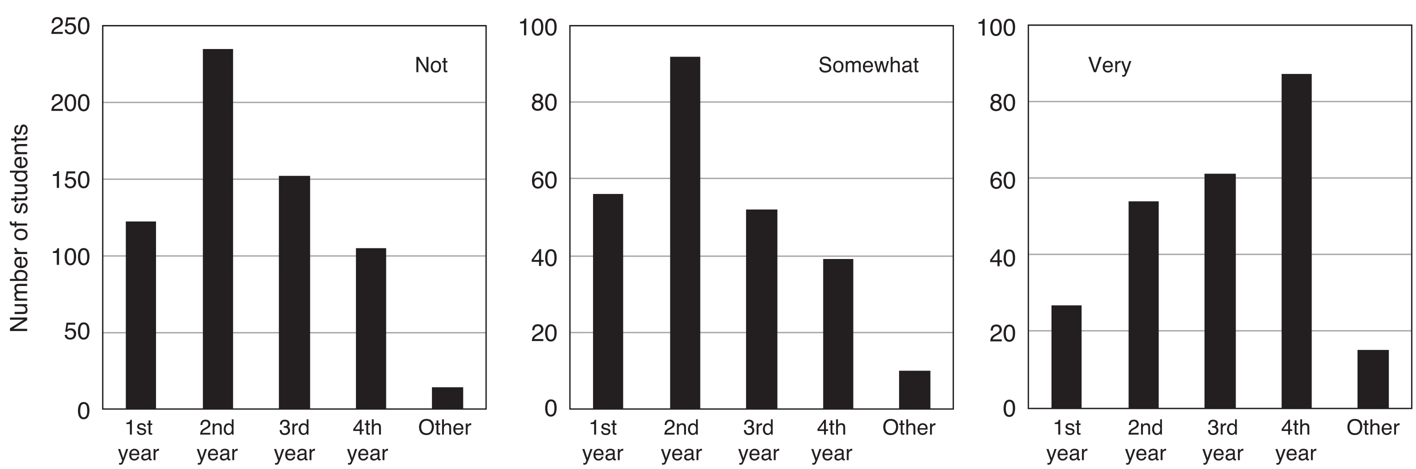

FIGURE 3: Histograms showing the year in college for the three subpopulations. The Very group is clearly further along in their undergraduate career than the other two groups.

