

Supporting Middle and Secondary Science Teachers to Implement Sustainability-Themed Instruction

by [Sheron L. Mark, PhD](#), University of Louisville, College of Education and Human Development, 1905 S 1st Street, Louisville, KY 40292

Abstract

In today's society, we face many complex environmental, social, and economic challenges that can be addressed through a lens of sustainability. Furthermore, our efforts in addressing these challenges must be collective. Science education is foundational to preparing students with the knowledge, skills, and dispositions to engage in this work in professional and everyday capacities. This article describes a teacher education project aimed at preparing middle and secondary preservice and alternatively certified science teachers to teach through a lens of sustainability. The project was embedded within a middle and secondary science teaching methods course. Work produced by the teacher candidates, including case-study research presentations and week-long instructional plans, is described.

Why Sustainability?

In today's society, we are confronted with many major environmental, economic, and social challenges, such as global climate change, infectious diseases, depletion of nonrenewable and natural resources, ocean acidification, decreasing biodiversity, wealth inequality, population growth, food insecurity, and building high-quality infrastructure (United Nations Development Programme, 2015). These diverse challenges can be strategically addressed through a lens of sustainability (Colucci-Gray et al., 2013). Even more, strategies to mitigate these challenges require large-scale cooperative action among many throughout society. Therefore, the larger public needs to be knowledgeable about major environmental, economic, and social challenges that they and others, near and far, face and ways in which they and others contribute to these challenges.

Science teachers are well positioned to significantly advance the goal of developing a sustainability-literate general public motivated by a personal stake in environmental, economic, and social challenges, both locally and abroad. Science teachers are tasked with developing students' understanding of scientific content and their skills in science and engineering practices (National Research Council, 2012). Fundamental scientific conceptual knowledge and crosscutting scientific lenses, such as scale and patterns, undergird understanding the various major challenges facing us currently and those challenges not yet manifested. Engaging in the scientific practices of questioning, analyzing, modeling, arguing, and communicating, along with engaging in engineering design to derive and optimize solutions, is necessary to take action to deepen understanding and improve our conditions.

Therefore, science teachers can support generations of children, adolescents, and young adults in developing the skills to understand and respond to sustainability challenges by infusing such topics in their everyday instruction.

The Sustainability Teacher Education Project was created to support the development of such knowledge and skills. The program was implemented with a group of middle and secondary science teacher candidates, who also mostly worked full-time as classroom teachers, as a part of their science teaching methods course. An overview of the project is provided, including teacher candidate learning experiences and products. There were two major products, including presentations on sustainability challenges, especially those relevant to the teacher candidates' local instructional contexts, and week-long instructional sequences focused on sustainability challenges. The presentations and instructional sequences were thematically analyzed (Saldaña, 2015) to identify major outcomes from the project.

Science Teacher Education Context

The Sustainability Teacher Education Project was implemented in the 2018 spring semester section of a middle and secondary science teaching methods course at a medium-sized university in the Southeast United States. Thirteen science teacher candidates were enrolled in the course. The candidates were enrolled in one of three programs: the traditional Bachelor of Science (BS) in Science Education, the traditional Master of Arts in Teaching (MAT) in Science Education, and the Alternative Certification MAT in Science Education. In the traditional BS and MAT programs, candidates complete all field and clinical placement work prior to being hired as a certified classroom teacher; however, Alternative Certification program candidates work full-time as provisionally certified classroom teachers while completing their program and certification requirements. One student was enrolled in the BS in Secondary Science – Biology program, and 12 students were enrolled in the Alternative Certification MAT program. Of the 12 MAT teacher candidates, five were teaching middle school science, four were teaching high school biology, and three were teaching high school chemistry. To protect the participants' identities, their racial, ethnic, and gender identities are reported separately. Six teacher candidates self-identified as female, and seven self-identified as male. Among them, one self-identified as Latinx, one as Middle Eastern, two as Asian American, and nine as White.

