# Integrating Sustainability into Science Teacher Education through a Focus on Climate Change

Emily Hestness, J. Randy McGinnis, and Wayne Breslyn

University of Maryland, College Park

Abstract

In this chapter, we report on our experiences integrating sustainability as an organizing theme in an undergraduate science methods course. The course modeled the use of sustainability as a lens for examining local and global challenges, with a particular focus on climate change. The development of the course was informed by ideas from the Next Generation Science Standards, our state's environmental literacy standards, and national teacher education standards. We describe key elements of the course design that promoted examination of climate change and its relationship to local and global sustainability issues. We present examples of teacher candidates' responses to the sustainability focus, suggesting the potential influences of the course on their understanding and concern related to sustainability, as well as their thinking about their future science teaching practice. As instructors, we reflect on lessons learned from the experience of designing and teaching the course, including its affordances and challenges. We conclude with recommendations for teacher educators interested in incorporating sustainability into their work with teacher candidates.

*Keywords:* science teacher education, science methods, sustainability, climate change

Integrating Sustainability into Science Teacher Education through a Focus on Climate Change

## Introduction

In the current global environmental, economic, and social landscape, sustainable decisions and actions that "meet the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987, p. 41) are increasingly critical. Currently observed impacts of climate change are "unprecedented over decades to millennia" (Intergovernmental Panel on Climate Change (IPCC), 2013, p. 4), and there is scientific consensus that human activities are "extremely likely" (IPCC, 2013, p. 17) the dominant cause. Such environmental dilemmas are bound together with global economic and social justice concerns, as nations most adversely affected by the problems – regardless of their contributions - have the fewest resources to adapt to their effects. The complexities of current sustainability challenges such as global climate change illustrate the interdisciplinary nature of the knowledge and skills required for their resolution. Addressing such multifaceted, and sometimes daunting, issues in the classroom is no insignificant task, and may require reformed approaches to teaching and learning. Yet as Nolet (2009) asks, "If, through reform of our education systems, it would be possible to effectively meet the tremendous challenges that lie ahead, wouldn't education reform be a moral imperative?" (p. 436).

The growing STEM education movement in the United States presents an opportunity to reorient science teaching and learning toward the study of the "grand challenges" of our time (Bybee, 2010, p. 31), many of which are linked to sustainability. The President's Council of Advisors on Science and Technology (PCAST) has argued that STEM education will play a central role in our nation's ability to resolve pressing energy, health, and environmental

challenges, and has the potential to "strengthen our democracy by preparing all citizens to make informed choices in an increasingly technological world" (PCAST, 2010, p. v). Toward this end, the *K-12 Framework for Science Education* (National Research Council, 2012), the foundation for the Next Generation Science Standards (Achieve, 2013), presents a vision for a future of STEM education in which learning in the realms of science and engineering can help students see how these disciplines "are instrumental in addressing major challenges that confront society today, such as generating sufficient energy, preventing and treating diseases, maintaining supplies of clean water and food, and solving the problems of global environmental change" (National Research Council, 2012, p. 9). In the current dialogue on STEM education, the need for a generation of citizens capable of understanding and addressing urgent global challenges is clear.

For sustainability to become a focus of teaching and learning in schools, there are important considerations for teacher education. While historically, sustainability education has rarely been included in the preparation of U.S. teachers, there is currently a movement underway to include sustainability education in teacher education (Nolet, 2009). For science teacher educators in particular, there may be natural synergy between sustainability education and existing teacher preparation efforts. Science teacher educators are responsible for preparing new teachers to address key curricular topics associated with sustainability, including relevant Disciplinary Core Ideas articulated in the Next Generation Science Standards (e.g., *Human Impacts on Earth Systems, Natural Resources,* and *Global Climate Change*). More generally, they are responsible for addressing broader teacher education standards such as those articulated by the Interstate Teacher Assessment and Support Consortium (CCSSO InTASC, 2013), which state that teacher candidates must understand how to "help learners use content to propose

solutions, forge new understandings, solve problems, and imagine possibilities" (p. 8) and "make content knowledge relevant to learners by connecting it to local, state, national, and global issues" (p. 8). Infusing sustainability into science teacher education can help to address these standards by framing science teaching and learning around real-world issues in need of solutions.

## Context for Our Science Methods Course Redesign

Interested in sustainability as valuable perspective to integrate into science teacher education, we redesigned a university-based undergraduate science methods course. Building on our prior experiences integrating climate change education into science teacher education (McGinnis, Hestness, & Riedinger, 2011; Hestness, McGinnis, Riedinger, & Marbach-Ad, 2011), we included a focus on the topic of climate change and its relationship to local and global sustainability issues. We saw the climate change education focus as particularly relevant in the context of the release of the Next Generation Science Standards, the first set of U.S. national science standards to explicitly include the topic.

