Journal of Pre-College Engineering Education Research (J-PEER)

Volume 9 | Issue 2 Article 1

2018

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Available online at http://docs.lib.purdue.edu/jpeer

Journal of Pre-College Engineering Education Research 9:2 (2019) 1–18

Refining an Instrument and Studying Elementary Teachers' Understanding of the Scope of Engineering

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Abstract

To effectively incorporate engineering into their instruction, K–12 teachers need sufficient knowledge of the engineering discipline. An important component of teachers' engineering knowledge is their understanding of the nature of engineering: what engineers do, the epistemological underpinnings of engineering, and the relationships between engineering and other fields of study. In this study, we present a quantitative tool that was developed to assess teachers' knowledge of a particular nature of engineering dimension: the scope of engineering, which describes the demarcation between engineering and non-engineering. This tool was used to assess the knowledge of teachers and engineering graduate students, before and after they participated in a research project focused on improving elementary science and engineering instruction. Our results indicate that the scope of engineering knowledge of all participants, including the engineering graduate students, improved over the course of the project. Unexpectedly, we found that engineering graduate students were no more knowledgeable about the scope of engineering than the teachers in the study. We explore potential reasons for this result, propose recommendations for future use of the scope of engineering instrument, and discuss promising avenues for future instrument development.

Keywords: nature of engineering, scope of engineering, instrument, elementary engineering education, pre-service teacher education

Introduction

Engineering is increasingly becoming a part of science standards and curricula across the United States. The Next Generation Science Standards (NGSS Lead States, 2013) place substantial emphasis on engineering, and many states have adopted their own engineering standards (Moore, Tank, Glancy, & Kersten, 2015). As engineering enters science curricula and classrooms, a significant challenge lies in preparing teachers to address this novel subject. Many teachers, especially at the elementary level, have limited preparation in engineering (Banilower et al., 2013), and lack deep knowledge of the subject (Hsu, Purzer, & Cardella, 2011). Given the importance of teacher knowledge for effective instruction (Ball, Thames, & Phelps, 2008; Bell, 2005; Gess-Newsome, 1999; Shulman, 1986), developing teachers' engineering knowledge is a key task for K–12 engineering education efforts.

While some disagreements exist regarding the engineering concepts that are most relevant for K–12 education (Custer, Daugherty, & Meyer, 2010; NAE, 2010), points of consensus can also be found. Understanding engineering design, and the skills associated with it, is often regarded as a crucial element of engineering knowledge (Brophy, Klein, Postmore, & Rogers, 2008; Cunningham & Carlsen, 2014; Moore et al., 2014; NAE & NRC, 2009; Sidawi, 2009). Another important set

http://dx.doi.org/10.7771/2157-9288.1207

of ideas relates to the *nature of engineering*: what engineering is, what engineers do, and engineering's relationship with other disciplines and society (Cardella, Salzman, Purzer, & Strobel, 2014; Karatas, Micklos, & Bodner, 2011; Lachapelle & Cunningham, 2014; NAE & NRC, 2008, 2009; NRC, 2014; Pleasants & Olson, 2019). At the elementary level, research into teachers' and students' views of the nature of engineering has documented multiple misconceptions (Capobianco, Diefes-dux, Mena, & Weller, 2011; Cunningham, Lachapelle, & Lindgren-Streicher, 2005, 2006; Karatas et al., 2011; Lambert et al., 2007; Montfort, Brown, & Whritenour, 2013), but additional work is needed in this area. The nature of engineering is multidimensional (Pleasants & Olson, 2019), but most research studies have used instruments that are not tailored to specific nature of engineering dimensions. In addition, while studies suggest that teachers' nature of engineering views can be positively impacted by professional development (e.g., Duncan, Diefes-Dux, & Gentry, 2011; Hasan, Yesilyurt, Kaya, & Trabiya, 2017; High et al., 2009; Yoon, Diefes-Dux, & Strobel, 2013), the specific areas in which teachers' knowledge develops is unclear.

The present study provides a targeted examination of elementary teachers' nature of engineering knowledge by focusing on a specific dimension: the "Scope of Engineering" (SOE), which addresses what does and does not fall into the domain of engineering work. The present work assesses elementary teachers' SOE knowledge before and after participating in a professional development project aimed at supporting elementary engineering instruction. As part of this project, elementary teachers were teamed with engineering graduate students who regularly visited their classrooms. Because no satisfactory instrument existed for measuring knowledge of the SOE construct, a key goal for the study was to develop such an instrument. Our work resulted in a set of survey items that tap the SOE construct and lay a foundation for the future development of a more comprehensive SOE instrument. Our work was guided by the following research questions:

1) How can project participants' SOE knowledge be measured?
2) What differences, if any, exist in teachers' knowledge of the SOE before and after participation in this project?
3) How do teachers compare to engineers in terms of SOE knowledge before and after participation?

Theoretical Framework: Defining the Scope of Engineering Construct

At its core, the SOE is an issue of demarcation: what falls under the umbrella of engineering and what does not. Engineering is fundamentally concerned with technology, but not all technological work is considered engineering (Davis, 1996; Mitcham, 1994). Many K–12 students think engineers fix cars or operate machinery (Chou & Chen, 2017; Cunningham et al., 2005; Fralick, Kearn, Thompson, & Lyons, 2009; Weber, Duncan, Dyehouse, Strobel, & Diefes-Dux, 2011), and though these are technological activities, they are not *engineering* activities. Fixing cars is a relatively unambiguous case of non-engineering, but not all technological activities are easily categorized. Engineers engage in a variety of technological work (Mitcham & Schatzberg, 2009; Trevelyan, 2007), and although engineering is often primarily associated with technological design (e.g., Dym, Agogino, Eris, Frey, & Leifer, 2005; NRC, 2012), engineers are also involved with research (Channell, 2009; Petroski, 1996; Vincenti, 1990), investigating technological failures (Matthews, 1998), overseeing technological projects (Florman, 1987; Trevelyan, 2007), and certain maintenance activities (Mitcham, 1994). Given the wide range of engineering work, defining a clear demarcation between engineering and other forms of technological practice is challenging.

To better understand the demarcation question in engineering, the issue of demarcation in science provides a useful touchstone. Because scientific knowledge occupies a privileged position in our society, philosophers have tried to distinguish science from non-science for over a century. Past philosophical efforts typically focused on identifying essential characteristics of scientific knowledge that make it fundamentally different from other knowledge forms (e.g., Popper, 1959/1972). However, those efforts were largely unsuccessful, and philosophers have been unable to formulate criteria that cleanly separate science from non-science (Laudan, 1983; Pigliucci, 2013). An alternative approach that shows greater promise is to view the sciences as being connected by a set of family resemblances (cf. Wittgenstein, 1953). Viewed this way, different disciplines can be more or less like science, and the boundary between science and non-science becomes fuzzy rather than distinct, although clear examples of science and non-science still exist (Dupré, 1995; Pigliucci, 2013). The advantage of the family resemblances approach is that it can account for the diversity of scientific fields while still identifying core (though not essential) characteristics of science that tie them together.