Overview of the Sustainability Teacher Education Project

The Sustainability Teacher Education Project consisted of two main parts. The first part spanned 3 weeks and included the following goals: (1) to introduce foundational knowledge about sustainability and current sustainability efforts, (2) to have science teacher candidates

consider their impact on sustainability, and (3) to deepen knowledge about a local sustainability issue and use the issue to design science instructional plans. The second part of the Sustainability Teacher Education Project involved the culminating assignment for the Science Teaching Methods course.

Part 1: Sustainability Knowledge Development

Students began by reading the *Sustainable Development Goals* from the United Nations Development Programme (UNDP; 2015), “Top 10 Myths About Sustainability” (Lemonick, 2009), and “The Search for Real-World STEM Problems” (Jolly, 2017). According to the UNDP’s (2015) *Sustainable Development Goals*, “World leaders, recognizing the connection between people and planet, have set goals for the land, the oceans and the waterways” (p. 3). The UNPD document introduced the teacher candidates to the seventeen sustainability goals that address environmental, economic, and social problems, such as clean water and sanitation, affordable and clean energy, climate action, responsible consumption and production, decent work, and economic growth. More specifically, teacher candidates learned about challenges to sustainability that must be overcome.

“Top 10 Myths About Sustainability” (Lemonick, 2009) supported further foundational ideas of sustainability among the teacher candidates by demystifying common beliefs and misconceptions regarding the topic, such as that there is no clear definition and goals for sustainability and that sustainability only focuses on recycling and “green” or renewable energy. As the teacher candidates would later be tasked with identifying, researching, and then teaching using a real-world sustainability challenge, the third reading, “The Search for Real-World STEM Problems” (Jolly, 2017), provided concrete strategies in identifying real-world problems and integrating them into one’s instruction. The strategies included identifying problems that students care about or facilitate students’ awareness of and interest in the selected problems, supporting students in identifying or selecting the problems themselves, choosing problems that can be tackled using multiple scientific and engineering approaches or that have multiple solutions, and choosing problems that can be realistically tackled in one’s teaching context.

The project was introduced approximately halfway into the semester. The first week of the project began with the *Sustainability in my Backpack* activity. With no other directions, the candidates were asked to look in their backpacks or handbags for a single item. In table groups, they were then asked to present their item to their group and to respond to the following questions:

1. From where did this product originate?
2. How much does this product cost?
3. What communities, landscapes, or conditions (e.g., land, ocean, atmosphere, or arctic tundra) are impacted by this product—positively or negatively?
4. What questions do you have about how this product came to be in your possession?

5. What changes might you suggest about the design, manufacture, transportation, and sale of this product?
6. How sustainable is this product? Why?

Following the table group discussion, the science teacher educator focused the class on defining sustainability and the boundaries of what counts as relevant to sustainability. Three questions guided the whole class discussion: (1) What is sustainability? (2) What scientific and social issues are relevant to sustainability? (3) How can you integrate sustainability into your science teaching?

Following the whole-class discussion, the science teacher educator modeled teaching science through the lens of sustainability by leading the class through the shared example of environmental justice in the local city, Louisville, Kentucky. Environmental justice focuses on the disproportionality of environmental burdens and risks placed upon communities with low-income status, especially communities of color, and the greater benefits and advantages to communities with higher-income status, especially those that are White (Bullard, 1996, 2000). Environmental burdens may include poor or toxic air, water, and land quality and high representations of industrial and manufacturing sites. Environmental benefits may include a thick, healthy, and expansive urban tree canopy and the widespread availability of social services, such as high-quality food options, healthcare services, and recreational options.

The class focused on a residential neighborhood known as *Rubbertown* (Figure 1), which was established in the early 1900s. Rubbertown is a major historical and controversial sustainability challenge that can capture the attention of students living in this city, particularly because many living only short distances away are not aware of Rubbertown and its impact. Presently, Rubbertown is a community of color with low-income status on the western periphery of the city that is heavily burdened by polluting industrial sites (Barnett, n.d.; Corsey, 2019; LouisvilleKY.gov, n.d.). The class gained background knowledge about Rubbertown by watching a short documentary in which residents described their neighborhood and living conditions, including the sights, smells, and sounds as a result of the industrial sites. They also recounted personal and family experiences from living in the neighborhood over generations. Many detailed instances of losing family members to cancer. Rubbertown was used as an example of how to engage students' interest in local sustainability challenges by underscoring the real lived impact on themselves and others. Rubbertown challenges sustainability because it undermines goals related to good health and wellbeing, high-quality air, and responsible manufacturing and production (UNDP, 2015). These connect to the *Next Generation Science Standards* (NGSS; NGSS Lead States, 2013) such as chemical reactions and energy sources and transformations involved in the industrial processes of producing rubber and other synthetic materials; interdependent relationships in ecosystems from Rubbertown's impact on consumption of raw materials and production of waste on other environmental, animal, and human aspects of ecosystems, both