The course redesign occurred at the confluence of several initiatives to promote change in K-16 education. At the university level, one of us (McGinnis) had taken part in a faculty workshop offered by our university's Office of Sustainability. Its purpose was to educate faculty about sustainability issues and to support the integration of sustainability into university teaching. The workshop included a project component, which afforded the opportunity for our work on redesigning the Elementary Science Methods course. At the state level, the relatively recent release of new Environmental Literacy Standards (MSDE, 2011) and the statewide adoption of the Next Generation Science Standards—both of which include components related to sustainability—also informed our approach to integrating the sustainability theme into the

course. A final impetus was our involvement in a multi-year National Science Foundation-funded research project, MADE CLEAR (Maryland and Delaware Climate Change Education, Assessment, and Research; www.madeclear.org, www.ClimateEdResearch.org). The project seeks to develop a model of climate change education for our region and includes a teacher education component. Our participation in each of these contexts – a university interested in incorporating sustainability into teaching, a state adopting new science education and environmental literacy standards, and a regionally-focused research project on climate change education – all influenced our approach to integrating sustainability into our science methods course, illustrating the variety of contextual factors that may shape the ways in which sustainability can be incorporated into science teacher education.

## Background

### Conceptualizing Sustainability in Science Teacher Education

For the purposes of our science methods course, we framed sustainability according to the widely used World Commission on Environment and Development (1987) definition of sustainable development as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (p. 41). We saw this definition as having the potential to resonate with teacher candidates in terms of its future orientation and their interest in both the immediate and long-term wellbeing of their elementary learners.

In reviewing the literature on the inclusion of sustainability in teacher education, we were drawn to the notion of presenting sustainability as holistic in framing real-world dilemmas, by including environmental concerns as embedded in a multidimensional framework. For example, Odgers' (2009) Australian study conceptualized sustainability in terms of eight themes defined

by UNESCO (2004): *Gender Equity, Health Promotion, Environment, Rural Development, Cultural Diversity, Peace and Human Security, Sustainable Urbanization, Sustainable Consumption*. Similarly, Summers and Childs (2007) described UNESCO's definition of sustainable development as identifying three key areas: society, environment, and economy. Buchanan (2012) described the view of sustainability outlined in Australia's National Curriculum, which stated that sustainability education should focus on environmental, social, cultural, and economic systems. Like these teacher educators, we sought in particular to make connections between environment, economy, and local and global society as we presented sustainability in our course.

We were also interested in potential connections between sustainability and responsible action. Other researchers who have drawn on the World Commission on Environment and Development to frame sustainability, have highlighted the orientations toward the role of action within this definition – or a view that certain kinds of actions are required for a sustainable future. For example, Summers and Childs (2007) analyzed student ideas about sustainability using a framework with several action-oriented elements, including "personal responsibility" and "precaution in action". Other studies engaged pre-service teachers in recommending actions to promote sustainability (Weiland & Morrison, 2013; Buchanan, 2012) or in leading community-based service projects around sustainability (Odgers, 2009).

Amongst these emerging tenets of sustainability – its future orientation, its holistic and multifaceted nature, and its linkages to action – a number of philosophical issues arise. Most fundamentally are such questions as, "*What should be sustained?"* (answers to which are inherently value-laden), and "*Sustained for whom*?". As Buchanan (2012) noted, some have argued that any attempt at predicting the needs and circumstances of an undefined future

generation is unrealistic and futile. In connecting such questions to science teacher education, further questions emerge around how science teachers can foster students' understandings of the complex nature of science and sustainability – including the notions that they are value-laden, and that decisions to act (or to refrain from action)—have moral and ethical implications.

## Linking Sustainability with Science and Environmental Literacy Standards

In preparing future educators to enter public school teaching environments, we were aware of the need for making connections between sustainability and the standards-based curricula they would be responsible for teaching.

**Next Generation Science Standards (NGSS).** The Next Generation Science Standards include connections with sustainability across Disciplinary Core Ideas, Crosscutting Concepts, and Core Science and Engineering Practices. For the elementary grade levels with which we were concerned, we noted a number of Disciplinary Core Ideas that offered potential connections to sustainability concepts. Disciplinary Core Ideas in Life Science (e.g., Biodiversity and Humans) and Earth and Space Sciences (e.g., Human Impacts on Earth Systems; Natural Resources) relate human interactions with the natural environment that have the potential to impact sustainability. For example, they encourage students to examine the ways in which habitat changes may affect the organisms within a habitat (3-LS4-4)—which could include organisms crucial for sustainably meeting society's current and future needs. They highlight that human use of renewable and nonrenewable energy sources has environmental implications (4-ESS3-1), an area of exploration that could illustrate the intersections of social, economic, and environmental concerns embodied in the notion of sustainability. They also promote the examination of the impacts of human activities on air, land, water, and other living things, while

noting that human actions can also help to protect natural resources and environments (5-ESS3-1), potentially connecting to the responsible action dimension of sustainability. Also potentially connected to action through problem solving were some of the Engineering, Technology, and Applications of Science ideas present in the NGSS. For example, they emphasize the notion that designing solutions to problems requires an understanding of the desired features or criteria of a solution and the constraints available materials and resources (3-5ETS1). Considering design solutions for sustainability-related concerns in this way could provide a way to develop deeper understandings of environmental issues important to society, as well as the possible moral and ethical implications of various possible solutions.