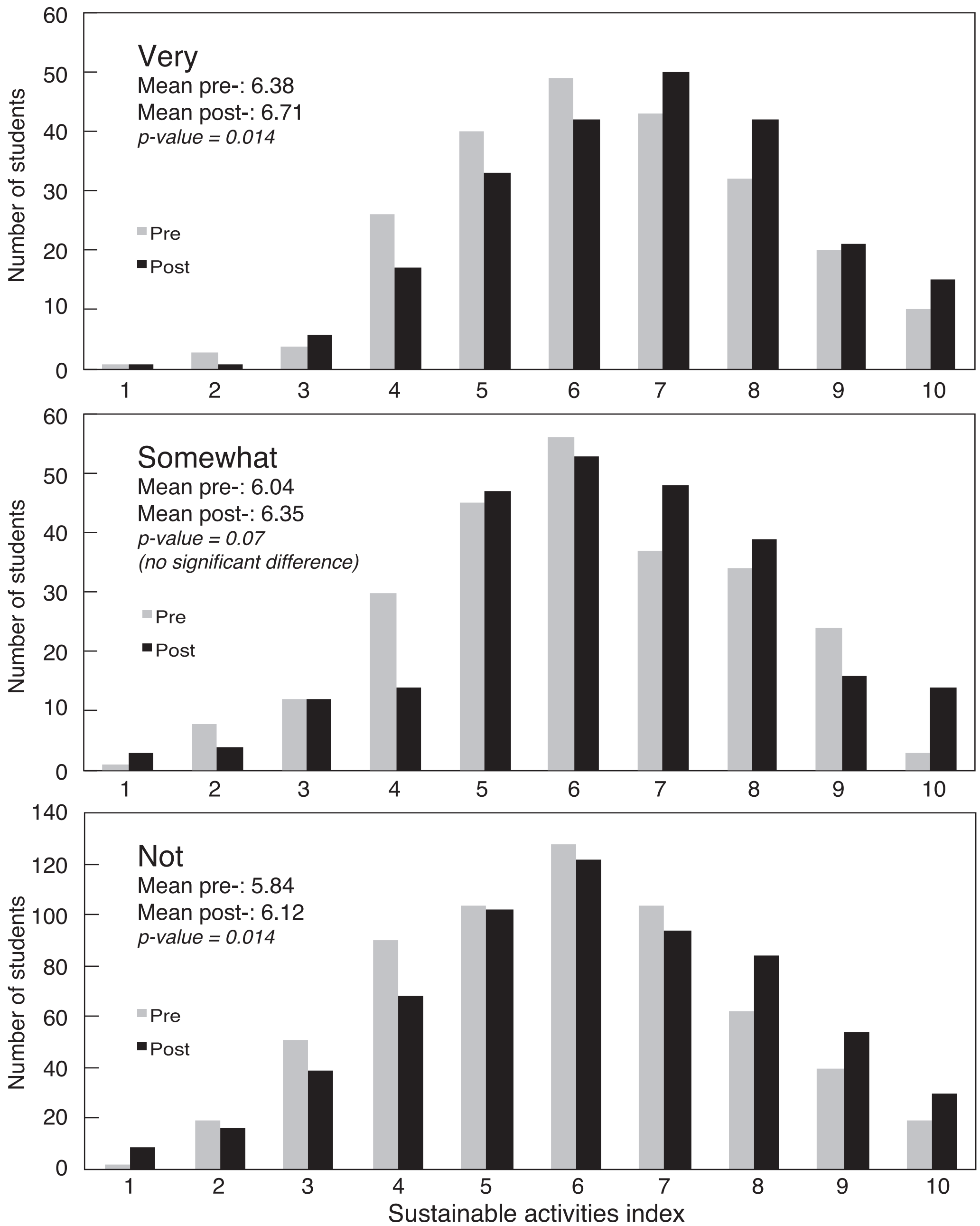

FIGURE 4: Sustainable activities indices for the three subpopulations, showing pre and post values, means, and statistical significance.

"No" Responses

Of those students who responded No, 28% referenced the cause as the course design/instruction (N1); a slightly larger proportion (36%) of Very group expressed that sentiment (Fig. 6). The second largest number of those responding No noted an inadequate feeling of empowerment, or that the problem is simply too difficult (N3). These responses ranged from comments noting that solutions are up to people with more training or authority, to ones noting that the problem is so large that it is beyond any single person's ability to effect change: "I am not sure how I could help on a larger scale." Others responded that they had no sense of where to begin to tackle the problem or even expressed a more defeatist attitude, noting the overall problem is just too difficult to tackle or solve: "I believe that the human population has passed the point of no return."

Approximately 15% of all students cited the fact that their chosen profession would not provide them the opportunity to use what they had learned to help society overcome problems of environmental degradation (N2). This proportion does not hold true for the Very group, in which only one person (less than 2%) made a similar statement.

Beyond these three main groups of those responding No, a small handful in the Very group noted that they had either no interest in the topic or no desire to actually help society on this topic (N4), or that they were already doing as much as they could possibly do and could see no room to add more to their actions (N5).