geographically close and more distant; engineering design by critiquing and redesigning aspects of Rubbertown's industrial and manufacturing processes; and human impacts and sustainability.

Figure 1

Historical Environmental Justice Site, Rubbertown in Louisville, Kentucky

Next, the teacher candidates completed a potential student learning activity in which they used *Google Maps Street View* to virtually tour neighborhoods highly represented among their students. Through the lens of sustainability, they identified burdens and benefits. Examples of burdens included exposure to polluted water, air, or soil; a lack of green space or tree canopy; and a lack or absence of full-service grocery stores that would provide fresh, healthy food options, such as vegetables, fruit, and uncooked or unprocessed meat and seafood. Benefits may include plentiful access to parks, walking trails, and playgrounds; multiple options for fresh, healthy, and affordable food options; and safe and clean streets and pavements.

Focusing on the identified neighborhood features, the teacher candidates then made explicit connections to underlying scientific concepts in order to understand why those features of their students' neighborhoods were impactful to residents. They were asked to explain, from a scientific perspective, (a) what services were provided from the features identified as benefits and (b) what harm was done by the features identified as burdens. For example, the presence of trees in a neighborhood and the extent of the tree canopy was connected to the ecosystem services of trees, including carbon sequestration, which can mitigate the greenhouse effect and urban heat island effect, and permeable soil surfaces surrounding trees play important roles in stormwater runoff filtration and water quality. Similarly, there are nutritional differences in meals prepared from raw, fresh, and healthy produce and meats or seafood as compared to prepackaged and heavily processed food sources, which, in turn, can affect individuals' health over the long-term. As a final step, the teacher candidates identified a set of neighborhood burdens that they wished to address and collaborated to devise action plans to mitigate those challenges (e.g., a tree-planting campaign, farmers' markets, and new public transportation route offerings).

To conclude the first week of the project, students engaged in online research to identify a potential local sustainability challenge using the strategies outlined in Jolly (2017). To provide guidance in this research and further support their growing knowledge of sustainability challenges in their local context, the teacher candidates read the article "An Environmental Injustice Tour of West Louisville" (Smith, 2015) and *Environmental Issues, Louisville, KY* (Barnett, n.d.). Sustainability is one specific framing of the interconnectedness between science, technological and engineering advancements, and society. To deepen the teacher candidates' understanding of this concept and its relevance to science teaching in middle and secondary classrooms, they were also assigned to read "Appendix J: Science, Technology, Society, and the Environment" from the NGSS (NGSS Lead States, 2013).

The following week, the teacher candidates continued to learn about specific sustainability challenges and how science and engineering are used to mitigate these challenges. Their own university was used as a case study for exploring efforts in using science and engineering to achieve sustainability goals. For this purpose, a university administrator

involved in sustainability efforts visited the class and reinforced some of the fundamental ideas and definitions of sustainability introduced so far. Then, he led the class on a university tour highlighting various science and engineering sustainability initiatives implemented by the university. These initiatives included: a community garden, composting, rainwater collection, single-stream university-wide recycling, solar energy panels, buildings enabled with sensors to adapt lights and heating to building occupancy, faculty research on alternative materials and energy sources, student design competitions, and green parking using grass-covered parking lots, as opposed to impervious paved surfaces. Recalling that sustainability also includes economic and social considerations, the university also worked to grow student awareness of the social and economic exploitation of laborers worldwide to support sustainable consumerism. The university also provided economic incentives for using public transit, bicycles, and other shared transportation.