Beyond the potential connections with Disciplinary Core Ideas, we sought to emphasize to teacher candidates the ways in which NGSS Crosscutting Concepts and Core Science and Engineering Practices related to the sustainability-infused activities presented in the course. For example, we saw opportunities to connect with the Crosscutting Concepts of *Cause and Effect*, *Systems and System Models*, and *Stability and Change* while engaging participants with sustainability concerns such as the depletion of natural resources and global climate change. During activities related to these sustainability topics and others, we also asked participants to identify NGSS Core Science and Engineering Practices they saw as relevant. We noted frequent opportunities to connect in particular with the practices of asking questions and defining problems (e.g., What can be done about local sea level rise concerns?), analyzing and interpreting data (e.g., making sense of the temperature and carbon dioxide relationships depicted by the Keeling curve), and engaging in argument from evidence (e.g., suggesting potential environmental, economic, and social impacts based on local sea level rise projections). We see the broad nature of both the NGSS Crosscutting Concepts and Core Science and

Engineering Practices as having many additional possibilities for connections to the theme of sustainability.

**State Environmental Literacy Standards.** More than thirty states and the District of Columbia have developed, or are in the process of developing, state Environmental Literacy Plans (NAAEE, 2013). Often, these include new sets of standards that teachers will be responsible to address, as is the case in our state. Taking this into consideration, we designed our course with connections to state Environmental Literacy Standards, which include a dimension specifically related to sustainability (Table 1).

**Table 1.**
*Standard 8 (Sustainability) topics from Maryland Environmental Literacy Standards (MSDE Department of Education, 2011)*

**Standard 8: Sustainability**

*The student will make decisions that demonstrate understanding of natural communities and the ecological, economic, political, and social systems of human communities, and examine how their personal and collective actions affect the sustainability of these interrelated systems.*

**Topics**

A. Intergenerational Responsibility
B. Interconnectedness of Systems
C. Influence of Economic Systems on Sustainability
D. Influence of Social and Cultural Systems on Sustainability
E. Limits of Ecological Systems
F. Action Component

## Course Overview

Here we describe the innovations we included in our Elementary Science Methods courses relevant to teacher candidates' understanding of sustainability and related teaching strategies. We note that while we implemented these innovations with future elementary teachers, we see them as applicable to middle and high school teacher education as well. As an emerging topic in science education that is included in the NGSS, we view climate change

education as *the* key area to address in science teacher education for sustainability. Prior research on the inclusion of climate change within science teacher education has suggested that teacher candidates can benefit from opportunities to increase relevant science content knowledge, gain familiarity with curricular resources, and discuss their developing views and understandings related to the topic (McGinnis et al., 2011; Hestness et al., 2011). In addition to these areas, we also sought to foster connections between climate change education and the theme of sustainability.

**Blended Learning Experience Focused on Sea Level Rise**

To introduce the climate change component of our course, teacher candidates participated in a blended learning experience focused on sea level rise. Outside of class, teacher candidates completed a web-based module that we developed, in which they examined sea level rise projections for two cities in our region (http://www.climateedresearch.org/science-methods/sea-level-rise). As they engaged in the module, teacher candidates responded to questions related to climate science content and pedagogy. Back in the classroom, they debriefed the experience, considering in particular the value of presenting learners with locally relevant aspects of the issue. In small groups, they next explored sea level rise on a global level, examining a web-based interactive map of sea level rise projections for the world. They compared the potential impacts of sea level rise, locally and globally, on human health and safety, economy and tourism, and ecosystems. Finally, teacher candidates viewed a video depicting the current impacts of sea level rise in the Pacific island nations of Tuvalu and Kiribati, discussing the value of supporting students in understanding climate change as a locally and globally important issue.

**Discussion of Sensitive Topics in Science Education**

During the first in-class session focused on climate change that followed the online sea level rise module, we introduced the idea of sensitive topics in science education, using climate change as an example. Prior to this session, teacher candidates completed an online version of the Global Warming's Six Americas survey (Yale Project on Climate Change Communication and George Mason Center for Climate Change Communication, 2013), and reported their results to us via email, commenting on their own levels of concern regarding global climate change. We shared with teacher candidates the most recent national statistics regarding public opinion of climate change, illustrating the point that teachers may encounter – and must sensitively respond to – a variety of perspectives in the science classroom. We followed up with a brief presentation on sensitive topics in science education, and research-based strategies for addressing such topics in the classroom. Teacher candidates also completed a journal reflection on the ethical dimensions of science education, discussing their ideas in small peer groups during class time.

**Investigation of Global Temperature and Atmosphere Data**

Drawing on research-based recommendations for teaching sensitive topics, we engaged teacher candidates in a data analysis activity related to changes in the Earth's temperature and atmosphere over time. In small groups, teacher candidates examined data on Earth's temperature or atmospheric carbon dioxide concentration over one of four timescales. Using a modified jigsaw approach, the small groups compared their analyses in order to posit an explanation of the connection between greenhouse gases and temperature. We discussed the concept of the greenhouse effect, and viewed an online animation modeling the phenomenon. We shared findings from science education literature describing the alternative conceptions of the greenhouse effect that students and teachers may bring to the classroom; for example, the confounding of the greenhouse effect and the ozone hole as mechanisms for global warming.

Teacher candidates discussed how data could be used in the classroom to help students develop their understandings of science constructs related to climate change.

