Is This an Authentic Engineering Activity? Resources for Addressing the Nature of Engineering With Teachers

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Abstract

Including engineering as part of K–12 science instruction has many potential benefits for students, but achieving those benefits depends on having classroom teachers who are well prepared to effectively implement engineering instruction. Science teacher educators, therefore, have an essential role to play in ensuring that engineering is incorporated into science instruction in productive ways. An important component of that work is developing teachers' understanding of the nature of engineering: what engineering is, what engineers do, and how engineering is both related to yet separate from science. Teachers must understand these concepts to implement engineering design activities that authentically reflect the field. In this article, I describe a sequence of instructional activities designed to help teachers, either preservice or inservice, develop their knowledge of the nature of engineering. At the core of the instructional sequence is a set of stories that provide teachers with descriptions of authentic engineering work. Surrounding the stories are activities that help teachers draw accurate conclusions about the nature of engineering and draw out the implications of those conclusions for instructional decision-making. I provide an overview of the instructional sequence and also share details from my own work with teachers, including transcripts of classroom conversations and the impact of instruction on teachers' knowledge.

Introduction

The inclusion of engineering as part of K–12 science education (NGSS Lead States, 2013) has the potential to provide students with valuable learning experiences. Engineering design activities can help students deepen their understanding of science ideas by applying them to novel contexts (Apedoe et al., 2008; Brophy et al., 2008; National Research Council [NRC], 2012). They are also opportunities to give students access to engineering as a powerful way of engaging with the world (Katehi et al., 2009). As currently conceptualized, science teachers are primarily being asked to develop students' engineering practices (Cunningham & Kelly, 2017; NRC, 2012). Typically, this is done by including engineering design experiences as part of science units that leverage key science concepts. Engineering design tasks can take a variety of forms, and not all engineering tasks are necessarily ones of design (Purzer & Quintani-Cifuentes, 2019). Rather, they involve extending the development of the structure and function of a novel technology that will achieve a set of requirements established by a specific problem context (Advancing Excellence in P-12 Engineering Education [AE^3] & American Society for Engineering Education [ASEE], 2020; Katehi et al., 2009). Importantly, classroom engineering design experiences should be authentic (AE^3 &ASEE, 2020), in the sense that they enable students to participate in engineering practices that are aligned with those of the professional community (Berland et al., 2016).

Achieving engineering's potential within science instruction requires a lot from science teachers regarding their knowledge and practice. Teachers not only need to be able to effectively guide student learning during engineering design experiences but also be knowledgeable about what constitutes an authentic experience. Thus, teachers will need an adequate understanding of the nature of engineering, especially how engineering design differs from scientific inquiry (Pleasants & Olson, 2019). This, however, creates a puzzle for science teacher educators because very few K–12 teachers have had much formal instruction in engineering (Banilower et al., 2018). Because of their limited experiences with engineering, gaps exist in teachers' knowledge about the nature of engineering in general and the distinctions between science and engineering (Antink-Meyer & Meyer, 2016; Deniz et al., 2020; Pleasants, 2021; Pleasants et al., 2020). Therefore, science teacher educators have much responsibility in addressing those gaps.

This article presents a sequence of learning activities designed to help teachers develop a more robust understanding of the nature of engineering. The activities focus on establishing core characteristics of engineering design that distinguish it from scientific inquiry as well as the implications of those distinctions for classroom instruction. The activities can be (and have been) used with both preservice and inservice teachers at the elementary or secondary level with some modifications to the materials based on grade level. The activities do not address everything teachers need to know about effectively teaching engineering in the science classroom. They also do not aim to develop teachers' nature of engineering pedagogy (i.e., how to teach K–12 students about the nature of engineering). Rather, they more modestly aim to provide teachers with a baseline understanding of the nature of engineering upon which to build additional knowledge of engineering pedagogy. Given that the activities are but one piece of a larger whole, they were designed to be implemented in a relatively short amount of instructional time, approximately 2 hours, which is appropriate for a once-per-week meeting of a science methods course or as a part of a professional development experience.

In this article, I first discuss some of the foundational concepts that guided my design of the instructional sequence. I then present an overview of the sequence of learning activities, the instructional materials that accompany them, and how I have implemented them with teachers. The materials are all available on the website (http://rennercenter.oucreate.com/stories-of-engineering-work/), and samples are included in the Appendices A and B. The final section shares evidence of teacher learning and suggestions for future use of the instructional materials.