After the university sustainability tour and questions, the teacher candidates presented their sustainability case research and plans for sustainability-themed science teaching. The presentations' workshop format supported the teacher candidates' ongoing and collective content development of a suite of diverse sustainability challenges that existed, especially locally, as potential real-world science teaching problems. They also learned about varied ways of planning lessons and implementing instruction from their peers.

Part 2: Culminating Assignment

For this assignment, teacher candidates had to develop a detailed plan for instruction spanning 5 sequential days. The teacher candidates were provided a template to complete the assignment. The assignment integrated all aspects of science teaching covered over the course of the semester, including topics unrelated to sustainability, such as differentiated instruction and culturally relevant teaching. Sustainability was incorporated into this assignment by requiring all teacher candidates to use a sustainability case centrally in their instructional plans. The teacher candidates were also asked to explicitly address how they will make this sustainability-focused instructional plan compelling and interesting to their students. The major aspects of instructional planning addressed by the teacher candidates in completing this assignment included providing background information on the sustainability challenge selected and an argument explaining the relevance of the challenge to the students in their local contexts; the instructional context of the week-long plan, including the state science standards to be addressed, essential questions, ideas, and skills underlying daily instructional targets, and common misconceptions to be overcome; specific knowledge of students' cultural backgrounds, prior knowledge, and skills relevant to the topics; plans for pre-, formative, and summative assessments; plans to incorporate technology into teaching; plans to communicate learning and progress to students and families; overviews of the whole week of instruction with at least 3 days of instruction detailed more in-depth; and plans to connect learning to students' college and career readiness. This was an individual assignment that each teacher candidate submitted in the last week of the semester.

Analyzing Teacher Candidate Work

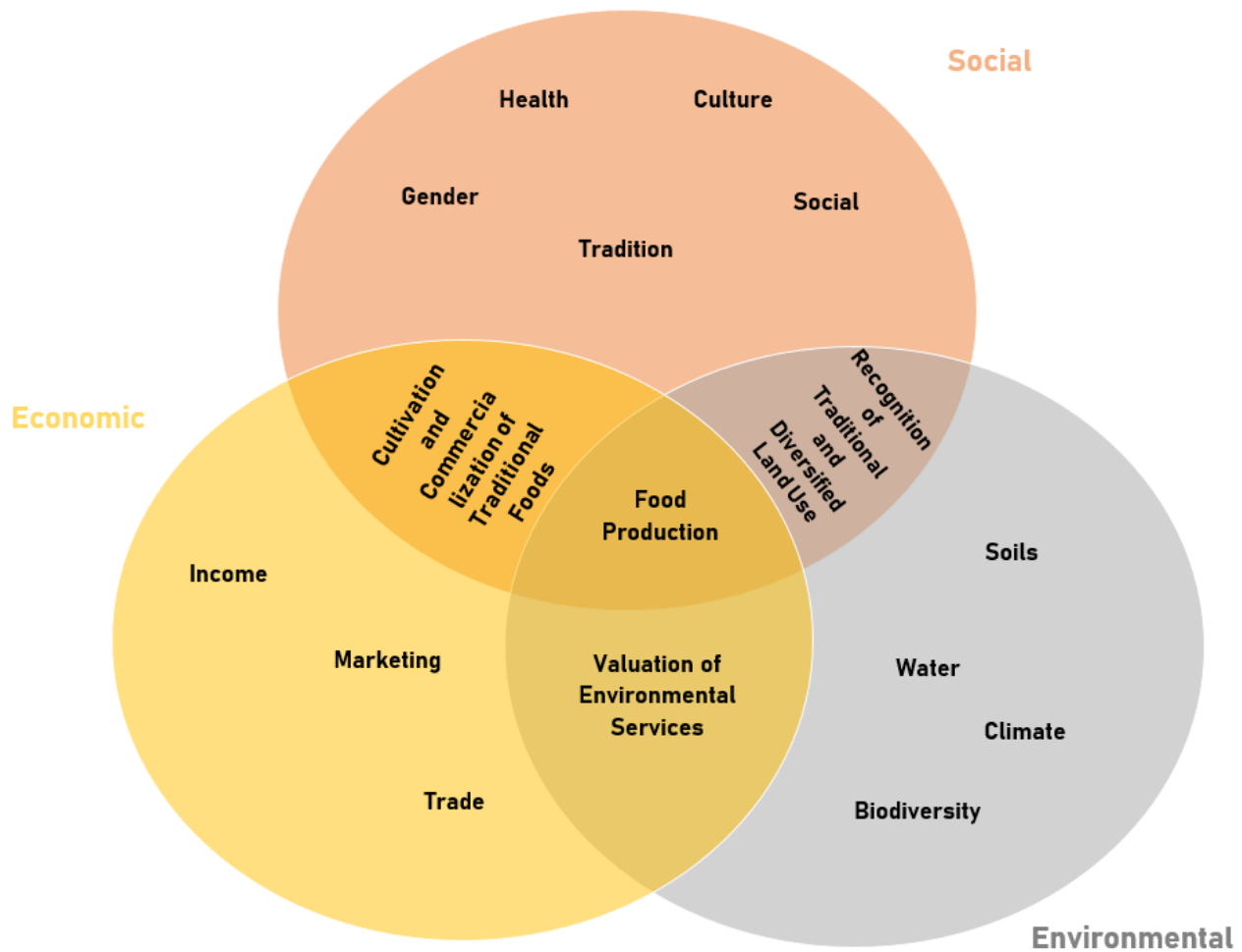
Understanding of Sustainability and Sustainability Challenges