**Integration of Formal and Informal Assessment Strategies**

Throughout the climate change education components of the course, we modeled strategies for assessing students' thinking. One example was the use of self-generated drawings (DrawnToScience.org; Katz, McGinnis, Hestness, Riedinger, Marbach-Ad, Dai, & Pease (2011)), in which teacher candidates responded to prompts such as "Draw all that you know about the causes and effects of global climate change" or "Draw all that you know about the causes and effects of sea level rise". Teacher candidates had the opportunity to add to their drawings at different points in the course, which helped them to recognize changes in their understanding over time. With a small sample of teacher candidates, we engaged in individual interviews in which they discussed their drawings in greater depth. Finally, we introduced teacher candidates to the idea of learning progressions, a theory guiding the development of the NGSS, and shared with them a draft hypothesized learning progression on sea level rise (http://www.climateedresearch.org/publications/2012/SLR-LP.pdf). Teacher candidates completed a multiple choice assessment instrument we developed in order to help us validate the learning progression. This instrument modeled ways to gain additional insight into students' thinking from multiple-choice assessments, by including an open-ended writing component that asked users to explain their reasoning for selecting a given response.

## Teacher Candidates' Responses to the Sustainability-Infused Course

To gain insight into the potential influences of the sustainability-related innovations in our methods course, and to inform appropriate adaptations for future iterations of the course, we

examined teacher candidates' end-of-semester journal reflections. We analyzed their writing with the following questions in mind: How might the infusion of sustainability into a science methods course, through a focus on climate change education, have the potential to influence teacher candidates': (1) understanding and concern regarding sustainability and, (2) thinking about their future teaching practice? Using *understanding*, *concern*, and *science teaching practice* as organizational categories (Maxwell, 2013), emergent themes within each of these domains revealed a number of insights about the potential influence of the course. We elaborate on themes related to participants' views about sustainability, levels of concern regarding sustainability, and thinking about their future teaching practice, presenting relevant excerpts from teacher candidates' writings.

**Views and Understandings of Sustainability**

**"Before, I just viewed the topic as glorified recycling." [Broader understandings of sustainability].** In the end-of-course journal reflection, most teacher candidates described their understanding of sustainability as more complex than before. A number of participants described their prior understandings of sustainability as simply encompassing environmentally-friendly practices such as recycling and composting, not fully considering its multidimensional nature and its relevance to environmental, economic, and sociocultural issues. As one participant described,

> I don't think I ever really thought about sustainability connecting to so many different things. Initially, when I thought sustainability, I thought recycling… The idea of sustainability can be connected to almost everything we do in our everyday lives… My understanding of sustainability has grown from a one-definition perspective to something

> that can be connected to many different aspects of science teaching. (Carolyn, journal reflection)

Participants who described the increasing complexity of their conceptions of sustainability further discussed moving beyond vague understandings to specific examples of cause and effect relationships impacting sustainability, especially regarding the use of natural resources. Some also expressed more globally-oriented and future-oriented perspectives on sustainability.

> When we first began learning about sustainability… I had a very narrow understanding of the term. I did not initially realize how large-scale sustainability really is, and I didn't necessarily understand how many areas of our world this term applies to. (Alexa, journal reflection)

Comments like these provided evidence that many teacher candidates may have developed broader and more complex understandings of the nature of sustainability through their participation in the course.

**"I already had a good understanding." [Stable understandings of sustainability].**

Unlike their peers who noted more complex views of sustainability, a smaller proportion of participants felt that they came to the course with a strong understanding of sustainability, and that the course may have solidified—but not significantly changed—their understandings. As one participant stated,

> To be perfectly honest, I don't believe my understanding of sustainability has changed very much, if at all, over the course of the semester. I've always been one to keep abreast of current events and to stay privy to new scientific data. I've understood for a good while now that sustainability has always been important for human life to continue

> and it will only increase in importance as the world's population continues to rise… We have to be intentional about creating a sustainable present and future. (Thomas, journal reflection)

It is possible that teacher candidates who were already particularly interested in sustainability may have evolved less in their understandings in comparison with their peers. However, participants in this group commented that the course did provide some new perspectives, even if it did not lead to major shifts in their thinking.

**"[When I heard] that sustainability would be a focus of the class, I did a mental eye roll in my head." [Initial resistance to the sustainability focus].** Several participants described initial resistance to the sustainability topic that may have influenced the extent of change in their thinking. Notably, however, we noted very little resistance to the inclusion of the climate change topic in particular. Fortunately, those who stated that they were initially skeptical of the sustainability focus of the course appreciated the diversity of activities and perspectives presented. As one participant stated,

> At first, when Professor McGinnis announced that sustainability would be a focus of the class, I did a mental eye roll in my head. I have taken many science classes throughout my school career, and we emphasized global warming and sustainability in almost all of them… I have a great [amount] of experience with sustainability as a topic, and I am pretty tired of it… but we explored it in new and interesting ways that I did not expect… Over the semester, I learned that sustainability can be introduced in new ways. Through this, I felt that it became relevant to me again and not the same old tired topic. (Jake, journal reflection)

Other participants shared this sentiment. An important implication here is that teacher candidates and teacher educators may have different ideas about the novelty of the sustainability topic. As another participant noted:

> Sustainability is not something new to me as a college student. I would hope that holds true for most people my age. (Ellen, journal reflection)

This points to the value of presenting sustainability to teacher candidates in ways that provide new perspectives and can specifically support them in considering their future roles as teachers—a potential perspective that sustainability-oriented teacher education can offer beyond improving only participants' personal understandings of sustainability.