As with the case of demarcation in science, engineering and non-engineering cannot likely be separated by a set of essential criteria. Given the diverse set of activities with which engineers are involved, a family resemblances approach is likely to be the most fruitful for defining the SOE, just as it is for demarcation in science. Fully elaborating the family resemblances of the diverse fields of engineering is beyond the scope of this paper, but several are discussed here to provide a sense of the SOE. These should not be taken to be unambiguous separations between engineering and non-engineering, but rather as indications of what makes certain activities more (or less) like engineering.

Engineering work is often done in the context of the design and development of novel technologies (Dym et al., 2005; Petroski, 1996; Vincenti, 1990). In contrast, engineers tend not to physically carry out the production of technologies, nor do they typically operate those technologies (Dym & Brown, 2012; Kroes, 2012; Trevelyan, 2007; Vincenti, 1990). Engineers also engage in research, and while their research borrows many of the methods of the natural sciences, it is focused on technological rather than natural phenomena and is often closely tied to technological design and development (Banse & Grunwald, 2009; Mitcham & Schatzbeg, 2009; Vincenti, 1990). Engineering frequently includes analyses of existing or planned technologies, often using theoretical ideas from science (Bucciarelli, 1994; Dym & Brown, 2012); the analytical character of engineering work is unlike crafts-based or artisanal approaches to technological design (Petroski, 1996; Vincenti, 1990).

Based on the distinctions described above, one way to describe the SOE is to place various technological activities on a spectrum, ranging from "more like engineering" to "less like engineering." Figure 1 provides an example spectrum, and it importantly does not identify a clear line separating engineering from non-engineering. Rather, certain activities are considered closer to or more distant from engineering practice. Repairing a device such as a car, for example, is more distant from the work of engineering, as engineering does not typically entail the design of cars, nor theoretical analyses or investigations of automobile systems. A more ambiguous activity, located in the middle of the spectrum, is that of overseeing a technological project. In itself, supervising a project such as the creation of a new bridge does not resemble engineering, but if the overseer had also been involved in the design of the bridge, or was conducting analyses of the bridge as it was being built, then greater resemblance might be shown.

Literature Review

Although the "SOE" nomenclature has not been used, many prior studies have identified gaps in teachers' and students' SOE knowledge (e.g., Cunningham et al., 2005, 2006; Fralick et al., 2009; Thompson & Lyons, 2008; Weber et al., 2011). Knowledge of the SOE is regarded as important for K–12 students because many engineering education efforts seek to generate student interest in engineering as a career pathway (Brophy et al., 2008; NRC, 2012). Promoting genuine student interest in engineering requires that those students understand what engineering is and is not (i.e., the SOE); students who are interested in engineering based on erroneous understandings of the discipline will not be well served. Understanding the SOE also contributes to students' ability to distinguish science and engineering, which is especially important given that engineering is often incorporated into science instruction, and concerns have been raised about potential conflation of these two disciplines (Antink-Meyer & Meyer, 2016; McComas & Nouri, 2016).

One method that has often been used to investigate students' knowledge of the SOE is the Draw-An-Engineer-Test (Knight & Cunningham, 2004). The test tasks the respondent with drawing "an engineer doing engineering work" and provides a space for the respondent to write about what the engineer is doing. Studies of elementary and middle school students' drawings have indicated that many students do not have well-developed or accurate ideas about what engineers do. Students' drawings often show engineers repairing engines, doing construction work, or engaging in other skilled-labor tasks that fall outside the

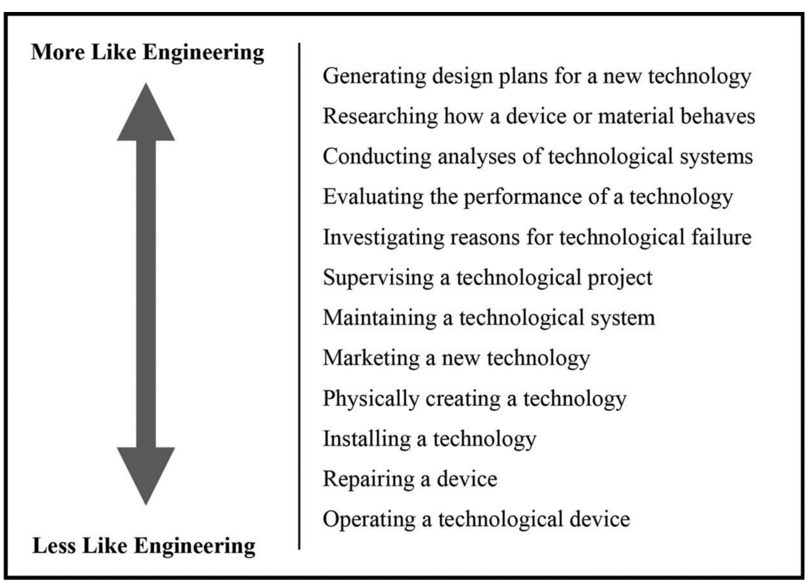

Figure 1. Resemblance of various technological activities to engineering.

range of engineering work (Capobianco et al., 2011; Chou & Chen, 2017; Fralick et al., 2009; Rynearson, 2016; Thompson & Lyons, 2008; Weber et al., 2011). A different open-ended approach that has been used to assess SOE views is to ask respondents "What is engineering?" and "What do engineers do?" Like the findings from the Draw-An-Engineer-Test, studies that used this approach have similarly found evidence of misconceptions about the SOE among elementary students and teachers (Cunningham et al., 2005, 2006; Lambert et al., 2007). Although these open-ended approaches have revealed some misconceptions about the SOE, a significant limitation of the instruments is that they were not specifically designed to elicit respondents' SOE thinking. When respondents produce single drawings or definitions of engineering, they are unlikely to convey their full range of thinking about the SOE.

A more direct approach to assessing SOE views is to task participants with categorizing various activities as either engineering or non-engineering. Cunningham et al. (2005, 2006) gave elementary students and teachers a categorization task and found that, while teachers performed better than students, both groups frequently made inaccurate categorizations. Over half of the teachers, for example, indicated that engineers install wiring, repair cars, and drive machines as part of their jobs. In a later study, they found that elementary students' categorizations were improved after completing an Engineering is Elementary unit (Museum of Science, Boston) (Cunningham & Lachapelle, 2007). A similar version of the activity-categorization task was also used by Hammack, Ivey, Utley, and High (2015), who found evidence of misconceived views among middle-school students. Ozogul, Miller, and Reisslein (2017) used a different categorization task with K-5 students and found that older students tended to have fewer misconceptions than younger students. Interviews can also be used to assess participants' SOE views. Montfort et al. (2013) interviewed high-school students about a range of nature of engineering topics that included the SOE. They found that, while about half of the interviewed students accurately associated engineering with designing and planning activities, most students also indicated that engineers are involved with "the mechanistic work of building and fixing" (p. 7).