The first goal of the Sustainability Teacher Education Project was to grow teacher candidates' knowledge of sustainability and sustainability challenges. It was important for the teacher candidates to understand the complexity and breadth of sustainability challenges involving environmental concerns as well as intertwined social and economic factors. This was an important outcome because it would bolster their understanding of the interconnected nature of science, engineering, technology, and society and their ability to teach science in ways that are embedded in authentic sociocultural contexts.

To this end, each teacher candidate's presentation was analyzed to identify how the sustainability challenge was defined or framed. In most of the presentations, the teacher candidates forefronted environmental challenges, but most also included economic or social considerations in arguing the significance and relevance. Examples of environmental sustainability challenges presented by students in these ways included the water quality of the local *Beargrass Creek* watershed, along with economic impacts on the fishing industry and social impacts on local residents' opportunities to recreate; the negative impact of *Lee's Lane Landfill* on soil, air, and water quality, along with social impacts on residents' equitable access to safe and healthy neighborhoods and economic impacts on property values; and the impact of intensive, industrial farming on depleting soil nutrients and chemical leeching of pesticides into groundwater reserves, along with low costs of food for consumers as an economic driver and social relevance for students living in rural, agricultural communities. In arguing the complexity of intensive industrial farming as a sustainability challenge encompassing environmental, economic, and social considerations, one teacher candidate, Henry, sourced and presented the graphic depicted in Figure 2.

Figure 2

Defining the Scope of Considerations for Food Production as a Sustainability Challenge



From *Agriculture at a Crossroads: International Assessment of Agricultural Knowledge, Science and Technology for Development: Synthesis Report*, edited by B. D. McIntyre, H. R. Herren, J. Wakhungu, and R. T. Watson, 2009, p. 19
https://www.gaiafoundation.org/app/uploads/2017/09/Agriculture-at-a-crossroads-Synthesis-report-2009Agriculture_at_Crossroads_Synthesis_Report.pdf). Copyright 2009 by the International Assessment of Agricultural Knowledge, Science and Technology for Development.

It was expected that the science teacher candidates would forefront environmental challenges because the composition and quality of the physical environment are more directly aligned with topics traditionally conceived as related to science teaching. Therefore, it was encouraging to see sustainability challenges developed for middle and secondary classroom science framed primarily from a social or economic lens. In one such economically focused presentation, Drea focused on the unsustainable business practices and false marketing of Volkswagen, which was driven by profit margins. Volkswagen was found to be using installed devices to artificially lower the emissions of one of their vehicles that was marketed as environmentally friendly. Two other teacher candidates' presentations

focused primarily on social sustainability challenges, thereby emphasizing the social relevance of science. Trent presented on challenges to decent work, specifically safe working conditions and living wages for migrant farm workers in the U.S. agricultural industry. Migrant farm workers are subject to harsh working conditions, including exposure to pesticides, poor nutrition and healthcare, and long hours of manual labor in extreme weather. Gary presented on the U.S. opioid crisis arguing that governmental agencies prioritize economic interests and support large drug companies over responding to individuals' social needs for quality and responsive healthcare, especially for those within communities with low-income status.