### Personal Concern Regarding Sustainability

**"I don't think I really understood how important taking sustainable actions was." [Action orientation].** In analyzing participants' end-of-semester journal entries, several key themes emerged regarding participants' levels of concern related to sustainability. Many participants noted becoming increasingly concerned about sustainability through their participation in the course. In some cases, this concern was accompanied by a stated desire to change personal actions, although taking sustainable personal actions was not explicitly emphasized in the course. Several teacher candidates showed evidence of concern related to the impact of current actions for future generations. For example, one participant stated:

> It has become clearer to me that I have a large impact on our rising temperatures, melting ice, and disappearing land. All of these things will directly affect future generations and how our world functions. Now that we have the science to explain why these things are

> happening, I need to be more aware of what I can do to prevent these drastic changes from happening so rapidly. (Rebecca, journal reflection)

As demonstrated in this statement, most participants with an apparent action orientation did not give specific examples of actions they intended to change, however, they saw behavior change as an important dimension of sustainability. A few participants suggested specific actions related to the course sustainability focus, such as reducing their consumption of fossil fuels or carbon footprint. As in the *Broader Understandings of Sustainability* theme previously described, several participants specifically noted that responsible action to promote sustainability should go beyond commonly recognized environmentally-friendly actions, such as recycling and composting.

**"It is evident in our everyday lives." [Relevance]** Examining real-world examples of sustainability concerns prompted many participants to comment on the relevance of sustainability to their own lives and the lives of others—a realization that appeared to influence their levels of concern. Participants noted new understandings of how sustainability relates to concerns beyond only ecological ones. For example, one participant noted:

> Prior to this class I was not concerned about what could happen to people's livelihoods, not to mention the impact rising sea levels would have on my life. (Briana, journal reflection)

In addition to the personal relevance of sustainability, a number of participants also commented on its relevance to global society. As one participant noted:

> I was able to take what I have learned from the global perspective and see how a place that I have grown to love will change if the environment is not taken care of properly.

> This has impacted how I see my immediate environment and I will start to think of sustainability and other global issues on a spectrum of myself, my habitat, my environment, society, and finally the globe. (Kelly, journal reflection)

The recognition that sustainability is not only a matter of environmental problems – but relevant to their own daily lives and the lives of others – appeared to influence participants' areas of concern related to sustainability.

**"I became much more aware of sustainability issues and the fact that they need to be addressed before it is too late." [Awareness leads to concern].** A final theme that emerged regarding participants' levels of concern about sustainability was the relationship between awareness and concern. A number of participants noted that as they became more aware of sustainability issues, they became increasingly concerned about the impacts of these issues. As two participants reflected:

> The world has so many environmental issues that I never knew about. These issues could have such a detrimental effect to society if they were to continue to grow and become more threatening. It is important that people educate themselves in these sustainable practices that address these global issues in order to keep our world a livable and thriving place for everyone. (Laura, journal reflection)

> [Before], I don't think I really understood [the importance of] taking sustainable actions. I knew that our actions as people were threatening animals, and that eventually climate change would begin to affect us as people and our future generations, but I didn't really understand how close we were to that point. In some of the statistics we viewed, we

> could see that we would begin losing land to sea level rise in as few as 50 years. That's soon! I don't think I would have come to this understanding and reflection without the multiple exposures we had to this topic. (Sarah, journal reflection)

Such cases demonstrate how increased awareness of real-world sustainability issues instilled a sense of urgency for some of the participants.

**Thinking about Teaching**

**"Traditional forms of assessment are no longer enough for our students."**

**[Alternative ways of assessing student thinking about sustainability]**. Many participants were drawn to the notion of assessing students' thinking about sustainability using alternative forms of assessment modeled in the course. They noted that opportunities to reflect on and communicate their own ideas regarding sustainability helped them to recognize changes in their own thinking over the semester, and could be potentially valuable tools to use in their future science classrooms. In particular, teacher candidates responded positively to the use of drawings as an assessment tool. Having responded to the prompt, *"Draw all that you know about the causes and effects of global climate change"* early in the course, and then having had the opportunity to add to their drawings at the end of the course, many participants noted the apparent changes in their thinking. As one teacher candidate stated,

> The drawing is where I noticed most of my growth. After seeing the drawing I did at the beginning of the semester, I felt like I needed to add A LOT. I couldn't even fit all the things I would have liked to add. (Madeline, journal reflection)

Through drawing, participants noted new dimensions becoming a part of the ways in which they conceptualized sustainability. For example,

> I was able to see that I was very much focused on the environmental aspect of sustainability and not necessarily the economic aspect that would be greatly affected. (Anne, journal reflection)

Participants also noted that the drawing assessment strategy for gaining insight into students' thinking about sustainability offered the affordances of being less intimidating and more creative than traditional forms of assessment, such as multiple choice tests. A number of participants expressed interest in using this particular activity in their own future science classrooms.

