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Developing and Integrating 'Sustainable Engineering Stories' for Science Teacher Education (Work-in-Progress)

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Abstract:

To achieve pre-college STEM education policy goals, preservice science teachers (PSTs) must understand engineering as a field with specialized disciplinary knowledge, practices, and career paths. PSTs are often unfamiliar with engineering, so related interventions are needed. Similarly, PSTs must be equipped to integrate authentic engineering activities that connect with real-world issues like sustainability. Storytelling about sustainable engineering offers a practical method of introducing PSTs to authentic engineering projects, practices, and careers. This work-in-progress, funded by ASEE's Engineering for One Planet (EOP) initiative, illustrates the impact of engaging PSTs in reading and reflecting upon a set of "Sustainable Engineering Stories" during science teaching methods courses at two institutions.

During the summer of 2024, the researchers interviewed engineers from various disciplines about projects oriented toward sustainability. From those interviews, we created a set of eight Sustainable Engineering Stories for PSTs enrolled in their elementary science methods courses. During the fall 2024 and spring 2025 semesters, these stories were implemented as part of an intervention to develop PSTs' knowledge of engineering as an environmentally and socially responsible human endeavor (i.e., aligned with the EOP framework). Before and after the intervention, PSTs were surveyed about their understanding of sustainable engineering and related self-efficacy for teaching about engineering and sustainability.

Throughout the science methods classes, PSTs read and reflected on six Sustainable Engineering Stories in groups and, later on, worked in those groups to develop, present, and individually reflect upon their own Engineering Stories. Data sources for the study were PSTs' reading reflections and pre- and post-survey responses. Surveys comprised several open-ended and quantitative questions related to sustainable engineering and self-efficacy, and reading reflections consisted of three open-ended questions related to each Sustainable Engineering Story. The researchers analyzed data collaboratively using open coding and descriptive statistics, meeting regularly to collaborate and corroborate these analyses.

Results showed increased self-efficacy and a deepened understanding of sustainable engineering as an environmentally focused and socially responsible human endeavor that hinges upon communication and design under constraints. Implications are discussed for pre-college engineering teaching and learning (e.g., for teacher educators, preservice teachers, and researchers) and show how sustainable engineering may be practically integrated into the elementary science methods curriculum.

Introduction

Following current K-12 science reform (NGSS Lead States, 2013), prospective teachers need disciplinary knowledge and skills to facilitate authentic, meaningful, and relevant engineering instruction (Flanagan et al., 2022). Environmental and sustainability problems offer particularly salient contexts (Vo et al., 2024). For instance, climate change and shifting resource availability are pressing global issues that can be leveraged for localized and open-ended pre-college engineering learning (Boz et al., 2024). By emphasizing meaningful contexts, learners may become more interested in pursuing sustainability-focused science and engineering careers (Savelsbergh et al., 2016).

To achieve reform goals and support learners in pursuing sustainable engineering careers, elementary preservice teachers (PSTs) need access to authentic career-based insights through teacher education programs that reflect the personal perspectives of sustainable engineers (Author, 2022; Boz et al., 2023). Scholarship in pre-college engineering education has established it as an inclusive (Calabrese-Barton et al., 2021), social (Bryan & Guzey, 2020), and human endeavor (Author, 2019) that emphasizes creativity, decision-making, and iteration (Wendell et al., 2017). Sustainable engineering encompasses these constructs while focusing on environmental literacy, social responsibility, and responsible business practices (Gannon, 2015).

PSTs often lack formal engineering training and are typically unfamiliar with the field (e.g., Author, 2016; Dunsmore et al., 2011). Consequently, they have limited opportunities to explore how sustainability intersects with engineering (Gannon, 2015; Gannon et al., 2022). To integrate environmentally focused engineering tasks in their future classrooms, PSTs need access to real-world examples of sustainable engineering. Storytelling provides a practical way for teacher educators to introduce PSTs to authentic engineering applicable in their classrooms. Such stories boost language and literacy integration in K-12 science (NRC, 2012) and help develop essential engineering literacies for understanding, communicating about, and engaging in engineering (Silvestri et al., 2021). This project, funded by ASEE's Engineering for One Planet initiative, highlights the impact of engaging PSTs in reading and reflecting on a series of so-called "Sustainable Engineering Stories" in their science teaching methods courses.

Framework: Storytelling about Sustainable Engineering

The basis of this study is *storytelling about engineering* (Lloyd, 2000): oral narratives of personal experiences that convey the cultural and contextual dimensions of engineers' professional practice (Johri & Olds, 2011). Among professional engineers, storytelling has been found to create shared language in design teams (Nguyen & Mougenot, 2022) and play a role in developing engineering identities (Korte, 2013). Additionally, storytelling has been explored as a valuable way to build engineering knowledge in educational contexts, including K-12 settings

(Acosta & Haden, 2023; Adams, 2007; Author, 2022; Lee et al., 2023). Stories can represent the realities of engineering practice in ways that classroom learning activities cannot, thereby providing students with authentic insights into the field (Gottschall, 2012; Rao et al., 2020).