Conceptual Foundations

As a science educator with experience teaching K–12 students and teachers about the nature of science, my conceptual foundation is the knowledge base on teaching and learning the nature of science (Lederman & Lederman, 2014; McComas et al., 2020)—applied here to the situation of teaching the nature of engineering. An important touchstone is the importance of what Clough (2006) refers to as "highly contextualized" nature of science activities, which are ways of giving learners access to examples of authentic scientific work, either historical or contemporary. A common way to do this is via the use of short stories that describe important episodes in the history of scientific thought while also illustrating how science works (Allchin et al., 2014; Clough, 2020b; Klassen & Froese Klassen, 2014; Metz et al., 2007; Rudge & Howe, 2009). The learning activities that I describe here take a similar approach, but in this case, they provide learners with stories of contemporary engineering practice, drawn from the perspective of professionals in the field—an approach suggested by Kruse et al. (2017). The learning activities use those stories to initiate and inform conversations about what engineering is, how it works, its relationship with science, and how it differs from science. In this respect, the activities draw upon the extensive literature highlighting the importance of explicit nature of science instruction (Khishfe & Abd-El-Khalick, 2002; Lederman & Lederman, 2014; McComas et al., 2020). More broadly, the explicit conversations about the nature of science and engineering that appear throughout the learning activities center on the investigation and exploration of questions. This is in line with the suggestions of Clough (2020a) regarding effective nature of science instruction and aligns with approaches advocated for teaching about the nature of engineering and technology (e.g., Kruse et al., 2017; Pleasants & Olson, 2019).

An important decision that I had to make within the instructional sequence was how thoroughly to address the nature of engineering, which is a highly complex and multifaceted construct (Pleasants & Olson, 2019). As desirable as it might be for all teachers to be experts in the nature of engineering as well as the nature of science, teacher educators rarely have the time to achieve such a goal. To inform my decisions regarding which aspects of the nature of engineering to focus on and the depth with which to address them, I utilized the Epistemologies in Practice (EIP) framework developed by Berland et al. (2016). The EIP framework describes characteristics of students' meaningful participation in disciplinary practices, rooted in the idea that those practices ought to be not only relevant to students but also reflective of authentic professional practices. The EIP framework emphasizes the goals and purposes of disciplinary practices, which is particularly useful when trying to establish what makes science and engineering different and, thus, how science instruction ought to differ from engineering instruction (McComas & Burgin, 2020; Pleasants & Olson, 2019; Pleasants, 2020). Just as scientists and engineers pursue different goals, so too should students pursue different goals when engaging in science or engineering practices in the classroom. Berland et al. (2016) define the goal of scientific activity as the creation of "knowledge products" that have certain characteristics, and their EIP framework focuses on a set of four "epistemic considerations": *nature*, *generality*, *justification*, and *audience* (Berland et al.'s, 2016, p. 1090). The goal of engineering work can also be described as the creation of knowledge products, but the products have different characteristics along the four epistemic considerations.

Using the dimensions of the EIP framework (Berland et al., 2016), Table 1 summarizes contrasting characteristics for science and engineering. Table 1 builds on the descriptions presented by Berland et al. (2016) and utilizes philosophical examinations of science and engineering, particularly those that attend to the relationships and distinctions between them (e.g., Chalmers, 2013; Giere et al., 2006; Meijers & de Vries, 2009; Mitcham, 1994; Vermaas et al., 2008; Vincenti, 1990). By necessity, the ideas in Table 1 represent only a first approximation of the complex ways in which science and engineering differ while nevertheless being deeply connected. Although they lack many nuances and complexities, the ideas in Table 1 serve as a useful starting point for teachers who are just beginning to explore the topic. These considerations serve as the main conceptual objectives for the instructional sequence described in the following section.

Table 1

Contrasting Epistemic Considerations for Science and Engineering

Epistemic consideration	For science	For engineering
Nature of the product	Description of a natural system that explains natural phenomena	A description of the form and function of a novel technological system.
Generality of the product	Descriptions are context-general: They make sense of specific phenomena and can also be generalized to a wide range of situations.	The technological system is context-specific: It must function within a certain set of requirements (criteria & constraints) that are unique to the situation at hand.
Justification	Descriptions are justified using empirical data, with careful attention paid to how those data were obtained. They are also justified in terms of coherence with established scientific knowledge.	Similar to science, technological systems are justified on the basis of data from empirical testing and consistency with established theory. They are also justified in relation to the established design requirement (e.g., budget or regulations).
Audience	Primarily, the scientific community. Secondarily, a broader range of interested parties, including people in decision-making roles and the general public.	A narrower audience of those closely involved in the specific design problem at hand (e.g., clients who initiated the design problem, users of the designed technology, or technicians who will implement the design).