Regardless of the method, the results found by the studies discussed here are consistent: elementary teachers and students at all grade levels hold inaccurate views about the SOE. More specifically, SOE misconceptions take the form of overbroad notions of engineering work; participants in the above studies often accurately associated engineering with the design of technology, but they also inaccurately identified maintenance, repair, or construction work as engineering. Yet while the above studies all investigated participants' understanding of the SOE, they did not use consistent constructs or methods. Some studies investigated participants' "conceptions of engineering" (e.g., Capobianco et al., 2011; Cunningham et al., 2006), while one investigated their "understandings of the concept of *engineering*" (Montfort et al., 2013, p. 6, emphasis in original) and another their "actual knowledge of engineering occupational activities" (Ozogul et al., 2017, p. 19). The varied terminology and research tools described above pose challenges to those seeking to compare results across studies. Instruments used to investigate "conceptions of engineering," for instance, might tap respondents' knowledge of the SOE, but also the relationship between engineering and science, or the cultural embeddedness of engineering. In order to continue the progress in this field of study, more precise terminology is needed for the constructs under study, and instruments are needed that tightly align with those constructs (NRC, 2001).

Methods

Study Context

This study took place within the context of an NSF-funded professional development and teacher education project focused on improving elementary teacher preparation for science and engineering instruction. A core component of the project was a 16-week student-teaching experience that placed a student teacher in a triad with a cooperating teacher and an engineering graduate student ("engineer" hereafter) who worked together to incorporate engineering into science instruction in Grades 3–5 classrooms. The engineers were either Ph.D. students (78%) or Master's students (22%), representing a range of engineering subdisciplines (agricultural and biosystems, aerospace, chemical, civil, electrical, industrial, mechanical, and materials). Project participants all worked in classrooms in a large urban school district that serves a diverse student population. Each engineer attended the elementary classroom one full day per week and received ongoing support by attending a weekly hour-long course on campus with project staff. Triads' classrooms were visited every other week by project research staff to conduct observations and provide instructional and organizational support.

Project participants completed multiple professional development workshops, summarized in Table 1, each of which addressed aspects of effective science and engineering instruction. Of most relevance to the present study, approximately 45 minutes of Workshop 2 were devoted to the following nature of engineering ideas: the various jobs that people with engineering degrees might hold after graduation, how design engineers consider criteria and constraints in their work, and the ways that scientific knowledge has impacted engineering and technology. The nature of engineering was also addressed for approximately 45 minutes in Workshop 3, with emphasis on the relationship between science and engineering. The relatively short period of time devoted to the nature of engineering during

Table 1
Descriptions of project workshops.

	Timing	Participants	Topics
Workshop 1	Three days prior to beginning semester	Engineers only	– Legal issues of working in schools, and the engineers' roles in the classroom – Elementary student cognition – Effective science and engineering instruction
Workshop 2	Two days, directly after Workshop 1	Engineers Cooperating teachers Student teachers	– Effective science and engineering lessons modeled for participants – Integrating science and engineering instruction – The nature of engineering – Co-teaching strategies – How to work and plan as a team
Workshop 3	One day, middle of the semester	Cooperating teachers Student teachers	– Science/engineering integration modeled for participants – Distinctions between science and engineering

the workshops was consistent with the focus of the project. Although we aimed to improve participants' knowledge of the nature of engineering, this was not our primary goal; rather, the bulk of the project's activities were directed toward facilitating the effective incorporation of engineering into science instruction in the elementary grades.

Although the workshops played important roles, the professional development model used in the present study treated teachers' classrooms as the key sites of teacher learning (Grossman, Smagorinsky, & Valencia, 1999; Morine-Dershimer, 1989). The engineers were viewed as critical in this regard: by serving as engineering content experts, they could facilitate the teachers' learning of engineering as the triads planned and implemented lessons as a team. The engineers were in a particularly effective position to communicate the SOE as they helped their triad members understand what they do as engineers. This mechanism of teacher learning assumes that engineers have relatively expert nature of engineering knowledge when compared to teachers, but this was an assumption that needed to be tested. For instance, studies of scientists have found that, while their nature of science views are generally more informed than those of science teachers and students, they are not necessarily consistent with the desired state (Glasson & Bentley, 2000; Schwartz & Lederman, 2008; Yore, Hand, & Florence, 2004). Similarly, engineers, particularly graduate students, may not necessarily hold completely informed nature of engineering views.

Participants and Data Collection

Data for the present study come from the first six semesters of data collection for the project (fall 2015–spring 2018). Each semester, ten student teacher/cooperating teacher/engineer triads comprised the treatment group for the project. A SOE survey (described below) was administered to all participants prior to and at the end of their participation. Student teachers and their cooperating teachers participated for a single semester, but all engineers participated for two consecutive semesters. In order to make comparisons across the three participant groups, we only used data from engineers' first semester of participation to ensure that all participants were compared on a single semester-long treatment. Nine cooperating teachers also participated in the project for more than one semester, and we similarly only used data from their first semester of participation for the present study. In total, pre-tests were available for 138 treatment group participants (50 cooperating teachers, 60 student teachers, 28 engineers) and post-tests were available for 136 treatment group participants (1 cooperating teacher and 1 student teacher did not complete a post-test).

A control group was also recruited for the study, consisting of 40 pairs of student teachers from the same teacher education program as the treatment group and their cooperating teachers. Control group participants taught the same grade levels and in the same geographic region as the treatment group, although school districts also included suburban and rural areas in addition to urban ones. Whereas treatment group participants completed surveys as pre- and post-tests, control group participants completed them only once near the middle of the semester. The timing for the control group surveys differed from the treatment group because control participants were on a schedule of two 8-week student teaching placements during the semester, and were recruited for the present study at the beginning of their second placement. Although the control group participants completed the survey near the beginning of their second placement, we treated their surveys as "pre-tests" for the purposes of analysis. The control group participants did not receive any engineering-specific professional development experiences during their first placements, and thus we assumed that their survey responses would not have been significantly different had they been given at the beginning of the first placement.