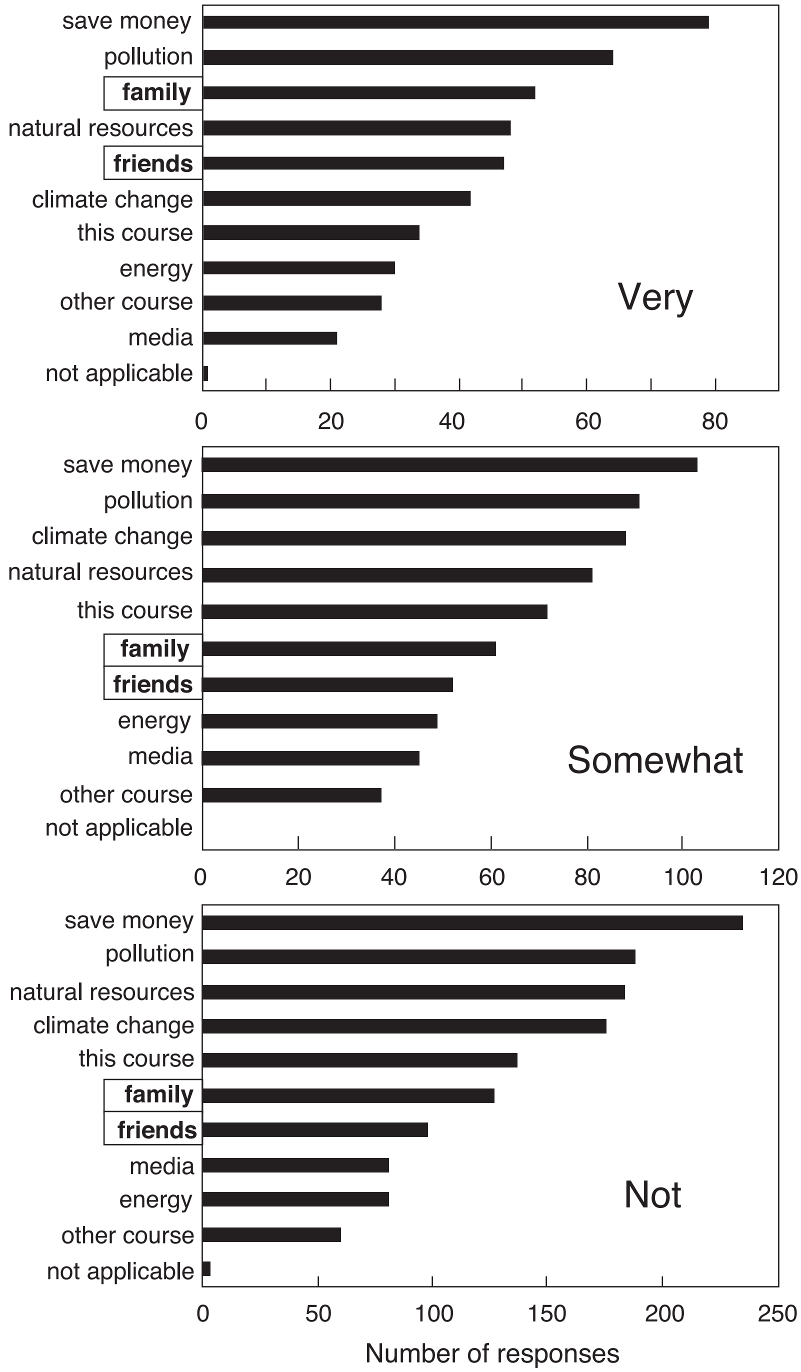

FIGURE 5: Student selections for factors that motivated their sustainable behaviors. The primary difference between the three groups is the ranking of family and friends; in particular, family and friends rank much higher as reasons in the Very group compared to the other two groups.

"Yes" Responses

Overall, the Yes responses were more evenly distributed than the No responses (Fig. 7). Within the total sample, the largest number noted a plan to help society overcome environmental problems by incorporating what they learned into their personal behavior (Y4). In contrast, the most common response in the Very group was a plan to help society through their chosen career, and the large majority of those responses (55 out of 68) specifically mentioned teaching (Fig. 7, right histogram). They often stated specifics about what they hoped to teach their students: "I can teach students how to reduce their impact on the environment," and that they could "engage students in different kinds of activities and make environmentally sustainable practices a commonality in my classroom." The use of evidence in the science to teach was also noted: "I would plan on using some of the teaching techniques and lessons used in this course to help educate more people about the data, and conclusions that can be reached from that data, to live and think more responsibly about the Earth and its resources." The other significant difference between the Very group and the whole population is that a much lower proportion of the

TABLE VI: Coding scheme.

Prompt, postinstruction only: As you think about your future, can you envision using what you have learned in this course to help society overcome problems of environmental degradation, natural resources limitations, or other environmental issues?			
Yes 82% $n_{total} = 923$, $n_{very} = 198$		**No 16%** $n_{total} = 183$, $n_{very} = 47$	
Code	**If yes, how?** Respondent states ($n_{total} = 846$, $n_{very} = 173$):	**Code**	**If no, why not?** Respondent states ($n_{total} = 140$, $n_{very} = 30$):
Y1	Some knowledge or increase in knowledge about Earth gained from the course, but no stated action, not even talking.	**N1**	Something about the course. Subcodes: a. Course was too general b. Course was too specific c. No solutions were included d. Course didn't provide motivation e. Other
Y2	A plan to communicate with other people what respondent has learned (generally passive).	**N2**	Something about their chosen field of study.
Y3	A plan to try to influence others—a conscious attempt to influence behavior.	**N3**	An inadequate feeling of empowerment: that it is up to others, or an impossible task, or too much for one person.
Y4	A plan to incorporate into personal action.	**N4**	No interest in doing anything.
Y5	A plan to incorporate into professional life. Includes subcodes for different professions: • T: Teacher at any level (K–16) • STEM: Profession within STEM • O: Other, non-STEM career	**N5**	There is no room for more change in actions.
Y6	Something that doesn't fit any of the categories, or doesn't directly address the question.	**N6**	Something unrelated or too general to code.