Description of Instructional Sequence

Part 1: Eliciting Teachers' Views on Engineering Versus Science Instruction (~35 minutes)

The learning sequence begins with a task designed to elicit teachers' ideas about what differentiates a classroom science activity from a classroom engineering activity. I give teachers a set of three brief vignettes that describe instruction taking place in a science classroom. I have developed both an elementary and a secondary version of the vignettes. The elementary version is shown in Appendix A, and both versions are available as text documents on the Renner Science Education Center website at http://rennercenter.oucreate.com/stories-of-engineering-work/. The teachers are tasked with rating each of the vignettes on the extent to which they think it describes science and engineering and providing a rationale for those ratings. I have them complete this task in small groups of three or four and require them to reach a consensus on their ratings and their rationales. Once the groups have managed to do this, I gather all groups together to share ideas as a whole class.

During the ensuing whole-group discussion, my goal is primarily to facilitate the exchange of ideas across groups by having them share their ratings and rationales. Where agreement exists, I help students formalize their consensus ideas, and where disagreements exist, I draw out students' arguments and counterarguments. Most importantly, I help students identify gaps in their knowledge. During their small-group conversations, many teachers begin to realize that distinguishing science and engineering is more complicated than it first appears, and they start to identify uncertainties about what makes something engineering. With the whole group, I assist teachers in generating questions that they have about what engineering is, how it works, and how it differs from science. In this way, I steer the discussion toward creating a need to know more about what real-world engineering is like, which sets the stage for the next part of the instructional sequence. Some of the questions I aim to ask during this whole-group discussion include the following.

- It seems like we all think that this vignette represents an engineering activity. What are some of the characteristics that make it that way?
- Many groups rated this vignette differently in terms of engineering. What makes it ambiguous?
- What are some features of an engineering activity that differ from a science one?
- What questions would you like to have answered so that you could be more confident in your rating?
- What questions do we need to have answered to resolve this disagreement?

The discussion can, of course, go in many different directions depending on what the teachers bring to the learning situation. Appendix C provides a transcript of a whole-class discussion that occurred in an elementary science methods course that I taught. That transcript is presented as just one example of what might be expected from the conversation as well as how it might be guided in productive directions.

Part 2: Giving Teachers Access to Examples of Real-World Engineering (~60 minutes)

Once I have established teachers' initial ideas and identified some gaps in their knowledge, I present students with a set of stories that describe the work of real-world engineers. I wrote these stories based on interviews I conducted with practicing engineers who span a range of subdisciplines (e.g., aerospace, chemical, and biological engineering) and work contexts (e.g., academia, research and development in established industries, and startups). Each story gives an overview of the projects that the engineer works on but primarily focuses on the overall characteristics of the kinds of work the engineer does. The characteristics that I chose to highlight in the stories are those aligned with the epistemic considerations described in Table 1. An example story is shown in Appendix B, and the full set of stories is available on the Renner Science Education Center website (http://rennercenter.oucreate.com/stories-of-engineering-work/). The current versions of the stories have been used with teachers of all grade levels and have been modified over time based on feedback from teachers and professional engineers. Revisions will continue to be made and new stories added to the set, and all of these will be available on the website.

To start this phase of the instructional sequence, I divide the teachers into small groups of three to four and give them access to the set of stories. I task each teacher with reading a single story that is different from the ones read by their group members. This is a critical part of the activity because each story offers unique perspectives on engineering. As can be seen in Appendix B, embedded in the stories are questions and text boxes to serve as mediation strategies (Metz et al., 2007) that overtly draw the reader's attention to key characteristics of engineering and help the reader make the desired connections from the reading. The open-ended questions are constructed to point the reader toward more informed views about the nature of engineering. Voss et al. (2021) call such questions "convergent," and found them to be more effective than "divergent" questions that only elicit the reader's thinking. Clough (2020a) similarly emphasizes the need for such "educative" questions. When I have them read the stories during a class session, I do not typically require teachers to write out responses to the embedded questions, but I do point out that the questions are there to highlight particularly important points from the stories. I let them know that thinking about the embedded questions will be helpful for the task that follows.