Planning to Teach Sustainability-Related Science Lessons

The second goal of the Sustainability Teacher Education Project was to support the teacher candidates in furthering their abilities to plan and implement instruction for middle or secondary science students and to do so through a focus on sustainability. Thus, analysis focused on the instructional strategies that teacher candidates employed to design student learning experiences in order to advance their students' knowledge and skills in science and sustainability.

Student learning experiences were varied, involving case-study research and designing solutions; laboratory investigations; use of or participation in models, games, and simulations; reflections on and building upon everyday experiences; arts-integrated learning experiences; and engaging with and learning from science and engineering career professionals. Paralleling their own learning experiences as teacher candidates in the science teaching methods course, many of the teacher candidates planned instruction for their own students involving learning about specific cases of sustainability challenges, often local. Their students would then be required to utilize scientific research practices, often collecting and analyzing data, to develop their understanding by constructing explanations about underlying phenomena relevant to the sustainability challenges. Alternatively, students would engage in argumentation about the significance of the sustainability challenges.

Case Study Research

Some of the units were organized as case study research experiences extending across the days of instruction. For instance, Tanya planned for her students to first conduct a literature review to gather, organize, and communicate scientific information and background information on humans' role in urban heat islands. In the second stage of research, the students would learn

the tools needed to calculate impervious surfaces in their own neighborhoods ... [and] understand what those surfaces mean in terms of reflecting or absorbing and dispersing heat energy ... Students will work in pairs and choose a neighborhood in Louisville and complete an assessment of that neighborhood's greenspaces and impervious surfaces. They will then [engage in a third round of] research [to determine] what that particular neighborhood could do to improve. (Tanya)

Similarly, Henry planned a series of research opportunities centered on intensive industrial farming to support students in developing the necessary background knowledge to understand the sustainability challenge and, subsequently, engaging in argumentation on the issue. Following an introduction to intensive industrial farming, Henry planned for his students to research the impact on soil quality by planning for his students to

practice measuring the pH of a substance using pH paper and analyze how soil samples with highly acidic or alkaline pH measurements could negatively affect the plants growing in that soil ... [as well as to] analyze the pH of soil samples from near their homes to see how healthy the soil near their residence is and hypothesize why it is neutral/acidic/alkaline.

Following two days of these investigations, students would engage in case study research and

choose one sustainable farming or traditional farming practice and propose why that practice is good from a sustainability standpoint, or why it may not be. If [students] choose a traditional method, they should analyze how to make it better using various small sustainability improvements. (Henry)

Some teacher candidates designed the case study research as a culminating summative assessment that required the students to apply their understanding of relevant sustainability concepts learned earlier in the instructional sequence through other forms of learning activities that were not necessarily research-based (e.g., using a digital simulation as a model to understand energy transformations or using a variety of materials to construct a model of an ecosystem). Adeline planned a summative assessment that would require

students' application of knowledge regarding ecosystem interconnectedness and involved a "research project in which each student designs a potential solution to improve the health of their local watershed" as a common case study of focus.

Laboratory Investigations

Laboratory investigations were also planned by teacher candidates in order to engage students in scientific practices to explore and understand relevant phenomena underlying sustainability challenges. For instance, Wyatt planned for his students to "conduct an investigation to demonstrate how chemical weathering can occur through acid rain" to explore the sustainability challenge of air pollution. Harrison planned for his students to conduct an experiment to measure and compare the heat capacity of Earth's surface materials, namely, soil and water, to explore the sustainability challenge of increasingly extreme weather and climate.