Data from the control group were used for two purposes. Control group responses were compared to the pre-test responses of the student teachers and cooperating teachers

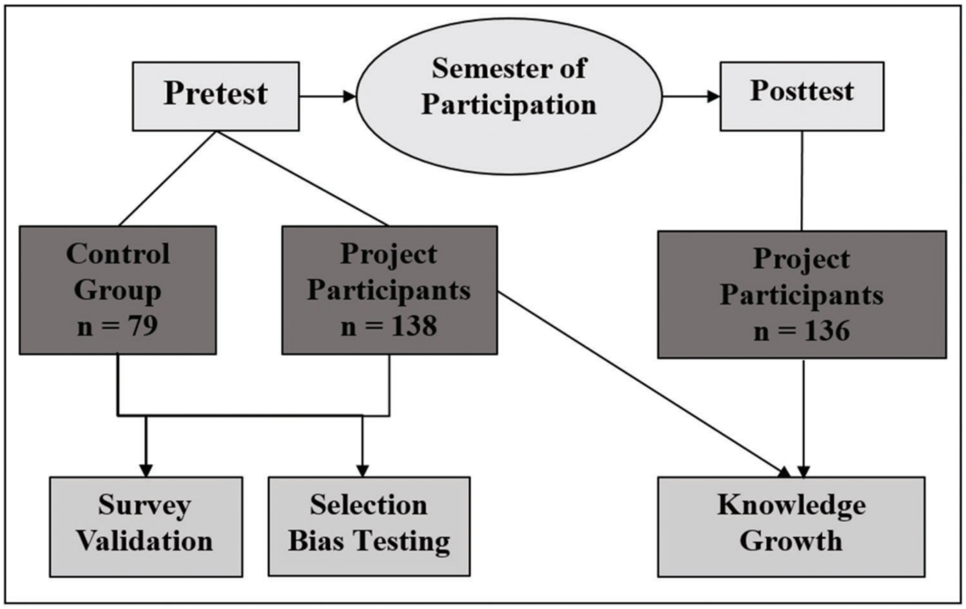

Figure 2. Data collection plan for the study.

from the treatment group to determine whether a selection bias existed for treatment group participants. That is, we wanted to know whether the treatment group participants were already more knowledgeable about the SOE than the control group. Control group responses were also used for the purposes of survey validation, described in greater detail below. Figure 2 summarizes the data collected from participants in the study and how they were used.

Instrument Construction

Item Selection

Investigating participants' SOE knowledge requires an instrument that is highly aligned to the construct (NRC, 2001), but as discussed above, many of the available instruments that tap nature of engineering knowledge do not specifically target the SOE. One promising instrument for assessing SOE knowledge is the "What is Engineering?" survey, developed by Engineering is Elementary (Museum of Science, Boston) and included in the Appendix. The survey was initially created for use with elementary students (Cunningham et al., 2005), but has also been administered to teachers (Cunningham et al., 2006). Since its development, the survey has been expanded and revised, and the form used for the present study consisted of three questions:

a. An open-ended question that asks: "What is an engineer?"
b. Respondents select from a list of 37 activities examples of things an engineer might do, such as: "Develop smaller cell phones" or "Repair cars."
c. Respondents rate on a Likert-type scale the importance of 21 activities to an engineer, such as: "Driving machines" or "Solving problems."

The three items are aligned to the SOE construct to varying extents, and a task for the present study was to identify those that were most closely aligned to the SOE construct (NRC, 2001).

Question (a), which asks "What is an engineer?", has many of the same shortcomings as other open-ended tasks: it has the potential to elicit ideas related to the SOE, but is also likely to elicit ideas that relate to other nature of engineering dimensions. More importantly, responses to this question may not address the SOE at all (e.g., a response that states that "engineers solve problems" does not clearly convey anything about the SOE). We therefore opted not to use this question to measure SOE knowledge.

Question (b) appears to be closely related to the SOE. The task of categorizing various activities as things that engineers might or might not do appears highly related to the SOE construct. The drawback of this question lies in the dichotomous nature of the task. If a family resemblances perspective is taken for the SOE, the most appropriate question is not whether an activity definitively is or is not engineering, but the extent to which it is *like* engineering (see Figure 1). Dichotomous questions force respondents to sharply differentiate activities that may only differ in their relationship to engineering work by degrees, thus producing a threat to validity. Furthermore, respondents might choose to place the dividing line between engineering and non-engineering in idiosyncratic ways. For instance, a respondent might identify "fixing computers" as something an engineer would do not because it is activity that is *highly* like engineering, but because it is at least *somewhat* like engineering.

Question (c) has a potential advantage over question (b) in that participants can rate activities as more or less important to engineers. This kind of task is more in line with the family resemblances approach to characterizing the SOE. To further investigate this potential advantage, and the possible issues with question (b), cognitive interviews (Willis, 2004) were conducted with a sample of ten project participants, all of whom were cooperating teachers or student teachers. The cognitive interview questions focused on how respondents decided to categorize the activities in questions (b) and (c), and participants' responses were transcribed and analyzed with respect to their patterns of reasoning.

When answering question (b), most respondents stated that all the activities *could* be done by engineers, but that some were more likely to be done than others. Most respondents chose to only select the "likely" items from the list, but some selected all the activities because they could see some potential connection between each one and engineering. Respondents reported similar patterns of reasoning for question (c): most viewed certain activities as more relevant to engineering than others, while acknowledging that all of the activities could *potentially* be linked to engineering. Unlike question (b), however, no respondents rated all of the items equally highly on the Likert-type scale; those items that were only potentially related to engineering were rated lower than the others. Based on the responses to the cognitive interviews and the arguments above, we determined that the format of question (c) is best suited to assessing SOE knowledge, and we therefore used only that question in subsequent analyses.

However, a concern with question (c) is that certain items do not directly relate to the SOE construct. For example, rating the importance of "using their creativity" to engineers does not likely tap participants' SOE knowledge. Creativity might be a component of the family resemblances picture of engineering, but essentially all disciplines require creativity to some degree. "Brainstorming different ideas" is another item that appears to have only weak connections to the SOE. Participants' thinking about this item likely relates more to their ideas about what engineering design entails, rather than issues of demarcation. Thus, additional analysis and refinement of question (c) were needed to make it appropriate for targeting the SOE construct. Below, we present how we modified this question to generate a "Scope of Engineering Scale" (SOE-S) that is highly aligned to the construct. The analysis used to generate the SOE-S utilized pre-test data from project participants along with data collected from the control group ($n = 217$).

Development of SOE-S

Question (c) asks participants how important a set of 21 different activities are to the work of an engineer. Participants used a Likert-type scale to rate each item from 1 (not important) to 5 (very important). Of 21 activities, the 14 considered to be associated with engineering, such as "using models" and "testing ideas," were labeled as "accurate." The remaining 7 activities, labeled "inaccurate," represent activities that are far removed from engineering work, such as "using power tools to build things" and "driving machines." Whether the items were considered accurate or inaccurate was determined by the developers of the survey (Museum of Science, Boston) by giving the items to a sample of engineers. Prior to analyzing these items, responses for the 7 "inaccurate" items were reversed, as lower ratings (i.e., rating them as less important for engineers) on these items are more correct. Table 2 provides descriptive statistics for all 21 items.

Table 2
Descriptive statistics for question (c) items ($n = 217$).