After the teachers have had time to read their individual stories, I then have them work in their groups to make sense of what they have read by drawing broader conclusions about what engineering is and how it differs from science. I task each group with composing answers to the set of questions in Table 2 using specific examples from the stories that they read. Each group is responsible for composing a single set of answers that reflects their group consensus. Note that the questions in Table 2 draw attention to the epistemic considerations described in Table 1.

Table 2

Questions Used to Synthesize Key Ideas from Engineering Stories

For engineering	For science
What kinds of projects do engineers work on?	How do those projects differ from scientific ones?
What kinds of products do engineers create during their work?	How do those products differ from those created by scientists?
Who is the intended audience for the products that engineers create?	How does that compare with the audience for scientific research?
What kinds of things do engineers do to support/justify their products?	How does that compare with how scientists support their ideas?
How would you describe the overall goal/purpose of engineering work?	How does that compare with the overarching goal/purpose of scientific work?

While small groups are working on this task, I circulate among them to ensure that they are focusing their attention on synthesizing insights from what they read rather than simply summarizing to one another their various stories. I have found that groups can get sidetracked describing the details of the individual stories and miss the bigger picture that the questions in Table 2 are trying to address. Therefore, I play a very active role during these small-group conversations to keep them productive and help the teachers make sense of what are a challenging set of questions. Sometimes teachers get stuck on a certain set of questions, and I encourage them to leave those aside for the moment to address other ones. I tell the groups to note any questions that they feel particularly unsure about and explain that they will be addressed with the whole group. As I circulate among the groups, I note instances where they are drawing accurate conclusions about the nature of science and engineering, where they are not, and which questions will need to be examined in more depth with the whole class. Table 3 gives examples of accurate conclusions that teachers often draw from the stories as well as examples of uncertainties and inaccuracies that can emerge during their small-group work.

Table 3

Example Conclusions About Engineering and Science That Emerge From Stories

Informed conclusions about engineering/science	Potential areas of uncertainty/ inaccuracy
Engineers develop technologies (both tangible and intangible) for use in specific situations. They try to meet the needs of a specific user or client or resolve a specific problem within a company. Science is more about developing knowledge that can be applied broadly.	Teachers will often associate engineering with problem-solving and creating technologies without placing sufficient boundaries on the goals and products. Not all problems are engineering problems, and engineers are not the only ones involved in the creation of technology.
Engineers are designers, which means that their products are not the technologies themselves (because someone else is going to produce them) but rather the plans for those technologies.	Teachers might not distinguish between the design/development of a technology and the physical production or implementation of it.
Because engineers' ideas are implemented by other people (clients, customers, or other workers in a company), those people are an engineer's audience. Those people often do not share the engineer's technical background. In contrast, scientists primarily communicate their ideas to other scientists (and only sometimes interact with lay audiences).	Teachers will often think of "everyday people" as an engineer's audience. But more often, as is the case in the stories, the engineers do not interact directly with members of the public. They more often interface with other technical professionals inside a company or perhaps a customer or client (who is part of another company or organization). This is related to the specificity of an engineering project: Engineering designs are tailored to the unique needs of the specific audience.
Engineers put their ideas through rigorous testing and collect data to verify that they work. They use many of the same methods that scientists use, although their purposes differ.	Teachers usually recognize the substantial similarities between the methods of science and engineering. If they focus too much on the methods, they can struggle to differentiate between the two fields.

When the small-group conversations start to become less productive, I bring the whole group back together. During the ensuing whole-group discussion, I do not try to thoroughly address every question in Table 2. Instead, I prioritize the questions that groups struggled to answer. I elaborate on those concepts, fill in gaps in their thinking, address any misunderstandings that arise, and bring in relevant examples from the stories. Although nuances and complexities are sure to arise during this conversation, my main goal is to establish a consensus around the core set of contrasts regarding science and engineering that are summarized in Table 1. Below are example questions that I pose to teachers to help them progress toward that goal.

- Engineers are often described as designers of technology rather than as builders or fixers. What are some examples from the stories you read that support that idea?
- When we say that an engineer has designed something, what exactly has that engineer created?
- Scientists typically try to create knowledge about the world that they can apply to any situation. To what extent can engineers' designs be applied to new situations?
- For those who read the story about Armin, who were the recipients of the designs that he developed? How is that like what was going on in Suzanne's story? How about Kiana's?
- What sorts of things do engineers do to convince people that their ideas will work? Who are the people that they need to convince? How does that compare to what scientists do?