Very group had responses that were coded Y3, a conscious attempt to influence others' behavior (Fig. 7, right histogram). Three respondents (1.5%) in the Very group noted that they felt a "responsibility" or even a "moral obligation" to help society. This is a small number, but notable in that these words did not come up at all in the Somewhat group and only twice in the Not group, which is twice as big as the Very group.

It is worth noting in Table VI that a total of 65 responses were coded as Y5(T), 55 of which fell into our Very group, four in the Somewhat group, and six in the Not group. All six responses in the Not group, however, mention teaching or education in a general sense, rather than specifically as a classroom teacher.

Interdisciplinary Problem-Solving and Systems-Thinking Skills

In the responses to essay questions, we looked only at the responses from students in the designated teacher preparation courses (Table V). The essay questions were designed to differentiate between levels of understanding, and a student in an introductory course would not be expected to score a 4 on the questions (Table IV). The responses for the known future teachers were highly variable

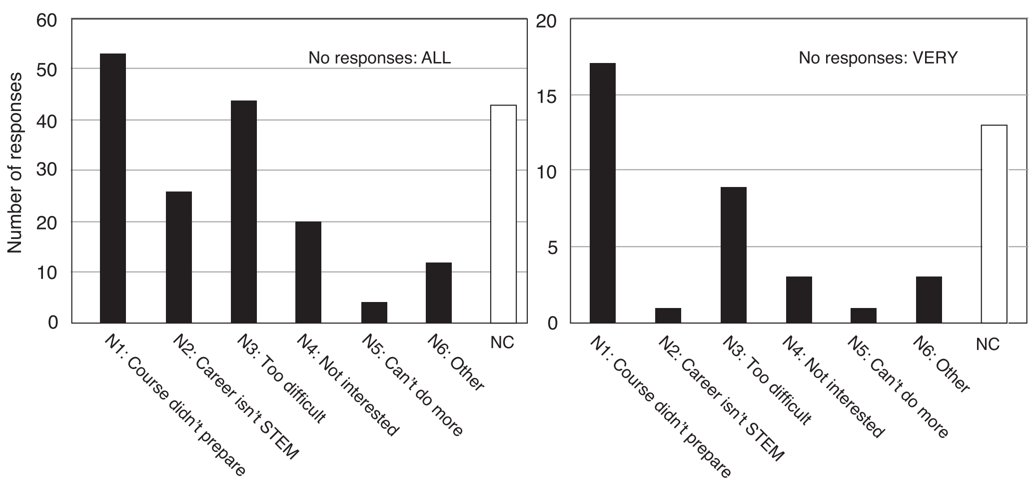

FIGURE 6: (left) Histogram of coded responses for all 183 students who responded No; (right) histogram of coded responses for the Very group.

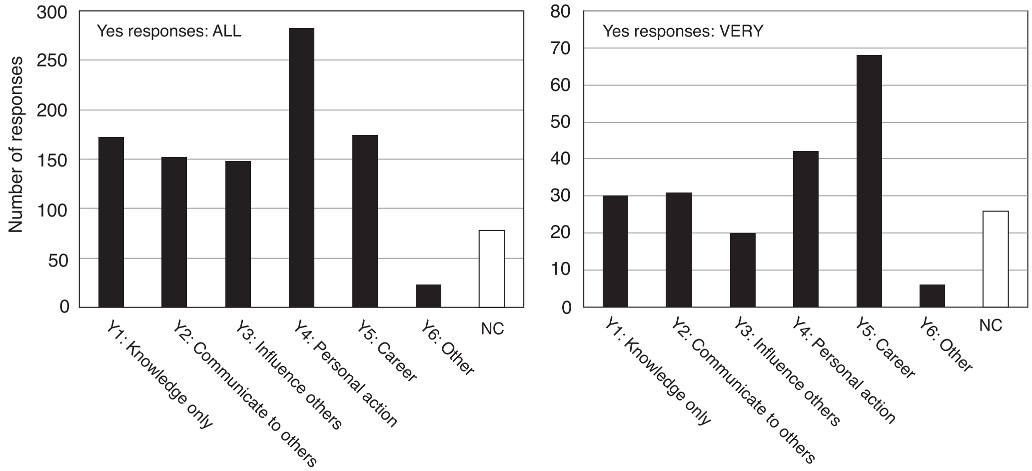

FIGURE 7: (left) Histogram of coded responses for all 923 students who responded Yes; (right) histogram of coded responses for the Very group.

and all scored below 2 on the rubric. Given the generally very low scores, we decided to explore these responses for emerging themes.