SOE-S item (*denotes "inaccurate" item)	Mean (out of 5) (*item scores reversed)	Standard deviation
Using math	4.84	0.41
Using models	4.68	0.58
Testing ideas	4.90	0.36
Working as a team	4.75	0.53
Doing experiments	4.59	0.73
Solving problems	4.92	0.30
Sketching ideas	4.58	0.70
Using their creativity	4.85	0.40
Understanding science	4.75	0.52
Reading about inventions	4.08	0.90
Writing down their ideas	4.57	0.63
Writing reports for other engineers	3.92	1.09
Brainstorming different ideas	4.82	0.41
Telling other people what they found out	4.44	0.83
*Driving machines	3.45*	1.13
*Building houses	3.63*	1.21
*Repairing engines	3.41*	1.22
*Using power tools to fix things	3.20*	1.14
*Using power tools to build things	3.01*	1.16
*Fixing broken things for other people	3.09*	1.24
*Driving people from place to place	4.34*	0.98

Examination of the 21 items in Table 2 reveals several issues. First, many of the "accurate" items show near-ceiling performance, with correspondingly low standard deviations. Such items offer little capacity to discriminate participants' SOE knowledge or assess knowledge growth (DeVellis, 2003). The near-ceiling performance on the "accurate" items is not necessarily surprising, as prior research has shown that inaccurate SOE views are typically those of over-permissiveness, wherein too many activities are categorized as engineering rather than too few (Cunningham et al., 2005, 2006, 2014; Lambert et al., 2007). As noted above, a more important issue is that some of the 21 items are not aligned with the SOE construct. For instance, while respondents' views on the importance of "Understanding science" to engineers are related to the nature of engineering in general, it is not an SOE issue. The same is true for many of the "accurate" items, including "Working as a team" and "Using their creativity." Finally, the co-presence of "accurate" and "inaccurate" items means that combining all items into a single scale score is not likely to be appropriate. Even after reversing the ratings for the "inaccurate" items, they may not function similarly to the "accurate" ones (Barnette, 2000).

To investigate further, the internal reliability of the items was calculated. Cronbach's α based on standardized items for the 21 items was 0.753, which is acceptable but not as high as desired (DeVellis, 2003). More troublingly, the mean inter-item correlation was 0.127, ranging from −0.403 to 0.860, which provides evidence that the items do not all cohere into a single scale. To further investigate this possibility, a principal components factor analysis (PCA) was conducted using SPSS version 24. The Kaiser–Meyer–Olkin measure for these data was 0.860, exceeding the recommended value of 0.6 (Kaiser & Rice, 1974), and Bartlett's test of sphericity (Bartlett, 1954) was statistically significant at $p < 0.001$, indicating that the data were suitable for factor analysis.

Exploratory PCA revealed four components with eigenvalues greater than 1, explaining 26.5%, 17.3%, 6.1%, and 5.9% of the variance respectively. The screeplot of the four components showed a clear break after the first two, and thus only those components were retained for further investigation (Cattell, 1966). The two-component solution explained 43.8% of the total variance. Using an oblimin rotation solution, a simple structure was found such that both components loaded strongly on multiple items, and nearly all items strongly loaded on only one component (Thurstone, 1947). The varimax solution produced nearly identical results. The pattern matrix, structure matrix, and communalities for these items are given in Table 3. These results support the separation of this survey into two separate subscales.

As expected, the factor analysis separated the "accurate" from the "inaccurate" items. The subscale formed by the "inaccurate" items was promising in that the items are clearly related to the SOE. The coherence of the seven "inaccurate" items is indicated by their Cronbach's α statistic of 0.899, a nearly optimal value (DeVellis, 2003). In addition, the mean inter-item correlation of the seven items was 0.561, ranging from 0.425 to 0.862 (inter-item correlations not shown), indicating high coherence among the items. The corrected item-total correlations, shown in

Table 3
Pattern and structure matrix for PCA with oblimin rotation.

Item	**Pattern coefficients**		**Structure coefficients**		**Communalities**
	Component 1	**Component 2**	**Component 1**	**Component 2**	
Brainstorming different ideas	**0.720**	0.118	**0.700**	−0.005	0.503
Writing down their ideas	**0.706**	0.050	**0.697**	−0.070	0.489
Using their creativity	**0.601**	0.063	**0.591**	−0.039	0.353
Sketching ideas	**0.601**	0.075	**0.589**	−0.027	0.352
Testing ideas	**0.572**	0.184	**0.541**	0.086	0.325
Reading about inventions	**0.566**	**−0.303**	**0.618**	−0.400	0.471
Solving problems	**0.556**	0.223	**0.518**	0.128	0.317
Telling other people what they find out	**0.549**	−0.046	**0.557**	−0.140	0.313
Using models	**0.548**	−0.058	**0.558**	−0.151	0.314
Understanding science	**0.537**	−0.077	**0.550**	−0.168	0.308
Working as a team	**0.526**	−0.182	**0.557**	−0.272	0.343
Doing experiments	**0.507**	−0.122	**0.528**	−0.209	0.293
Writing reports for other engineers	**0.461**	−0.104	**0.479**	−0.182	0.240
Using math	**0.426**	−0.101	**0.443**	−0.174	0.206
Using power tools to fix things	−0.037	**0.867**	−0.185	**0.874**	0.765
Repairing engines	−0.044	**0.847**	−0.188	**0.854**	0.732
Building houses	0.077	**0.808**	−0.060	**0.795**	0.637
Using power tools to build things	−0.096	**0.806**	−0.233	**0.823**	0.686
Driving machines	0.021	**0.746**	−0.106	**0.742**	0.552
Fixing broken things for other people	−0.116	**0.710**	−0.236	**0.729**	0.545
Driving people from place to place	0.070	**0.676**	−0.045	**0.664**	0.445

Note. Major loadings for each item are in bold.

Table 4, were also high for this group of items, providing further evidence of their high internal reliability.

The subscale formed by the 14 "accurate" items did not show as high an internal reliability as the subscale formed by the seven "inaccurate" ones, although it did have a greater internal reliability than the full set of 21 items. The lower internal reliability of the "accurate" items is evidenced by the lower communalities of those items in Table 3. Cronbach's α for these items was 0.838, which is acceptable (DeVellis, 2003) but lower than that of the "inaccurate" items. The mean inter-item correlation for the "accurate" items was 0.270, ranging from 0.063 to 0.473 (not shown), which does not show high coherence among the items. The corrected item-total correlations for the "accurate" items subscale, shown in Table 5, are also far less than those of the "inaccurate" items subscale.

Table 4
Corrected item-total correlations of the seven "inaccurate" items.

SOE-S item	Corrected item-total correlation
Driving machines	0.648
Building houses	0.700
Repairing engines	0.792
Using power tools to fix things	0.824
Using power tools to build things	0.748
Fixing broken things for other people	0.658
Driving people from place to place	0.576

Table 5
Corrected item-total correlations of the fourteen "accurate" items.