Student Scientific Discourse

Some teacher candidates also planned learning experiences that would support their students in engaging in scientific discourse, particularly within diverse contexts. To this end, these teacher candidates planned culminating experiences for students to communicate what they learned from their instructional units to their families, mayors and government officials, and science and engineering professionals. The students would communicate via written letters, research presentations, and science career development events. At the science career development events, students would have opportunities to engage in dialogue with the professionals in order to grow their knowledge about the various careers, as well as to hear from the professionals what is required in terms of education and social experiences (e.g., perseverance) to achieve success in those careers. For example, Tanya planned for her students "to complete a letter to government officials describing the negative impact of Louisville's heat islands and how we can improve them." Tanya also planned for her students to write letters to their families. Frances planned for her students to "create an action plan for [their] sustainability project . . . and present their action plan to [a science/engineering] expert."

Drea provided opportunities for engaging in scientific discourse among students, among students and their families, and between students and science and engineering professionals. Drea's instructional unit focused on Volkswagen's unsustainable business practices, but she also planned opportunities for student choice and building upon students' lived experiences by allowing students to share with each other what they experience on a daily basis. Then, as a science teacher, Drea facilitated students' understanding of these experiences through a scientific and sustainability lens. Drea's middle school had an

upcoming science, technology, engineering, arts, and mathematics (STEAM) family night, and she planned to use this platform for her students to demonstrate their growth and new knowledge to their families. The aforementioned student-driven research inquiries would be shared with families at the STEAM night event:

Students will . . . select one of the environmental justice issues they learned about [from their classmates] during “speed dating” [where classmates share what they experience in their neighborhoods] and then research possible sustainable solutions to these problems. They will work in pairs and spend a day researching and planning using their iPads, a day creating their [research] posters, and a day practicing their [STEAM night] presentations. (Drea)

Engaging with Scientific Experts

Given the Volkswagen and car manufacturing industry focus that launched Drea’s sustainability unit, she also planned scientific discourse and career development opportunities for her students by inviting a representative of the Ford Motor Company, which is local to the university, to share with her students their manufacturing processes with her students. She planned to support her students in devising questions for the visiting expert in order to prepare students to engage in active dialogue as opposed to primarily listening:

I would like to try and have someone who works at the Ford Motor Company in town come speak about how they are making cars more sustainable. I would also like to give the students the opportunity to come up with questions for them. (Drea)

Many other teacher candidates also planned to include science and engineering experts in the sustainability unit learning experiences, in-person and virtually. Raine emphasized how important it is for his students to engage in science in socially connected ways and not solely or primarily in terms of “intellectual” ideas:

I plan on bringing in guest speakers like local engineers and ecologists from academia and industry. . . . Students should be exposed to individuals who are working in the fields associated with the material I teach in the classroom. This allows them to identify with the material in a way that is social rather than just in terms of intellect. (Raine)

Integrating the Arts

Some teacher candidates also included opportunities for students to explore sustainability challenges and demonstrate their growth in knowledge and skills through creative artistic expression. For instance, Raine also designed an assessment in which students were to “draw an illustration that details why renewable resources are an important part of America’s energy future.” In so doing, he allowed students to engage in scientific argumentation about sustainable energy use through a visual arts medium. Another teacher candidate, Anderson, planned to incorporate the arts as differentiated assessment options in assembling a culminating portfolio on climate change that included “making a video, analyzing a graph, writing a paper, drawing a comic, performing a skit, and analyzing a current article, among others.”

Facilitating Social Relevance of Sustainability

In planning instruction, the teacher candidates also explained why the sustainability topics would be relevant and interesting to their students and how they would actively facilitate development of their students’ perceptions of the topics as personally relevant. For instance, informed by knowledge of his students, Wyatt explained why his students would be interested in the unit on industrial air pollution and acid rain:

[My students] lack the resources of green space and clean water . . . they are especially engaged when I bring in environmental and social justice issues into our academic conversations. By focusing on the unequal burden shared by people living in an urban environment caused by burning coal for energy, I can increase student investment . . . Furthermore, I can empower them by showing them how to make their voices heard through effective communication with their state and local representatives. (Wyatt)

Noting prior student interest in environmental and social justice issues, Wyatt planned to emphasize these perspectives on the sustainability challenge as the motivation to learn the scientific concepts and skills to actively address the challenge. Anderson also stated how he planned to facilitate students’ perceptions of relevance regarding urban heat islands:

Not every student can afford to simply switch to an electric car or utilize wind or hydroelectric power instead of coal or oil; however, they can make small changes ... I can also connect [the scientific and sustainability concepts] to their interests (video games, sports, and *Netflix* are among the more popular interests to my students); for example, I can discuss how activities like going outside [instead of watching TV or playing video games] can limit their usage of fossil fuels ... At the same time, I can address that as temperatures rise, it will affect sea levels and further the heat island effect ... and will make going outside [as a viable change to implement] more difficult. (Anderson)

Anderson planned to not simply put forth ideas of unattainable behavioral changes for his students and, instead, help make connections between changes needed and actions that they can reasonably implement. He also planned to make them aware of possible effects that they would experience first-hand (e.g., increasing surface temperatures in their local neighborhoods) related to the sustainability challenge of focus.

Integrating Student Interests

Beyond the topics being engaging or the teacher candidate emphasizing particular connections or perspectives to the sustainability challenges, some teacher candidates also structured student learning experiences based on knowledge of their students' preferred classroom activities. Adeline indicated this by stating:

My students have historically expressed great interest in activities that are hands-on and interactive. Therefore, I think the lesson in which they build a watershed then subsequently "pollute" it and observe how it enters the water stream will be a very engaging and informative lesson. (Adeline)

Discussion and Conclusion

As a result of the Sustainability Teacher Education Project, which was situated within a middle and secondary science teaching methods course, the teacher candidates engaged in research to learn about sustainability challenges and engaged a varied set of instructional strategies to support their middle and secondary science students in learning science through the lens of sustainability. The sustainability challenges addressed by the teacher candidates were complex, reflecting the multifaceted nature of sustainability, involving environmental, economic, and social considerations. The teacher candidates planned rich

and varied research experiences for their students in order to explore foundational scientific phenomena and holistic sustainability challenges, as well as opportunities to connect the material being learned to socially relevant experiences beyond the classrooms in their homes, communities, and future careers. Facilitating the social relevance of classroom science is a necessary step for genuine student interest and sustained engagement in academic science (Rodriguez, 2015). Additionally, structured career development opportunities, in which students grow their knowledge of scientific careers and interact with career mentors, can successfully support them in sustaining interests in science careers (Mark, 2016). It was, therefore, very encouraging to see both of these areas of instructional planning robustly addressed by the teacher candidates.

As teacher educators designing and implementing course learning experiences, it is important to be sensitive when engaging potentially political topics, such as sustainability, in order to not alienate or marginalize any teacher candidates by privileging any one or few political perspectives. Fortunately, all teacher candidates actively and positively participated in the project and indicated no strong negative reactions or resistance to ideas of sustainability. In fact, all teacher candidates readily agreed that we currently face significant sustainability challenges and that people of color, communities with low-income status, and the environment are harmed in ways based on uninformed or poorly regulated behavior. They identified necessary changes from individual to organizational levels.

Despite this positive implementation, in the future, greater attention will be paid to preparing to engage potentially contentious and political topics in the classroom (Mark, 2021), especially if students have different perspectives regarding, for instance, man-made drivers of climate change, corporations' roles in sustainability, shared accountability in global carbon emissions, and protecting endangered species. Teaching Tolerance (2019), a project of the Southern Poverty Law Center, provides some guidance to educators preparing to engage in difficult conversations in the classroom. An important first step in this preparation involves conducting a self-assessment in which one identifies where one may have weaknesses in knowledge or perspectives (e.g., biases) regarding the topic, where one may have strengths on which to capitalize during the classroom discussions (e.g., multiple sources of rigorous data to support one's argument), and where one may have needs to address (e.g., need to gather background information or additional data on a topic). A second step in preparing to engage in difficult and sensitive classroom discussions involves preparing to respond to strong emotions, such as anger, denial, blame, guilt, shame, or confusion. Acknowledging and productively responding to students' emotions can maintain the overall class' focus on collective data-driven inquiry and prevent becoming distracted by emotionally charged interactions and mediation.

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