**"It is my responsibility to present this information to my future students."**

**[Importance of infusing sustainability into science teaching].** The end-of-semester journal reflections suggested that some participants may have had new realizations about the importance of infusing sustainability into their future science teaching practice. Their rationales typically included ideas about environmental wellbeing as well as the value of engaging students in science in meaningful ways. With regard to environmental wellbeing, participants noted that increasing students' awareness of sustainability issues had the potential to empower them to take action regarding environmental problems and make the world a more hospitable place for future generations. Participants noted potential challenges of integrating sustainability into science education, especially related to the climate change topic, but tended to view it as important nonetheless. As one participant noted,

> Although it's controversial, I really think it's important to address this with students in age-appropriate ways. This issue of climate change will only become more prevalent, therefore, our future students need to be well educated about these issues so that they can

> be proactive about it and possibly change the way the majority of people think about climate change. (Valerie, journal reflection)

With regard to benefits for student learning, participants noted several ways in which incorporating sustainability into science teaching could support the greater goals of science education. For example, participants noted that sustainability had the potential to promote greater interest in science and to promote science learning. Some participants were able to see the ways in which sustainability concepts could support goals and objectives embedded in their science curricula. One teacher candidate reflected that:

> Prior to [the course], I did not spend much time thinking about ways to address issues surrounding sustainability in my current placement or when I become a teacher in the near future. Over the course of the semester, I began to realize how prominent the topic of sustainability is in so many science objectives. (Christy, journal reflection)

As this statement suggests, some participants saw value of integrating sustainability into their science teaching not only in terms of promoting environmental wellbeing, but also in terms of supporting science teaching and learning goals for which they would be responsible in their future classrooms.

**"[The activities] were meaningful to my repertoire." [Ideas for incorporating sustainability in the classroom]**. A final way that the sustainability-infused science methods course appeared to influence participants' thinking about their future science teaching practice became apparent in participants reflections on – and stated intentions to use – some of the teaching activities modeled in the course. Particularly appealing to many participants was the blended learning experience in which they examined local sea level rise projections for our

region. They expressed interest in using technology, such as interactive web-based maps, for helping to teach about sustainability-related issues that can be difficult for students to visualize. A number of participants also commented on the value of examining the climate change topic through a variety of perspectives (e.g., local and global) and learning activities. As one participant noted,

> I can see how this experience can apply to my own future classroom. This shows me that simply giving my student one viewpoint or one exposure to a topic is not necessarily enough for them to develop the desired understanding. People need multiple experiences and exposures with a topic in order to truly understand its significance and importance. (Leah, journal reflection)

This statement suggests that some participants may have extended their learning from the approach modeled in the course to thinking about the value of providing opportunities for in-depth exploration of big ideas related to science, including sustainability.

## Reflections and Recommendations

In reflecting on our experiences integrating sustainability into our science methods course, we see a promising starting place for reimagining teacher education in the context of the global sustainability challenges currently facing our world. Most would agree that there is a crucial need to make sustainability a part of all learners' educational experiences. We acknowledge that the "natural habitat" (Buchanan, 2012) of sustainability-focused education does not rest in science education alone. However, as the U.S. science education community refocuses its efforts to address the NGSS, it is possible that this era of policy change in the field could present a timely opportunity to consider sustainability as an integrating theme – with

science education leading the way for other disciplines. For sustainability to become well-integrated into science education, approaches to teacher education matter. Fortunately, there is a "budding movement" (Nolet, 2009) to include sustainability in science teacher education, beginning with the introduction of *Education for Sustainability* frameworks in some nations and the nascent efforts now emerging in the U.S. To nurture and cultivate this movement, we benefit from sharing our experiences with one another as science teacher educators. Toward this end, we synthesize some of our key insights from our initial experiences integrating sustainability into a science methods course.

**Framing Sustainability in Terms of Real-World Dilemmas**

We were drawn to the notion of framing sustainability in terms of real-world dilemmas, choosing to focus primarily on global climate change and its embedded sustainability concerns. Pointing to an increasingly familiar issue, now entering many U.S. science curricula with the introduction of the NGSS, helped make sustainability issues concrete for teacher candidates and facilitated envisioning possibilities for infusing sustainability topics into their future science teaching.

While we emphasized that sustainability includes environmental, economic, and social aspects, we found it productive to begin with the environmental dimensions of sustainability concerns, especially since these presented the clearest connections to school science curricula (e.g. topics covered in Life Science and Earth Science standards). From the starting place of environmental dimensions of sustainability concerns, we subsequently encouraged teacher candidates to consider economic and social impacts of the issue. For example, by engaging in the online sea level rise module, teacher candidates reasoned about how an environmental issue

could impact economics (e.g., tourism) and society (e.g. people's homes and livelihoods). A potential disadvantage that we noted is that this approach – that is, a focus on how environmental problems may impact the economy and human communities – may downplay the role of economics and human activities in leading to the environmental problems in the first place. We recommend, then, that teacher educators emphasize the reciprocal nature of the environmental, economic, and social dimensions of sustainability in the context of real world problems.

In addition, we noted the value of using real-world problems that can be examined on local and global scales. While examining future sea level rise impacts in our local region, as well as current impacts in other regions of the world – including developing nations, many teacher candidates expressed concern, empathy, and a sense of urgency regarding the problem. Conversation around these impacts on communities, regardless of their inhabitants' contributions to the problem of global warming, presented an opportunity for discussion of the moral and ethical issues embedded in science education, and dialogue amongst teacher candidates about how best to navigate potentially sensitive issues in the classroom. While beginning this conversation in the context of one real-world problem, teacher educators can also guide teacher candidates in considering ways that these pedagogical concerns and relevant teaching strategies can extend across other aspects of the curriculum.