Item	Corrected item-total correlation
Using math	0.364
Using models	0.485
Testing ideas	0.409
Working as a team	0.469
Doing experiments	0.399
Solving problems	0.373
Sketching ideas	0.470
Using their creativity	0.451
Understanding science	0.469
Reading about inventions	0.556
Writing down their ideas	0.599
Writing reports for other engineers	0.424
Brainstorming different ideas	0.578
Telling other people what they found out	0.490

In part, the lower internal reliability of the "accurate" subscale is likely due to participants' near-ceiling performance on those items, which reduces the variability of the items and therefore also the ability of those items to covary (DeVellis, 2003).

Based on these analyses, the seven "inaccurate" items were separated from the "accurate" ones, and only the "inaccurate" items were used for the Scope of Engineering Scale (SOE-S). The "accurate" items were not used in further analysis because they showed sufficient issues to prohibit further use, including:

- Several of the items do not appear related to the SOE (e.g., "Using their creativity" and "Working as a team").
- Among the items that are potentially related to the SOE, many are vague (e.g., "Sketching ideas" and "Writing down their ideas").
- Most of the items show a ceiling effect (see Table 2).
- The internal reliability of the items does not indicate a coherent scale.

Because the SOE-S developed here contained only inaccurate items, it was considered a *misconception* scale; the SOE-S indicates the presence of *inaccurate* views rather than accurate ones. This was not considered problematic, as prior research indicates that less-informed individuals tend to associate too many activities with engineering rather than too few (Cunningham et al., 2005, 2006, 2014; Lambert et al., 2007). The SOE-S therefore assesses the extent to which respondents have overly broad views of the SOE. The SOE-S is consistent with our conceptual framework in that the items on the scale are not ambiguous in their similarity to engineering; each item is an activity that is far to the "less like engineering" side of the continuum. An individual with an informed view of the SOE would therefore assign those activities lower ratings.

Results

Comparison of Treatment and Control Groups

Because treatment group participants self-selected into the project, the pre-test scores of the treatment group were compared to scores of the control group on the seven-item SOE-S described above. The mean SOE-S scores for the treatment group teachers and control group teachers are given in Table 6. A one-way ANOVA model was used to

Table 6
Mean SOE-S pre-test scores for treatment and control group teachers.

Experimental group	Mean SOE-S score (and standard deviation)
Treatment group cooperating teachers (n = 50)	24.64 (6.99)
Treatment group student teachers (n = 60)	23.57 (5.99)
Control group cooperating teachers (n = 39)	23.38 (6.29)
Control group student teachers (n = 40)	22.13 (6.48)

Table 7
Results of resampling analysis.

Semester	Observed total within-triad variance	Mean total within-triad variance based on random assignment	Probability of randomly obtaining within-triad variance *lower* than that observed
1	286.3	267.9	0.639
2	238.3	211.7	0.850
3	289.0	226.0	0.960
4	599.0	584.9	0.532
5	453.3	352.8	0.996
6	189.3	199.9	0.349

compare the SOE-S scores shown in Table 6. The homogeneity of variance assumption was met for the test (Levene's test $F_{(3,185)} = 0.581$, $p = 0.641$), and no significant differences were found between any of the four groups ($F_{(3,185)} = 1.149$, $p = 0.109$). Based on these results, we have no evidence that the treatment group participants were any more knowledgeable about the SOE than those in the control group prior to participating in the project.

Knowledge Growth of Treatment Group

To investigate how project participants' understanding of the SOE changed over the course of the project, the seven-item SOE-S described above was used to compare treatment group participants' SOE knowledge on the pre-test and post-test. Pre-test and post-test data were available from 49 cooperating teachers, 59 student teachers, and 28 engineers.

Potential Influence of Triad Structure

A complexity introduced into the dataset is due to the triad structure of the project. While the project was structured similarly for all participants, the experiences of the three members of a given triad were most similar to each other's. For this reason, triad members could not be assumed to be independent, and their SOE-S scores might have tracked similarly from the beginning to the end of the semester. To determine whether this was the case, SOE-S gain scores were calculated for each participant by subtracting their pre-test from post-test scores. For the purposes of this analysis only, engineers' data from both semesters of participation were used, with a gain score calculated for each semester. The variability of these gain scores was then calculated within each triad for a given semester of data collection.

For each semester of data collected, the within-triad SOE-S gain score variance was calculated, and then summed across all ten triads. If membership in a particular triad influences SOE-S score gains, then this total variance should be *lower* than would be expected if participants were not related via triads. To test this possibility, a bootstrapping method of resampling was employed (Efron, 2003). For each semester of data collection, the dataset was resampled by randomly reassigning all participant responses to new triads and calculating the total within-triad SOE-S gain score variance. The resampling procedure was iterated 10^5 times to generate an empirical distribution of total within-triad variances. The observed total within-triad variances for each semester were then compared to the empirical distribution, and the results are shown in Table 7.

Table 8
Correlation matrix between triad members' SOE-S post-test scores.

Participant groups	Cooperating teacher	Engineer
Engineer	$r = 0.15$ ($p = 0.25$)	
Student teacher	$r = 0.00$ ($p = 0.99$)	$r = -0.16$ ($p = 0.22$)

For each semester of data collection, the null hypothesis tested was that the observed total within-triad variance was equal to the mean total within-triad variance based on random assignment. The alternative hypothesis was that the observed total within-triad variance was *lower* than what was found by random assignment (a one-tailed test). The p-values associated with this hypothesis test are provided in Table 7. The probabilities of obtaining the observed within-triad variances all fall above an alpha level of 0.008 (adjusted from 0.05 to account for six separate tests), indicating that they are not significantly lower than what would be expected by chance. These results provide evidence that the triad structure did not significantly impact the distribution of SOE-S gain scores.

To further investigate the possible influence of the triad structure on our data, we calculated the correlations between SOE-S scores of the members of each triad. We investigated the correlations between post-test SOE-S scores because scores were most likely to be related after the triad members spent a semester working together. These correlations are shown in Table 8, and they show no evidence that triad members' SOE-S post-test scores were significantly related. The correlations between triad members' scores were all very small and not statistically significant. In sum, these results indicate that the triad structure of the project is not in any way visible in participants' SOE-S scores.

ANOVA Analysis of Data

Based on the analysis above, participants in the study could be considered practically independent, and an ANOVA model was used to analyze the SOE-S scores.

Table 9
Mean (with standard deviation) pre-test and post-test scores on SOE-S.

Participant group	Pre-test (of 35)	Post-test (of 35)
Student teacher (n = 59)	23.56 (6.04)	27.90 (5.77)
Cooperating teacher (n = 49)	24.78 (6.94)	28.12 (5.61)
Engineer (n = 28)	26.07 (5.30)	28.82 (5.48)

Table 9 gives mean SOE-S scores and standard deviations for each treatment group at the time of pre-test and post-test. A mixed between-within subjects analysis of variance was performed to compare these means. The homogeneity of inter-correlations assumption was met for these data using an alpha level of 0.001 (Pallant, 2013) (Box's test $M = 6.667$, $p = 0.369$). The homogeneity of variance assumption was also met (Levene's test for pre-test $F_{(2,133)} = 1.388$, $p = 0.253$; for post-test $F_{(2,133)} = 0.133$, $p = 0.875$).