To give a more detailed sense of how this conversation might unfold, transcripts are provided in Appendices D and E for an elementary methods course and a secondary methods course, respectively.

As teachers start to reach a consensus regarding the key nature of engineering ideas, I start to identify implications that exist for classroom instruction. For instance, based on what has been established about the nature of the products that engineers create, I point out that classroom engineering activities ought to foreground design rather than physical construction. Engineers do create physical objects to use as prototypes for testing and communicating their ideas; however, the crucial point is that the act of making a product is not necessarily synonymous with engineering because engineering involves more than making. I also emphasize the importance of context within classroom engineering. Like authentic engineering projects, a classroom engineering activity ought to include requirements (criteria, constraints, and specifications) that are derived from the specific context of the engineering problem.

Part 3: Returning to the Examples of Science and Engineering Instruction (~25 minutes)

The last component of the learning sequence is a return to the vignettes used at the beginning of the sequence. The teachers are given about 10 minutes to work in their small groups to revise their ratings of the vignettes and their rationales as needed. The teachers are then brought together as a whole group to share their revisions and their reasoning. In most cases, the teachers do not drastically alter their ratings; they do, however, often suggest more concrete and fully developed reasons for their ratings. In addition to having teachers share their revised rationales, I ask them to explain how those rationales are informed by the stories and our previous conversations. During these conversations, teachers often point out that some vignettes have the potential to represent engineering (or science) but are missing certain key characteristics. Thus, a fruitful line of questioning to pursue is how one of the described activities could be modified such that it more authentically represented science, engineering, or both. This is a particularly worthwhile thought exercise for scenarios in which teachers have assigned midpoint ratings for both science and engineering. For an example of how this discussion might unfold, a transcript is provided in Appendix F.

To wrap up the discussion, as well as the instructional sequence, I reestablish the purpose of examining the vignettes in the first place. I emphasize the goal of providing students with authenticopportunities to engage in scientific inquiry and engineering design. Classroom activities need not be facsimiles of professional practice, but they ought to accurately reflect what professional scientists and engineers do. Examining the authenticity of a classroom activity and thinking about how it might be made more authentic is an important aspect of instructional decision-making. I often follow up the instructional sequence by having teachers read Whitworth and Wheeler's (2017) article in *The Science Teacher* as well as Appendix I of the *Next Generation Science Standards* (NGSS; NGSS Lead States, 2013), which describes the place of engineering design in the standards, to reinforce key points from the activities.

Assessment

The instructional sequence provides numerous opportunities to learn about teachers' informal thinking by listening to small-group conversations and the ideas shared with the whole group. To supplement what can be learned via the classroom conversations, I have students submit their groups' responses to the set of questions in Table 2 as well as their revised set of ratings and rationales for the three teaching vignettes. Table 4 shows an example of how teachers answered the questions in Table 2 based on the engineering stories. Included in that table are several annotations in italics that identify areas where the teachers' thinking needs to be revised—possibly something to address in a subsequent class session.