**Addressing Issues Teacher Candidates See as Relevant to Future Roles as Educators**

We noted that teacher candidates were most receptive to the sustainability focus of the course when they saw it as meeting their needs as future educators. In particular, they expressed a need to learn how to foster student understanding of the science behind sustainability issues, as well as their local and global relevance. In light of this observation, we recommend that science

teacher educators make explicit the ways in which activities within their sustainability-oriented courses can support teacher candidates in their future teaching contexts. Teacher candidates were particularly receptive to aspects of the course they saw as supporting them in areas in which they would be professionally evaluated as teachers, such as successfully teaching a standards-based curriculum.

We connected to standards by looking for connections to sustainability within the NGSS, infusing these into the learning activities embedded in our course, and making these connections explicit. We noted that within the NGSS, there was a range of possibilities for making connections to sustainability ideas. In introducing the NGSS and its relationship to sustainability-oriented science teaching, we found it useful to choose one focal core practice (Data Analysis and Interpretation) to integrate across the course interventions as a way to model its application in different kinds of learning activities. After engaging in course activities, we encouraged our teacher candidates to note additional NGSS Cross-Cutting Concepts and Core Science Practices they had seen modeled in the activities. In general, they were able to identify a variety of NGSS connections, which provided an opportunity to recognize the ways that sustainability integration could foster the integration of NGSS ideas (e.g., Cause and Effect; Systems and System Models; Stability and Change). In addition to national science standards, we found it beneficial to make connections to our state environmental literacy plan and standards, which our teacher candidates would be responsible for teaching. Knowing that they would be expected to integrate the state Environmental Literacy Standards into their teaching, teacher candidates were interested in learning about them both for supporting their future science teaching practice and because knowledge of these relatively new standards could help support them as strong applicants for teaching jobs in our state.

Several other aspects of the course were particularly appealing to teacher candidates in terms of the activities' roles in supporting their needs as future teachers of science. First, teacher candidates were enthusiastic about being introduced to resources (particularly online resources) that could support their teaching, especially resources that could be immediately used by students (e.g., online educational games related to sustainability issues). They were also receptive to the strategies modeled in the course for integrating technology into science teaching, such as the model of the blended learning experience on sea level rise. Finally, the alternative forms of assessment we modeled, such as the pre- and post-intervention climate change drawings, were well received as strategies that encouraged learners' creativity and could support teacher candidates in meeting their goals as engaging teachers of science.

**Presenting Sustainability in Creative Ways, Relevant to Teacher Candidates' Future Roles**

For most teacher candidates, we learned that our course was not their first introduction to sustainability. This meant that many came to our course with pre-existing ideas and varying levels of relevant background knowledge. Some came with a sense that sustainability was a "tired topic" that had been presented to them repeatedly as university students. Therefore, we found it essential to present sustainability in creative ways, and in ways teacher candidates saw as particularly applicable to their future roles as teachers – as opposed to simply teaching them about sustainability in general. This acknowledgement of their teacher identities, and their need to support their future students in understanding sustainability issues, was novel to most participating teacher candidates –even if the topic of sustainability itself was not.

In approaching sustainability in our course, we found it beneficial to include both sustainability-related science content and pedagogy. Prior research on the integration of

environmental education and sustainability in teacher education has suggested that content-based and method-based approaches can both support teacher candidates' learning, and that the chosen approach should be the one that best meets their particular needs (Weiland & Morrison, 2013). We found that with teacher candidates coming to our course with diverse levels of background knowledge, incorporating both content and pedagogy enabled those who required additional sustainability-related science content background to learn more, while those who already had strong content knowledge could still benefit from the pedagogy aspect. In this way, a blended approached helped us to meet the needs of our diverse teacher candidates.

**Incorporating Challenging Content and Ideas**

Along with our decision to include both content and pedagogical dimensions, came our decisions to introduce content at a relatively sophisticated level as well as to introduce some theory underlying our teaching approaches. We wondered how teacher candidates would respond to these choices. Overwhelmingly, we found that they were open to being challenged. For example, in the online sea level rise module (http://www.climateedresearch.org/science-methods/sea-level-rise), we challenged teacher candidates to examine sea level rise at the atomic-molecular level (e.g., the role of thermal expansion in contributing to sea level rise). In some cases, especially for those teacher candidates planning to teach in the early elementary grades, this level of content sophistication is beyond what would generally be required in the curricula they will teach. Nonetheless, teacher candidates were not resistant to interacting with complex science content, or at least did not express frustration about our decision to include it. In fact, some commented positively that they enjoyed being challenged and having the opportunity to expand their own content knowledge.

Similarly, in planning the sustainability-infused course, we considered the potential advantages and drawbacks of spending time introducing new theoretical ideas. For example, in introducing sea level rise content, we considered whether or not teacher candidates would find a learning progressions theoretical perspective useful, and whether we should introduce the learning progression we had been developing on the topic of sea level rise. Ultimately, we opted to introduce learning progressions theory (e.g., the work of Gunckel, Covitt, Salinas, & Anderson (2012)) and our sea level rise learning progression in an effort to give teacher candidates a new way to think about their students' learning process as they engage in increasingly sophisticated science content related to sustainability. This was also a way to keep our teacher candidates up-to-date on current ways of thinking in the science education community. Teacher candidates were receptive to being introduced to theory—especially when we used analogies to help communicate theoretical ideas and when we presented concrete learning activities and tools that we could explain were theory-based. An important finding for us was that science teacher educators should not be hesitant in incorporating challenging science content, complex sustainability issues, or theoretical ideas into teacher education. We found that teacher candidates were receptive to these ideas and to opportunities that stretched their thinking, particularly if they were able to see how it would benefit them in their roles as teachers.