No significant interaction was found between participant group and pre-test/post-test ($F_{(2,133)} = 0.853$, $p = 0.429$, partial $\eta^2 = 0.013$). A statistically significant main effect was found for pre-test/post-test ($F_{(1,133)} = 48.116$, $p < 0.001$, partial $\eta^2 = 0.266$), with an increase in scores from pre-test to post-test; the size of this effect was large (Cohen, 1988). Surprisingly, no statistically significant main effect was found for participant group ($F_{(2,133)} = 1.036$, $p = 0.358$, partial $\eta^2 = 0.015$). While engineers' SOE-S scores were apparently higher than those of the teachers, the evidence does not support a statistically significant difference in scores.

The results of the ANOVA analysis show a significant impact of the project on participants' SOE knowledge. The post-test scores for all groups show room for improvement, but the gains they made over a semester provide evidence of the project's efficacy in this knowledge domain. Because the SOE-S is based on misconception items, the gains in scores reflect a reduction in inaccurate views of the SOE. That is, on the post-test, participants were more likely to rate non-engineering activities (e.g., building houses) as *unimportant* for engineers.

Conclusions

The present study sought to develop a way to measure the SOE knowledge of participants in a professional development project, and to assess the extent to which their knowledge changed over the course of the project. The SOE-S developed for the study shows many useful characteristics as a measure of SOE knowledge. Using the SOE-S, participants were found to have improved their SOE knowledge over the course of the project. This finding held for all participant groups (student teachers, cooperating teachers, and engineers), with no differences found between the groups at pre-test or post-test. Potential mechanisms by which participants improved their SOE understanding during the project include: the workshop elements that addressed the nature of engineering; the presence of an engineer in each triads; and the act of planning, teaching, and communicating engineering to students (Arzi & White, 2008; Nixon, Hill, & Luft, 2017; Van Driel, Berry, & Meirink, 2014).

An assumption of the project in this study was that the engineers would communicate their nature of engineering expertise to the teachers. The results presented here, however, raise questions about that assumption. The SOE knowledge of the engineers was not significantly higher than that of the teachers, and all groups experienced similar gains on the SOE-S. Further, our analyses showed that the triad structure of the project had no significant influence on either SOE-S gain scores or post-test scores. Not only did the engineers not necessarily have greater expertise to share with their triad members, we have no evidence that the teachers' SOE knowledge became more similar to that of the engineer with whom they were teamed. What this indicates is that either all of the triads had extremely similar experiences or, more likely, that the presence of the engineers in the triads had a negligible impact on participants' SOE knowledge.

The fact that engineers did not score higher than the teachers on the SOE-S is interesting given that the engineers were expected to be experts in engineering. However, the engineers in the present study might not have been experts in the *nature of engineering* even if they did have expertise in the content and practices of engineering. One potential reason for this is that the engineers in this study were engineering graduate students, with limited industry experience. Of the 28 engineering graduate students in the present study, five had worked in industry for three or more years, four had an unknown amount of industry experience, and the remaining 19 had never worked full time in industry. Engineers with significant industry experience might be more knowledgeable about the nature of engineering, particularly the SOE. Another possibility is that engineers in general are not necessarily highly knowledgeable about the nature of engineering. Engineers do not generally need to understand the nature of engineering to do their work, and engineers might not regularly ponder the nature of their discipline, or do so accurately. A similar argument equally applies to scientists and the nature of science, and research has shown that while scientists tend to hold more accurate nature of science views than the public, they do hold some degree of inaccuracy (Glasson & Bentley, 2000; Schwartz & Lederman, 2008; Yore et al., 2004). Some studies have investigated how practicing engineers describe engineering work (e.g., Sheppard, Colby, Macatangay, & Sullivan, 2007; Trevelyan, 2007), or how engineering faculty define engineering (e.g., Pawley, 2009), but more work is needed in this area.

Future Use of the SOE-S

The SOE-S developed for use in the present study shows many promising characteristics as a useful way to assess the SOE construct. Given the ongoing interest in misconceptions about the SOE (e.g., Capobianco et al., 2011; Lachapelle & Cunningham, 2014; Lambert et al., 2007), the SOE-S is likely to be of value in future studies, especially those investigating the knowledge of teachers. Importantly, the SOE-S should not be regarded as a separate survey that can be administered in isolation. The seven SOE-S items were administered as part of a larger survey, and separating the SOE-S items would likely threaten their validity. In its current form, the SOE-S should be regarded as a method of scoring the "What is Engineering?" survey to assess the specific SOE dimension.

The SOE-S used in this study has value, but more work is needed to further develop a comprehensive SOE instrument. The items comprising the SOE-S used in the present study were all *negative* items, referring to activities that are *not* associated with engineering, which is limiting. The negative items were most informative because nearly all of the participants in the present study accurately rated the positive items as important for engineers, which is consistent with prior research (Cunningham et al., 2005, 2006, 2014; Lambert et al., 2007). The positive items used in the current study were uninformative for assessing growth in SOE knowledge, but different positive items might be developed that do not show this shortcoming. We must point out that because the SOE-S used in the present study was created using data from adults, not children, the reliability measures may not hold for younger populations. Similarly, the problems detected with certain survey items might not be present when administered to young students.

We are currently in the process of developing new items for a SOE survey that taps respondents' views on a greater range of activities. In line with the continuum shown in Figure 1, the items include activities that are very much like engineering (e.g., designing a computer chip), very much *not* like engineering (e.g., analyzing the themes of a novel), and also some that lie in the "blurry middle" (e.g., managing a construction team). As with the SOE-S used in this study, respondents rate each of these items on a 1–5 scale, but we have modified the prompt and the scale descriptions to be more in line with our framing of the SOE construct. Figure 3 provides an example of the pilot items that we are currently testing.

The items in Figure 3 show several promising characteristics. First, like the SOE-S, the items still allow us to detect whether respondents can accurately differentiate engineering work from the work of a technician or manual laborer. Second, the new items allow us to detect misconceptions that have not been previously reported but have emerged from our work with elementary teachers. We have found that many teachers are drawn to an overly broad definition of "engineers as problem solvers," with the result that some fail to distinguish which kinds of problems are engineering problems and which are not. "Planning a seating arrangement for a party," for instance, is certainly an act of problem solving, but ought to be located far on the "less like engineering" end of the continuum shown in Figure 1. Third, we have found that respondents use the full 1–5 Likert scale when rating the new set of items. This indicates the validity of the new items in terms of allowing respondents to express the range of their thinking about the SOE. However, a drawback of using items that lie at points all along the SOE continuum is that scoring the items in the middle of the continuum is challenging. We are currently developing a method of scoring the items in Figure 3 that gives a valid indicator of a respondent's SOE understanding.