Out of 49 responses to the interdisciplinary problem-solving essay question, the most common global challenge mentioned was global warming (7) or climate change (8). If combined with other answers that are directly related to warming, such as sea level rise (4), melting of ice (3), the total number of responses focused on a warming climate is 22, or 45%. The next most common answer was overpopulation (five responses out of 49, or 11%). Other challenges mentioned by one or two students were lack of clean water, extreme weather events, food shortages, poverty, running out of fossil fuels, earthquakes on the San Andreas Fault, and pollution of soils. Very few students made a connection between science and economic, social, or political decision-making.

Responses to the systems-thinking question were only available for 20 students in elementary science methods courses (Table V). Most students did not completely answer the question. As an example of a system, six students said "ecosystem" and three responded "pond ecosystem." Two mentioned a food chain or web, two described the water cycle, and one described the rock cycle.

DISCUSSION

Demographics

Our primary result from this survey—that 22% of respondents are very interested in teaching and another 22% are somewhat interested—is in and of itself interesting and compelling. This is an unexpectedly high percentage, considering that only nine of the 68 courses were designated teacher preparation courses (i.e., only students enrolled in a teacher preparation program would take these courses) and only 101 out of the 1,125 students in our matched sample (9%) come from those courses (Table V). Potential future teachers in our sample are distributed across the entire range of courses in which the survey was administered: primarily introductory science courses including geology, oceanography, meteorology, and environmental science, but also upper-level courses (considered anything above an introductory course) such as environmental justice and natural hazards.

In other words, future teachers are in all of our courses in the geosciences, and they constitute a significant percentage of the students in our introductory courses. Given this primary observation, we explored the demographic characteristics of these three subpopulations to compare them to each other, the nationwide population enrolled in teacher preparation programs, and the current teacher workforce.

Gender

The Report of the 2012 National Survey of Science And Mathematics Education (NSSME; Banilower et al., 2013) shows that, in the current teacher population, 94% of elementary teachers are female, along with 70% of middle school science teachers and 54% of high school science teachers. Our sample population does not discriminate between elementary, middle, and high school, and roughly matches the average of these three populations (73%), as might be expected. Nationwide, enrollment in teacher preparation programs is 74.3% female (U.S. Department of Education, 2013).

Ethnicity

Nationwide, enrollment in teacher preparation programs is 70.7% white or Asian, which is slightly less diverse than our study group (U.S. Department of Education, 2013). Both our subpopulation and nationwide teacher preparation enrollment is far more diverse than the current teacher workforce: at all levels (elementary, middle school, and high school), white and Asian teachers make up over 90% of current science teachers (Banilower et al., 2013). It is possible that we are seeing a real change in the demographics of the teacher workforce, as approximately 50% of the teachers surveyed in the NSSME have greater than 10 years of teaching experience, while both our survey and the Department of Education reports are looking at future teachers. It may be that the teacher population is in the process of diversifying and we are looking at two points on the timeline. It may also be that several years of efforts to broaden access to the geosciences are paying off (e.g., Levine et al., 2006; Carrick et al., 2016), and we are simply seeing more diverse enrollment in geoscience courses where we did much of our surveying. On the other hand, it is also possible that we are losing students from underrepresented groups who are interested in teaching somewhere between their introductory science courses and their first 10 years of teaching. Unfortunately, previous reports from the Department of Education do not include race and ethnicity data, so these possibilities cannot be tested.

Year in College

On the whole, the students in the Very group are further along in their undergraduate careers (Fig. 3). One potential explanation for this discrepancy is that in many teacher preparation undergraduate programs, the designated teacher preparation courses are only open to upperclassmen. However, as noted earlier, the relatively small number of students in these designated courses cannot completely account for this discrepancy. Another potential explanation is that we are selecting for third- and fourth-year students in our initial determination of the populations, in which we used career and major questions: students who are more confident in their major or career are more likely to be in their junior or senior year. This characteristic of the Very group is important to keep in mind in the interpretation of the rest of the results, but the relatively small numbers of respondents in each of these bins prevent us from making more quantitative comparisons.

To summarize, students who are very interested in the teaching profession look different from the entire sample population as well as the Somewhat and Not groups in gender, ethnicity, and year in college: respondents in the Very population are more female, more white/Asian, and have spent more time in college than the Somewhat and Not groups. The Very group resembles the current teacher population and teacher preparation population in gender, though our sample population is significantly more diverse than the current teacher population and somewhat more diverse than national teacher preparation enrollment. With what we know of the nationwide population in this category, the demographic alignment of our Very group gives us confidence that we have surveyed a representative sample of future teachers.