The stories in this study describe engineers' experiences working on projects focused on sustainability. We used these stories with PSTs to help them view engineering as both a technical and a human endeavor, supported by social responsibility, environmental literacy, and socially responsible business practices. By deepening and expanding PSTs' understanding, we aim for them to use these stories to inform how they introduce engineering to their future students. As previously shown, PSTs' reading and reflection on a series of engineers' narratives assisted their differentiation of design- and inquiry-based activities (Author, 2022). To extend this work, we hypothesize that by reading and reflecting on sustainable engineers' narratives, PSTs can gain and leverage their experiences as valuable assets for understanding sustainable engineering.

Methods

Participants included 44 elementary PSTs in 16-week science methods courses at two sites: a small northeastern college and a large southwestern university. The classes introduce K-6 science reform, emphasizing scientific inquiry and engineering design. PSTs engage in engineering design tasks, reflecting on their experiences as learners and teachers (Author, 2021), many of which focus on environmental issues (e.g., Author, 2024). The participants, primarily White females aged 18 to 21, reflected national trends in teacher education (Banilower et al., 2019), and were selected based on completing all intervention activities.

During the semester, PSTs read and reflected on a series of "Sustainable Engineering Stories" approximately biweekly (n = 6 stories total). The authors wrote the stories following the format and structure of a previously generated set of more general "Engineering Stories" by Author (2022). Each story portrays a single engineer and their work on a project they describe as exemplifying their professional practice. For instance, one story describes an environmental engineer's evaluation of the ecological impact of a proposed casino; another highlights a chemical engineer's development of a process for removing PFAS from the water supply. The set of stories was constructed to illustrate a range of engineering perspectives, emphasizing sustainable engineering as a *socially responsible, environmentally focused human endeavor that relies on responsible business practices* (The Lemelson Foundation, 2022). They showcase engineers' collaboration, teamwork, creativity, and commitment to sustainability.

Data for this work-in-progress study are primarily drawn from two surveys implemented at the beginning and end of the courses: (i) a 'nature of engineering' survey (Author, 2022) assessing PSTs' views on engineering, and (ii) a new 'sustainability' survey that assesses PSTs' sustainability perspectives, interest in teaching it, and self-efficacy in addressing sustainability

topics. Both surveys include a mixture of open-ended and Likert-type questions. The 'sustainability' survey was created because no validated PST-specific surveys exist for this topic. To triangulate our findings, we also used PSTs' written reflections on how the stories illustrated engineering practices and sustainability goals of sustainability. To analyze the quantitative survey items, we used paired-sample *t*-tests to examine changes in PSTs' views. We conducted qualitative content analysis for open-ended items to identify common categories of responses (Saldaña & Omasta, 2016). Written reflections were then used to corroborate these themes and further understand the impact of the stories on PSTs' understanding of sustainable engineering.

Findings

For this work-in-progress, we focused on the sustainability survey results, supported by PSTs' written story reflections. Tables 1 and 2 display average Likert-scale ratings (1-5) from pre-survey to post-survey. The p-values indicate paired-sample t-test results comparing mean ratings at these points. Three main trends emerged from the data: First, PSTs showed strong interest in addressing sustainability before and after the course, as indicated by Table 1. They generally agreed on the necessity of making sustainability a central scientific theme at all grade levels, with beliefs about its importance increasing from the pre-survey to the post-survey. Additionally, significant shifts ($p \leq 0.05$) occurred in PSTs' views on sustainability (Tables 2 and 3), aligning their perspectives with *social responsibility* and *environmental literacy* following the intervention. Connected, PSTs also prioritized recycling, renewable energy, and economic equality more after the intervention than beforehand.

Table 1

Summary of PSTs' 'Agree-Disagree' Responses on Pre- and Post-Sustainability Surveys

How strongly do you agree with each statement (from 1-5)?	PRE Mean (SD)	POST Mean (SD)	P-Value
I value sustainability as a goal in my personal life	3.57 (0.90)	4.09 (0.80)	**.00***
It is important for society as a whole to pursue sustainability	4.50 (0.70)	4.66 (0.61)	0.07
It is important for students to learn about sustainability in school	4.61 (0.58)	4.77 (0.57)	**.03***
Sustainability concepts should be included in the school curriculum	4.34 (0.83)	4.66 (0.61)	**.01***
Students should learn about sustainability at all grade levels	4.32 (0.83)	4.64 (0.65)	**.01***
Sustainability should be a central theme in science instruction	3.98 (0.95)	4.48 (0.76)	**.00***

Note. Significant p-values are boldly annotated with "*" symbols.