Implications for Future Teacher Education Efforts

The elementary teachers participating in the present study improved their understanding of the SOE, but we also found considerable room for growth in our participants' knowledge. We also found evidence that the partnership between the teachers and the engineering graduate students did not necessarily result in a transfer of SOE expertise from the engineers to the teachers. Our observations and interactions with our participants indicate that conversations about the SOE, and about the nature of engineering in general, were rare within the triads. Although triad members spent a great deal of time together during the semester, that time was most commonly devoted to immediate tasks at hand (e.g., planning lessons, gathering materials) rather than to conversations about the nature of engineering. We therefore caution against assuming that partnerships between engineers and teachers will necessarily lead to teachers better understanding the nature of engineering. If partnership projects are to promote teachers' nature of engineering learning, then project leaders will need to prepare the engineers to have meaningful conversations about the nature of engineering, and will need to find ways to make sure that those conversations actually occur in the participating teams. Even then, immediate concerns about lesson preparation and logistics will have a tendency to dominate teachers' attention (Dewey, 1929) and the impacts of such interventions may be limited.

Accurately conveying the SOE is challenging because engineering is at once narrower than many teachers initially believe it to be (e.g., engineers are not technicians, nor are they fixers or operators of equipment) and also broader in certain respects (e.g., engineers do more than just technological design). Based on the present study, and our work with the project more generally, we can advance several recommendations regarding how to facilitate teachers' learning of the SOE.

For the activities below, rate each according to how much you associate it with the work of an engineer.

	Not at all associated with engineering work	Slightly associated with engineering work	Somewhat associated with engineering work	More associated with engineering work	Strongly associated with engineering work
Analyzing the themes of a novel	○	○	○	○	○
Developing a new theory of gravity	○	○	○	○	○
Managing a team that is developing a new plastic	○	○	○	○	○
Planning a seating arrangement for a party	○	○	○	○	○
Researching how different types of tire treads perform	○	○	○	○	○
Supervising the construction of a bridge	○	○	○	○	○
Assembling the components for a new mobile phone	○	○	○	○	○
Installing wiring in a building	○	○	○	○	○

Figure 3. New pilot SOE survey items.

We have found that many elementary teachers strongly associate engineering with problem solving. Although that association is not incorrect, defining engineering *as* problem solving risks developing SOE misconceptions because most problems are not engineering problems (Brophy et al., 2008; Davis, 1996; Pawley, 2009). We recommend addressing this issue with teachers directly by helping them understand the boundaries on the types of problems with which engineers engage. A productive way of communicating this is to convey that engineers work on technological design and development projects and that within those projects, engineers are concerned primarily with *technical* problems (Pleasants & Olson, 2019). Here, technical problems mean those relating to the functioning or performance of a technology. In contrast, nontechnical problems might include what makes a technology aesthetically appealing or how to successfully market it. To illustrate this, we suggest providing teachers with a specific example of a company that is developing a new technological product (e.g., a mobile phone). Using that example, we would identify which activities would likely be done by engineers, and which would be done by other individuals within the organization (e.g., managers, salespeople, industrial designers, marketers, etc.).

Differentiating engineering from related disciplines and professions is a particularly useful way to develop an understanding of the SOE, particularly in terms of identifying activities that are "less like engineering" (see Figure 1). Distinctions between the work of an engineer and the work of a machine operator or a maintenance worker provide a useful starting place. Comparisons can also be made between engineers and scientists (or engineers and architects; cf. Vermaas, Kroes, Light, & Moore, 2008), which can then lead to deeper discussions about the kinds of activities that are emphasized within each discipline (e.g., designing a technology versus investigating a natural phenomenon) as well as those that overlap (e.g., managing research activities, communicating results). Helping teachers understand such distinctions (and similarities) is greatly facilitated when practicing engineers and scientists can be recruited to describe and compare their experiences.

Improving teachers' knowledge of the SOE, and of other nature of engineering domains, is crucial if teachers are to accurately convey the engineering discipline to students. Yet we also emphasize that while being knowledgeable about the nature of engineering is necessary for accurately communicating it to students, it is not sufficient. Research on teaching the nature of science has consistently shown that even teachers who understand the nature of science do not necessarily teach it well to their students (Hacieminoglu, 2014; Lederman & Lederman, 2014; Schwartz & Lederman, 2002; Southerland, Gess-Newsome, & Johnston, 2003). A similar situation is likely to be the case for the nature of engineering, and additional research is needed to determine how to not only improve teachers' knowledge of the nature of engineering, but how to positively impact their teaching practices and student learning.

Acknowledgments

This material is based upon work supported by the National Science Foundation under grant # 1440446. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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Appendix: "What is Engineering?" Survey

What is an engineer?

What kinds of things does an engineer do? Select from the following list all examples of things that an engineer would do for his or her job.

- ☐ Develop better bubble gum
- ☐ Steer ships
- ☐ Install cable television
- ☐ Improve bandages
- ☐ Draw diagrams of new technologies
- ☐ Fix headlights on cars
- ☐ Fly airplanes
- ☐ Nail beams together for new houses
- ☐ Figure out how to package bottles so they don't break
- ☐ Drive trains
- ☐ Come up with ways to keep soup hot for a picnic
- ☐ Develop smaller cell phones
- ☐ Invent warmer kinds of cloth
- ☐ Drive motor boats
- ☐ Operate cranes
- ☐ Improve camera lenses
- ☐ Invent waterproof materials
- ☐ Design tools for surgery
- ☐ Improve a truck by putting new wheels on it
- ☐ Build chimneys out of bricks
- ☐ Design ways to clean polluted air
- ☐ Drive garbage trucks
- ☐ Figure out ways to explore the ocean
- ☐ Run machines for doctors and scientists
- ☐ Install wiring
- ☐ Fix computers
- ☐ Think about ways to clean the air
- ☐ Figure out what materials to use to make bridges
- ☐ Put shelves together in a store
- ☐ Design smaller kinds of computers
- ☐ Drive racecars on a racetrack
- ☐ Pour cement for new roads
- ☐ Measure how much weight materials can hold before they break
- ☐ Figure out how tall you can safely build towers
- ☐ Cut glass to make windows in buildings
- ☐ Pack furniture into boxes in a factory
- ☐ Repair cars

What is Engineering Survey developed by EiE®, Museum of Science, Boston. Used with permission.

How important are each of the following activities to the work of an engineer?

	Not Important		Sort of Important		Very Important
Using math					
Driving machines					
Using models					
Testing ideas					
Building houses					
Working as a team					
Doing experiments					
Solving problems					
Sketching ideas					
Repairing engines					
Using their creativity					
Understanding science					
Reading about inventions					
Using power tools to fix things					
Using power tools to build things					
Writing down their ideas					
Fixing broken things for other people					
Writing reports for other engineers					
Brainstorming different ideas					
Driving people from place to place					
Telling other people what they find out					