Behaviors and Motivations

We find it particularly interesting that the Very group is more strongly influenced by family and friends in their decisions about sustainable behaviors than the rest of the sample population. This is perhaps not unexpected, however. Kyricou and Coulthard (2000) found that undergraduate students in the UK who were most interested in teaching as a career ranked the ability to combine their job with having a family and where they can contribute to society far higher in importance than students who were definitely not interested in teaching. In an international comparison of motivations for pursuing teaching as a career, Watt et al. (2012) found these motivations to be even stronger in the United States than in Australia, Germany, or Norway, which they hypothesized to be due in part to the low relative pay for teachers in the United States. As such, we might expect future teachers in the United States to be strongly influenced by their family and their communities.

In their motivations, the Very group also appears to be slightly more influenced by other college courses than the Somewhat and Not groups, both of which rank other courses last (Fig. 5). This difference may be explained by the fact that the Very group has, on average, been in college two years longer than the two other groups (Fig. 3) and may have simply taken more classes. This result may also reflect the nature of the courses in which 54 of the survey respondents in the Very group were enrolled: elementary science methods and secondary science methods, which typically include little science content and instead focus on pedagogy.

The open-ended responses provide some additional insights into behaviors and motivations. In the Very group, many expressed their comfort and ability to take action as an individual and in their career, but little or no confidence in their ability to influence others (other than children, perhaps, over whom they would have clear authority). The apparent lack of confidence could reflect a reluctance to influence behaviors, perhaps as overstepping the role of a teacher. Or it may be a reflection of the preservice status of these students: samples of preservice teachers at four stages in their training have shown the biggest growth in confidence after their student teaching (Gurvitch and Metzler, 2009).

The lack of confidence may also reflect their lack of knowledge about key concepts in sustainability, as may be suggested in their responses to essay questions. Although it is difficult to draw substantial conclusions from the sparse responses we examined, it is readily apparent that the concept of systems presents a particular challenge to future elementary teachers. However, systems and systems thinking are major components of the NGSS, and the ability to utilize systems concepts such as feedbacks, emergent phenomena, and multiple actions leading to a given outcome are critical in addressing sustainability. Alternatively, the responses may reflect drawing a distinction between global issues, where they feel they have no ability to influence others, and personal behaviors, which they report are more strongly influenced by friends and family. This may also reflect a lack of a deep understanding of systems, in which collective behaviors can emerge out of many individual actions.

In summary, a majority of the Very group embraced the idea that they could play an important role as a teacher in educating children about Earth and the choices they could make in the future, but they are not necessarily prepared to do so.

Limitations of the Survey

As noted earlier, the survey was administered by 61 instructors in 68 courses at 46 institutions. These institutions span a range of postsecondary institution types and include two-year colleges, four-year liberal arts colleges, regional comprehensive universities, and high research universities in 23 states. As such, it is a nationwide survey that reached undergraduate students in a wide variety of settings, but it is not, however, a random sample. The survey was given in courses taught by faculty who are highly involved in education reform efforts, which may influence the demographics of student enrollment. We don't feel this is a strong bias, however, given that the majority of responses came from introductory and general education courses, in which few students have the opportunity to make decisions about enrollment based on the instructor. As noted above, the alignment of our population with national trends suggests that our sample is sufficiently large to be considered representative.

In addition, the survey was given in multiple terms, and it is possible that some of the responses would have been influenced by the term or season when the survey was administered. In particular, student responses to the sustainable behaviors prompts about "walking or biking instead of using a car" and "purchasing locally-grown food" would be strongly influenced by seasonality in the northern latitudes. When the 1,125 matched responses are analyzed at this level, however, there are not enough responses in each category (e.g., northern latitude college in winter) to provide meaningful comparisons.

Implications of Our Results

These results provide a glimpse into the characteristics of the future teacher population and their behaviors and motivations towards sustainability. The glimpse we have of this population allows us to ask the questions: How prepared are future teachers to address the aspects of sustainability and systems thinking that are encoded in the Next Generation Science Standards? How can we as geoscientists and geoscience educators support them?

How Prepared Are Future Teachers?

Our group of students that we designated as very interested in teaching have some characteristics that distinguish them from the rest of the population we sampled. While they are generally further along in their college careers, they struggle with concepts related to systems and systems thinking, and to some extent with a sense of empowerment. These findings are similar to those of others: Hagevik et al. (2015) found that preservice elementary teachers who held bachelor's degrees and had taken at least two (and an average of four) science courses as part of their degree program reported feeling unprepared to teach sustainability concepts. Foley et al. (2015) report significant improvements in preservice teachers who take a sustainability course designed for them, but their understanding of systems thinking still lags behind all other conceptual measures.