Table 4

Example Student Responses to Questions Comparing Science and Engineering

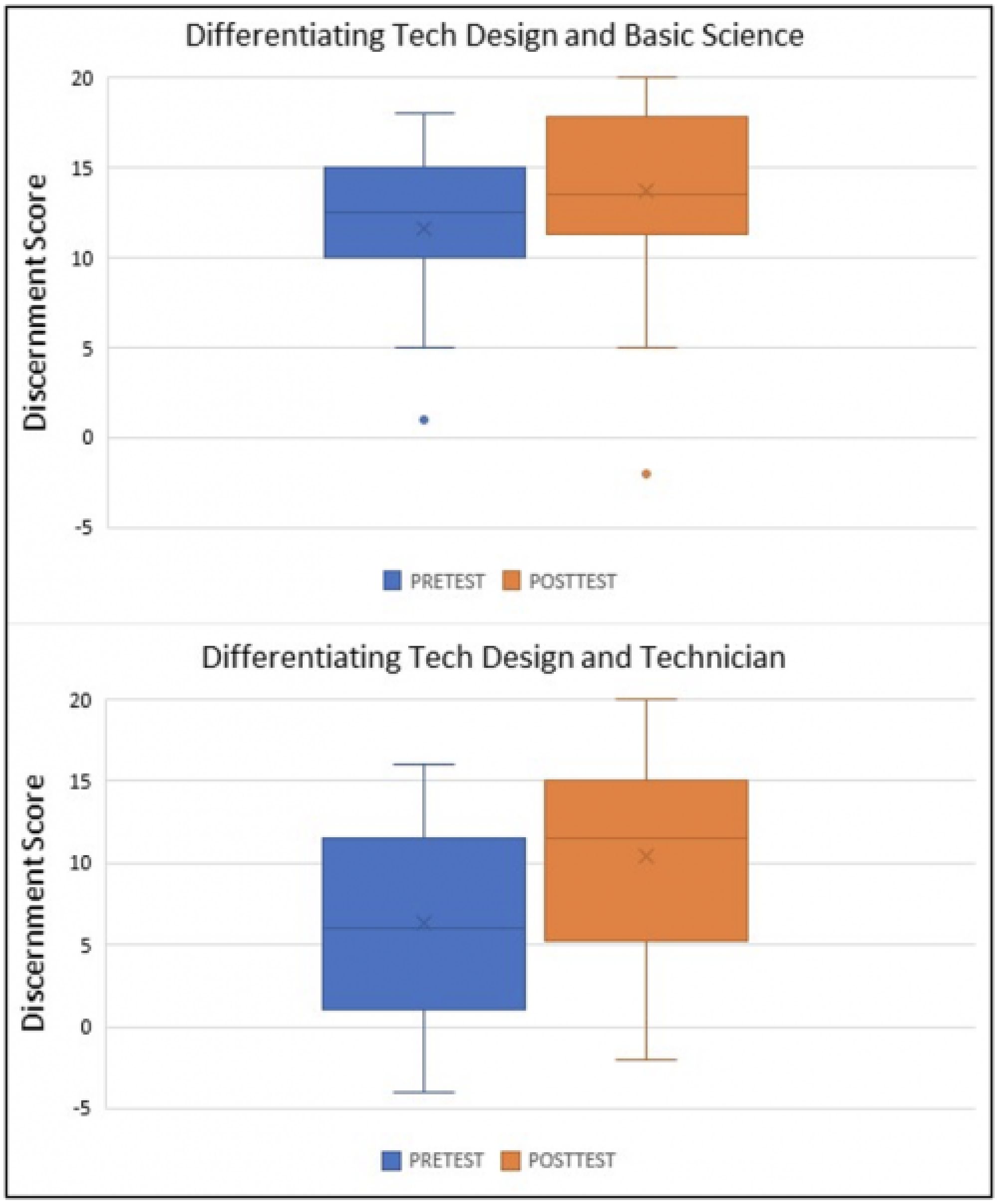
For engineering	For science
What kinds of projects do engineers work on? • "Engineers work to invent something or to modify an object that is already in place. They design technologies. Engineers also can analyze data to create a system that a producer can implement."	How do those projects differ from scientific ones? • "Scientific projects are more focused on explanations and learning. Science is less focused on application."
What kinds of products do engineers create during their work? • "Engineers can create tangible and nontangible technologies. The agricultural engineer created a computer method to automatically analyze data on pigs that are angry. The mechanical engineer talked about using 3D printing as a tool to bind metal together rather than welding." [*Some attention should also be given to the fact that engineers do not create the end product themselves; they are creating designs for those products.*]	How do those products differ from those created by scientists? • "Scientists create explanations and questions rather than technologies. Scientist might would look at the internal factors of the pig to understand why it behaves the way it does."
Who is the intended audience for the products that engineers create? • "The intended audience for the mechanical engineer's project is everyone. This project affects all people because instead of welding two different metals together, they are 3D printing them." [*This isn't quite right. The end product might be intended for a broad public audience, but engineers aren't producing the end product. The systems they design are instead directly intended for whoever is going to implement those designs—for instance, a technician, business owner, or city manager.*]	How does that compare with the audience for scientific research? • "Scientific research audiences are smaller, and it is targeted for other scientists to interpret the research or findings."
What kinds of things do engineers do to support/justify their products? • "Research, testing, collaboration, trials, revising, presentations, and demonstrations."	How does that compare with how scientists support their ideas? • "This is the similar part to where science and engineering overlap. They both do the same when it comes to supporting or justifying their products or ideas." [*There is plenty of similarity here to be sure, but it's worth noting that scientists will be justifying their ideas with respect to different sorts of values. For instance, engineers need to be mindful of cost, whereas scientists do not.*]
How would you describe the overall goal/purpose of engineering work? • "To make a change in everyday life for common people." [*This is pretty broad and could describe many different fields. It needs to be narrowed so that there is a clear focus on technological development.*]	How does that compare with the overarching goal/purpose of scientific work? • "The goal of science is to answer questions about how the world works and generate new knowledge."