Table 2

Summary of PSTs' Views on Sustainability with Annotated Significance

How does this fit with your view of sustainability (from 1-5)?	PRE Mean (SD)	POST Mean (SD)	P-Value
Acting in socially responsible ways	3.93 (0.95)	4.23 (0.94)	**.04***
Supporting responsible business practices	3.95 (0.86)	4.20 (0.82)	0.1
Promoting citizens' environmental literacy	4.02 (1.00)	4.36 (0.78)	**.02***
Ensuring that humans recycle and reuse materials	4.30 (0.95)	4.59 (0.62)	**.01***
Preventing climate change	4.11 (1.02)	4.30 (0.85)	0.24
Limiting the growth of the human population	2.93 (1.10)	3.18 (1.17)	0.15
Promoting economic equality	3.68 (0.93)	4.05 (0.89)	**.02***
Considering the needs of future generations	4.41 (0.79)	4.64 (0.61)	0.14
Using renewable energy sources	4.30 (0.95)	4.57 (0.79)	**.03***
Limiting human consumption of resources	4.32 (0.86)	4.45 (0.82)	0.2
Reducing pollution and waste	4.43 (0.85)	4.59 (0.69)	0.16
Encouraging organic farming practices	4.18 (0.81)	4.36 (0.89)	0.1

The surveys asked PSTs to describe challenges in integrating sustainability into teaching through an open-ended question. Our qualitative content analysis of these responses showed shifts from pretest to posttest. Initially, PSTs noted barriers, such as *curriculum and time constraints* (43%), *lack of teacher knowledge (14%), lack of resources* (17%), and *resistance from stakeholders* like parents and administrators (26%). While these issues remained, the way PSTs expressed them changed. *Curriculum and time* (41%) were framed as potentially controversial topics (e.g., climate change), likely causing *resistance from stakeholders* (28%). Fewer PSTs (4%) cited a *lack of teacher knowledge*, while more mentioned resource *shortages* (27%). Nonetheless, PSTs' self-efficacy for teaching engineering increased significantly, with a paired samples t-test indicating a rise from before ($M = 2.56$, $SD = 0.64$) to after ($M = 3.37$, $SD = 0.56$) the intervention ($p < .0001$). All PSTs reported being 'very' or 'extremely' likely to include sustainability topics in their instruction. Moreover, their definitions of "sustainability" moved from *general to informed, focusing* on five themes before and after (examples provided below).

Table 3

Summary of PSTs' Definitions of Sustainability with Examples and Percentages

Theme	Pre	Post	Example "Sustainability is…"
Resource Management	34%	19%	Using the Earth's natural resources responsibly and cinciously without overuse. (Carly)
Environmental Conservation	24%	34%	The process of maintaining the health of the world and environment around us. (Jane)
Future Generations	13%	23%	Meeting the needs of individuals without harming future generations. (Harriet)
Balance (Humans/Nature)	13%	15%	Creating efficient means of advancing humankind, while bettering nature and the environment. (Frank)
Community Well-Being	7%	9%	Behaving in ways most conducive to the existence of the planet and its people. (Wanda)
None	9%	0%	No definition provided

Supporting the impact of the stories on PSTs' thinking, many discussed the value of the stories in their individual Engineering Story reflections unprompted. For instance, Kelly (pseudonym) explained, "The Stories helped me understand what it means to be an engineer behind the scenes. It's not just about technical skills or problem-solving; it's creative, collaborative, and makes real-world impacts." Connie wrote, "I really enjoyed the Stories because we not only understood the projects, but we got the 'why' behind them." Julie discussed that "Including stories about how engineers are sustainable in their careers can introduce students to career paths and new ideas of sustainability. Similarly, Paula added, "I found it interesting when we read stories of real-life sustainable engineers and how they execute their work. This is something I would love to do in my class to show examples of how engineering may work."

Discussion and Implications

Overall, our findings support the use of Sustainable Engineering Stories to promote our intended learning goals. By providing authentic examples of sustainable engineering projects, the stories helped PSTs understand the nature of engineering and recognize how sustainability aligns with professional engineering practice. While PSTs viewed sustainability as an essential topic to introduce in schools prior to the intervention, their commitment to doing so increased over the semester. As they clarified their understanding of sustainability and its place within engineering, PSTs gained confidence in their ability to incorporate it into their instruction.

Trends in the data support similar research about storytelling about engineering (Acosta & Haden, 2023; Lee et al., 2023; Author, 2022) and expand upon it to emphasize sustainable engineering and related foci. Encouragingly, PSTs came to recognize sustainability in terms of environmental stewardship and social responsibility, consistent with the EOP framework (The Lemelson Foundation, 2022) and as emphasized in the stories. When writing the stories, we highlighted what motivates sustainable engineers to carry out their work (Gottschall, 2012; Rao et al., 2020). PSTs also formed more detailed understandings of sustainability (Gannon et al., 2022), gained related self-efficacy (Menon et al., 2024), and planned to use stories in their own future classrooms. The stories supported PSTs' disciplinary literacy (Silvestri et al., 2021).

Our work thus far indicates promising areas for further exploration and scaling up. As we continue to implement the intervention in Spring 2025, we will more extensively examine changes in PSTs' conceptions of the nature of engineering to assess how they integrate their ideas about sustainability into those views. We also plan to refine our implementation approach and examine which elements of the intervention are most influential for PSTs' thinking. We are also interested in examining deeply how PSTs apply their ideas about engineering and sustainability to their planned instruction. Beyond the current implementation project, we are interested in exploring how the stories might be connected to classroom engineering tasks that could reinforce and elaborate on the topics and concepts present in the stories.

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