Many future teachers in our survey population recognize that climate change is a significant issue that society is facing and will continue to face in the future (as can be inferred from the essay results); climate-related concepts are a significant part of the NGSS. However, that is not currently part of the teacher preparation or introductory geoscience curriculum in most places (Macdonald et al., 2005; Sullivan et al., 2014). Currently, most teachers rely on self-study and professional development to learn about climate change and its impacts (Sullivan et al., 2014), although others have begun to incorporate it directly into the teacher preparation curriculum with positive results (Hestness et al., 2015).

While possibly less knowledgeable about sustainability, our Very group distinguished themselves by being slightly more likely to engage in sustainable behaviors. Hagevik et al. (2015) similarly found that preservice elementary teachers were already "pro environmental," or likely to engage in a list of 13 behaviors, such as conserving water and energy. Even more distinctive was the influence that family and friends had on these behaviors. Our result is reflected in other studies that found that preservice elementary teachers tend to include or focus exclusively on relationships and people in describing their "sense of place" (Moseley et al., 2015), whereas most of the literature and pedagogy around sense of place focus on establishing a connection with nature and the biophysical environment (Semken and Freeman, 2008; Semken and Brandt, 2010).

Overall, it appears that current teacher preparation programs are not yet preparing future teachers to fully address the sustainability concepts in the NGSS, and that they are challenged by the essential components of sustainability related to Earth Science. But our results suggest that preservice teachers are primed for engaging more deeply—they already engage in sustainability behaviors; they are motivated by their communities to do so (Williams and Semken, 2011), possibly because they feel more connected to their communities to begin with; and they feel a responsibility toward their future students.

How Can We Support Future Teachers?

Geoscientists have an important role to play in preparing future teachers that goes beyond traditional geoscience content knowledge. The NGSS place sustainability concepts in the Earth and Space Science disciplinary core ideas and performance expectations: as states adopt the NGSS and revise their standards for teacher preparation accordingly, that content and those skills then become part of what future teachers are tested on as well. The content of our current courses, however, is largely divorced from the content expectations of the NGSS. Also, we cannot simply leave sustainability to others to teach: it must be embedded throughout the curriculum, giving preservice teachers multiple experiences engaging in sustainability-related activities (Nolet, 2009; Hagevik et al., 2015; Stratton et al., 2015)

For geoscientists, the primary leverage point in teacher preparation programs is introductory courses. Aligning introductory course content with the content of the NGSS is a critical step to supporting this audience, as well as all other students, as all will go on to be participants in our democracy, in which science knowledge connected to societal issues is becoming more important (Hein, 2006). In addition, alignment recognizes that many students who will be entering the college classroom in a few years will have been prepared on the basis of the NGSS, and will have a skill set and knowledge base that is based in those standards. Incorporating sustainability concepts as defined in the NGSS requires moving away from traditional textbooks, in which Earth and human impacts may constitute a single chapter or a portion of a chapter, toward new curricular materials that focus on analyzing and interpreting real data in all of its complexity and placing those analyses in the context of societal issues such as climate change.

Other STEM disciplines have developed materials that incorporate sustainability ideas into undergraduate introductory courses, including chemistry (Mahaffy et al., 2014) and physics (Rogers et al., 2013). In the geosciences, InTeGrate has been working toward this same goal (McConnell et al., 2013) and has developed and tested curricular materials using a rubric-guided process. The rubric comprises six sections: guiding principles, learning objectives and outcomes, assessment and measurement, resources and materials, instructional strategies, and alignment. The guiding principles are unique to InTeGrate, while the other five sections are drawn from best practices in curriculum development (e.g., Wiggins and McTighe, 2005; Cullen et al., 2012).

The guiding principles require that InTeGrate curricular materials:

- Address one or more geoscience-related grand challenges facing society;
- Develop student ability to address interdisciplinary problems;
- Improve student understanding of the nature and methods of geoscience and promote the development of geoscientific habits of mind;
- Make use of authentic and credible geoscience data to learn central concepts in the context of geoscience methods of inquiry; and
- Incorporate systems thinking.

The guiding principles are well aligned with disciplinary core ideas in Earth and Space Science, as well as with the science and engineering practices and crosscutting concepts within the NGSS (NGSS Lead States, 2013). A detailed alignment is provided in a supplemental file (available in the online journal and at http://dx.doi.org/10.5408/16-174s1), which shows that all of the practices and crosscutting concepts at the high school level are represented in one or more of the guiding principles. It is worth noting that, in an analysis of the distribution of the science and engineering practices (SEPs) throughout the NGSS, Kastens (2015) found that the practice of "Analyzing and Interpreting Data" is more common in the Earth and Space Science performance expectations than in the other disciplines, paralleling InTeGrate's emphasis on making use of real geoscience data.