To gather further information about teachers' thinking at the individual level, I use the Scope of Engineering Survey (SOES; Pleasants, 2021) as both a pre- and post-assessment. On this short survey (which takes about 7 minutes to complete), teachers rate different activities according to how strongly they associate them with engineering. The activities are grouped into several categories, the most relevant of which are Technological Design & Development (e.g., designing the production process for a chemical), Basic Science (e.g., using a telescope to search for new galaxies), and Technician (e.g., installing wiring in a building). An informed view of the nature of engineering would include a strong association (high ratings) for activities in the Technological Design & Development category and lower associations (low ratings) for the Basic Science and Technician categories. The SOES instrument allows for the calculation of a *discernment score* (ranging from -20 to +20) that is based on the difference between an individual's ratings for two different categories. For instance, a high (positive) discernment score for Technological Design & Development versus Basic Science would indicate an informed view of the nature of engineering. A negative discernment score for those categories would indicate that the respondent inaccurately associates Basic Science more strongly with engineering than Technological Design & Development.

During fall 2021, I implemented the instructional sequence with secondary and elementary preservice teachers. The preservice teachers completed the SOES electronically during the week prior to the single class meeting in which the instructional sequence took place. After that class, they were then tasked with completing the survey prior to the next week's class. A total of 32 preservice teachers completed both the pretest and posttest and gave consent for their data to be used for research purposes. Figure 1 shows an increase in their discernment between Technological Design & Development activities and those of Basic Science; a paired-samples *t*-test confirmed that difference to be statistically significant ($t(31) = 2.20$, $p = .035$). Figure 1 also shows an increase in discernment between Technological Design & Development and Technician work, which was also statistically significant ($t(31) = 3.62$, $p = .001$). Both of those discernments are essential. Distinctions between engineering and science are, of course, foregrounded in the instructional activities, but emphasis is also placed on associating engineering with the design of technology rather than its physical construction and maintenance. That distinction is highly relevant to classroom instruction because classroom engineering activities ought to focus on the design of technological products rather than physical assembly (AE^3 & ASEE, 2020).

Figure 1

Changes in Preservice Teachers' Discernment Scores



Conclusions and Future Directions

Incorporating engineering into science instruction in ways that are consistent with the vision laid out by the NGSS is complex and challenging (Pleasants et al., 2021; Schellinger et al., 2022; Watkins et al., 2018; Wendell et al., 2019). The learning activities that I describe here play a valuable role in preparing teachers to achieve that vision but are necessarily only one small part of what ought to be a much broader teacher education effort. As important as it is to prepare teachers to skillfully use engineering in their science instruction, an eternal challenge for teacher educators is that our time during science methods courses or professional development sessions is short and our objectives many. Considering these constraints, the goals of the learning activities that I present here are modest. They target key distinctions between science and engineering (Pleasants & Olson, 2019) so that teachers can better recognize how classroom activities that foreground engineering design ought to differ from those that foreground scientific inquiry (Whitworth & Wheeler, 2017). Ideally, these activities lay a foundation on which more complex ideas about engineering instruction might be built. Important areas for subsequent instruction to target might include:

- modifying published engineering activities to better reflect the nature of engineering,
- how to connect engineering activities to scientific concepts and practices,
- thorough examinations of the nature of science, potentially via historical stories (e.g., Clough, 2020b) or
- how to accurately convey the nature of engineering and science in the K–12 classroom.

In addition to serving as a springboard for further instruction, the materials used in the learning activities described here, particularly the engineering stories, can be readily modified for a variety of uses with teachers. Although I have had teachers read a single story during my instructional time with them, the stories could just as easily be assigned as readings to be completed outside of class. Instead of reading a single story, a teacher might read several, compose answers to the embedded questions, and then identify themes that cut across multiple readings. I encourage teacher educators to take up the materials, modify them, use them in novel ways, and share their results with the community.

Supplemental Files

Appendices-Pleasants-2022.docx

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