## Conclusions

We see great promise in the inclusion of sustainability in science teacher education, and believe that climate change can serve as a particularly useful focal topic in such efforts. By designing and implementing a sustainability-infused science methods course, we assisted our teacher candidates to begin examining sustainability as a potential unifying feature of their science curriculum. They considered ways in which their own actions had the potential to

contribute to a sustainable future by fostering learners' abilities to use science to understand global sustainability challenges, and eto ngage in scientifically informed decision-making and actions. Considering Nolet's (2009) argument for the education community's moral imperative to reform in ways that enable future generations to meet the grand challenges that lie ahead, we believe that the inclusion of sustainability in teacher education can contribute productively to this goal.

**Author notes**

- This material is based upon work supported by the National Science Foundation under Grant No. 1043262. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.
- The Science Methods course redesign reported here was completed as part of the Chesapeake Project, offered by the University of Maryland's Office of Sustainability: http://www.sustainability.umd.edu/content/curriculum/chesapeake_project.php

## References

Achieve, Inc. (2013). *The Next Generation Science Standards*. Retrieved from http://www.nextgenscience.org/

Buchanan, J. (2012). Sustainability education and teacher education: Finding a natural habitat? *Australian Journal of Environmental Education, 28*(2), 108-124.

Bybee, R.W. (2010). Advancing STEM education: A 2020 vision. *Technology and Engineering Teacher, 70*(1), 30-35.

Council of Chief State School Officers' Interstate Teacher Assessment and Support Consortium (InTASC). (2013). *Model core teaching standards and learning progressions for teachers 1.0*. Retrieved from http://www.ccsso.org/Documents/2013/2013_INTASC_Learning_Progressions_for_Teachers.pdf

Gunckel, K. L., Covitt, B. A., Salinas, I., & Anderson, C. W. (2012). A learning progression for water in socio-ecological systems. *Journal of Research in Science Teaching, 49*(7), 843-868.

Hestness, E., McGinnis, J. R., Riedinger, K., & Marbach-Ad, G. (2011). A study of teacher candidates' experiences investigating global climate change within an elementary science methods course. *Journal of Science Teacher Education*, *22*(4), 351-369.

Intergovernmental Panel on Climate Change (IPCC). (2013). Climate change 2013: The physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. T.F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, and P.M. Midgley (Eds.). Cambridge: Cambridge University Press.

Katz, P., McGinnis, J. R., Hestness, E., Riedinger, K., Marbach-Ad, G., Dai, A., & Pease, R. (2011). Professional identity development of teacher candidates participating in an informal science education internship: a focus on drawings as evidence. *International Journal of Science Education*, *33*(9), 1169-1197.

Maryland State Department of Education (MSDE). (2011). Maryland environmental literacy standards. Retrieved from http://www.msde.maryland.gov/NR/rdonlyres/EC79EC27-40BF-4017-894B-63A12A89A3D1/31625/MD_ELIT_STANDARDS.pdf

Maxwell, J.A. (2013). *Qualitative research design: An interactive approach*. Thousand Oaks: Sage.

McGinnis, J. R., Hestness, E., & Riedinger, K. (2011). Changing science teacher education in a changing global climate: Telling a new story. In J. Lin & R. Oxford (Eds.), *Transformative Eco-Education For Human Survival: Environmental Education In A New Era* (pp. 117-133). Charlotte, NC: Information Age Publishing.

National Research Council (NRC). (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

Nolet, V. (2009). Preparing sustainability-literate teachers. *Teachers College Record*, *111*(2), 409-442.

North American Association for Environmental Education. (2013). Environmental literacy plans. Retrieved from http://eelinked.naaee.net/n/elp

Odgers, B.M. (2009). Incorporating education for sustainability into a pre-service elementary school teachers' program. *International Journal of Learning*, *16*(9), 401-417.

The President's Council of Advisors on Science and Technology (PCAST). (2010). *Prepare and inspire: K-12 education in science, technology, engineering, and math (STEM) for America's future*. Retrieved from: http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-stem-ed-final.pdf

Summers, M., & Childs, A. (2007). Student science teachers' conceptions of sustainable development: An empirical study of three postgraduate training cohorts. *Research in Science & Technological Education, 25*(3), 307-327.

UNESCO. (2004) *United Nations Decade of Education for Sustainable Development: Draft International Implementation Scheme 2005-2014*. Paris: UNESCO.

University of Maryland, Office of Sustainability. (2013). The Chesapeake Project: Integrating sustainability across the curriculum. Retrieved from http://www.sustainability.umd.edu/content/curriculum/chesapeake_project.php

Weiland, I. S., & Morrison, J. A. (2013). The integration of environmental education into two elementary preservice science methods courses: A content-based and a method-based approach. *Journal of Science Teacher Education, 24*(6), 1023-1047.

World Commission on Environment and Development. (1987). *Our common future.* Oxford: Oxford University Press.

Yale Project on Climate Change Communication and George Mason Center for Climate Change Communication (2013). Global Warming's Six Americas quiz. Retrieved from http://environment.yale.edu/climate-communication