These curricular resources are designed specifically to allow for adaption to local issues and settings, as lack of adaptability has been cited as one barrier to widespread curriculum adoption (Ball and Cohen, 1996). Kastens and Turrin (2006) note that one advantage of state control over science standards allows for adaptability of general standards about sustainability to specific statewide or regional issues. Given that 80% of teachers credentialed in a given state also were enrolled in a teacher preparation program in that same state (U.S. Department of Education, 2013), the benefits of using locally adapted curricula in the college classroom are leveraged, providing future teachers with robust examples they can take into their own classrooms.

Refocusing an introductory course to address sustainability concepts does not necessarily mean dropping content. Strategies employed in the InTeGrate materials that address traditional geoscience content using the guiding principles described above include shifting the focus from causes to consequences and connecting processes to people.

Strategy 1: Shift the Focus From Causes to Consequences

In the most common introductory textbooks, chapters about mineral resources focus primarily on what mineral resources are useful, how and where mineral ores form, and occasionally how they are extracted (see, for example, Tarbuck et al., 2014, Chapter 23). In other words, these texts focus on the *causes* for the distribution of resources. The module, Humans' Dependence on Earth's Mineral Resources (Bhattacharya et al., 2014) takes a different approach that emphasizes the economic and environmental impacts of mineral resource extraction, and how these impacts influence the value of a resource in combination with its geologic distribution. In other words, the focus of the InTeGrate module is on the consequences of mining.

This strategy within this subject area aligns nicely with a high-school–level performance expectation in the Earth and Human Activity DCI: "Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity" (NGSS Lead States, 2013). In Unit 2 of the InTeGrate module, students develop and make use of concept maps to determine the causes and consequences of boom–bust cycles in cobalt mining, then analyze and explain trends in production and value graphs of rare earth elements. A component of that analysis requires learning more about how and where rare earth element deposits form, but the focus of the activities is on the consequences of this distribution, not the causes.

Strategy 2: Connect Processes to People

Rivers are another common topic in introductory geoscience courses, often including descriptions of landforms, sediment transport, and flooding (see, for example, Tarbuck et al., 2014, Chapter 16). Typically, the focus is on the processes involved in how rivers shape the landscape. River processes have a profound effect on people, however, and people have done many things to modify natural river processes. The module, Interactions Between Water, Earth's Surface, and Human Activity (DeBari et al., 2014) starts from this premise, focusing on flooding.

In Unit 4, students analyze and interpret stream gauge data from the Cedar River and compare it to precipitation data from a nearby weather station. Using the stream gauge data, they calculate a flood recurrence interval, and discuss how floods in 1993 and 2008—only 15 y apart— could both be considered 500-y floods, and how FEMA incorporates this information into their hazard maps. As a final activity, they choose a river in their hometown or a nearby stream and develop an informational brochure to help local residents understand the hazards and risks associated with flooding on that river, and to make recommendations for how residents can stay safe. In this way, the impact rivers have on people is directly tied to data analysis and developing an understanding of the processes involved in flooding. Because students relate stream flow to precipitation and human construction (such as dams and levees), calculate flooding risk, and evaluate the risk in the context of a community, this activity aligns with another high-school–level performance expectation in the Earth and Human Activity DCI: "Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity." This unit is particularly adaptable to local environments, since stream gauge data is available for rivers across the United States.

CONCLUSIONS

The Earth Science knowledge and skills embedded in the NGSS are substantially disconnected from the Earth Science content and skills that future teachers are currently receiving. The primary means by which future teachers receive their Earth Science content and skills are introductory-level general education courses, indicating that these courses are of significant importance beyond simply recruiting students into the geoscience majors. Specifically, the concept of sustainability is embedded in the Earth and Space Science disciplinary area of the NGSS, but is often not addressed in postsecondary Earth Science courses that future teachers are likely to take.

Our results suggest that future teachers are primed for engagement with sustainability through their behaviors and connections to community. This opens the door to curricula that emphasize sustainability and human connections to Earth and the environment, and are easily adaptable to local and regional issues and circumstances. These new curricula need not abandon concepts typically taught in introductory geoscience courses, but reframing them in a way that places consequences and people in a more prominent role, rather than focusing on causes and processes. Rethinking introductory geoscience courses has benefits that go beyond future teachers, however, and serve all students by helping them integrate their knowledge of Earth with relevant societal issues. More work addressing how to help students develop systems-thinking skills and other key concepts in sustainability would be of great benefit in this transition.

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