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Development and Validation of a Survey Instrument Targeting Teachers' Perceptions of the Scope of Engineering

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Keywords

perceptions of engineering, survey, instrument, teacher education

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Around the world, pre-college teachers are increasingly being called upon to address engineering, often as part of science instruction. Teachers are typically tasked with engaging students in authentic engineering design activities to promote students' development of design practices while deepening their knowledge of relevant science concepts. Planning and implementing engineering experiences that authentically reflect the field require that teachers hold accurate perceptions of what engineering is, how it works, and how it is related to yet distinct from science. As teacher education and research efforts in this area grow, there is a need for high-quality instruments that elicit key aspects of how teachers think about engineering. However, few instruments are currently available, and each has significant limitations. This study presents a new instrument, the Scope of Engineering Survey, that addresses a critical dimension of teachers' perceptions of engineering. The "scope of engineering" refers to the kinds of projects and activities that do and do not fall under the umbrella of engineering work. Individuals who hold accurate views on the scope of engineering understand the breadth of engineering work, but can also differentiate engineering work from that of technicians or scientists. This is essential for teachers, because holding accurate views on the scope of engineering places them in a far better position to design and implement authentic engineering activities in their classrooms. This study describes how the Scope of Engineering Survey was developed, provides evidence of the validity and reliability of the instrument, and gives recommendations for its future uses. Results from a large-scale field test are reported and baseline statistics are provided for key survey measures.

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Introduction

Engineering is becoming increasingly common as part of pre-college education, especially as a growing part of science instruction. In the United States, the introduction of the *Next Generation Science Standards* (NGSS; NGSS Lead States, 2013), which places emphasis on engineering practices alongside those of science, has led to the inclusion of engineering in many state science standards (Moore et al., 2015). Bringing engineering into the pre-college classroom typically involves engaging students in engineering design tasks that require students to apply knowledge of math and science while utilizing engineering practices (American Society for Engineering Education [ASEE], 2020; Brophy et al., 2008; Cunningham & Kelly, 2017; National Academy of Engineering [NAE] & National Research Council [NRC], 2009). When implementing engineering design activities in the classroom, the extent to which they authentically reflect the engineering field is of crucial importance (Whitworth & Wheeler, 2017). As stated in the *Framework for P-12 Engineering Learning*:

Therefore, it is necessary to continually evaluate whether engineering-related instructional activities are accurately depicted to children in a manner that is authentic to engineering. If not, we may expose children to something *called* engineering, which they dislike and therefore never explore the actual field. Concurrently, we may mislead or underprepare them by providing activities that they do enjoy but which have little relation to authentic engineering practice. (ASEE, 2020, p. 7)

To design and implement engineering instruction that achieves authenticity, teachers must hold accurate views about what engineering is, what engineers do, and how engineering is related to yet distinct from science (NAE & NRC, 2009; Park et al., 2020; Pleasants 2020; Pleasants & Olson, 2019a). A body of research is therefore emerging that examines teachers' perceptions of engineering and how teacher education might promote more accurate perceptions. Those studies have identified some common misunderstandings held by teachers and also point to some ways in which more accurate notions might be developed (Antink-Meyer & Meyer, 2016; Berland et al., 2014; Cunningham et al., 2006; Deniz et al., 2020; Ergün & Kiyıcı, 2019; Hammack & Ivey, 2017; Hammack et al., 2020; Pleasants & Olson, 2019a; Pleasants et al., 2020). However, an impediment in furthering those lines of inquiry is the paucity of available instruments. The handful of instruments that exist to investigate teachers' perceptions of engineering (e.g., Cunningham et al., 2006; Knight & Cunningham, 2004) have significant limitations (Pleasants & Olson, 2019b; Reinisch et al., 2017), and many researchers therefore rely on *ad hoc* methods of investigating teachers' views (e.g., Antink-Meyer & Meyer, 2016).

Ideally, a range of instruments ought to exist that are attuned to various data collection needs, including different instrument structures (e.g., interview protocols, open-ended survey items, forced-choice survey items). The goal of the present work is to contribute one such instrument to this area of research. The Scope of Engineering Survey (SOES) presented here is a quantitative instrument that is intended for use with pre-service and in-service teachers. It aims to elicit aspects of teachers' perceptions of engineering that are relevant for instructional practice, thus making it a valuable tool for teacher educators as well as researchers. This paper describes the motivation and theoretical underpinnings of the SOES, the design and development process used to create and refine the instrument, evidence of its reliability and validity, and recommendations for its use and interpretation. The research question guiding the present work is:

To what extent does the SOES provide valid and reliable information regarding the targeted aspects of pre-college teachers' perceptions of engineering?

The Current State of Instruments

Research into teachers' perceptions of engineering is growing, but the nascency of this area of inquiry means the choice of instruments is limited. Perhaps the most widely used instrument to assess students' and teachers' perceptions of engineering is the Draw-An-Engineer-Test (DAET; Knight & Cunningham, 2004). Based on the Draw-A-Scientist-Test (Chambers, 1983), the DAET asks respondents to "Draw an Engineer Doing Engineering Work" and provides space for the respondent to do so. Different versions of the DAET have been developed that retain that core task and layer on additional prompts for respondents to describe and explain their drawings (cf. Capobianco et al., 2011; Thomas et al., 2020; Weber et al., 2011). Although originally designed for use with students, the DAET has also been used with teachers (e.g., Ergün & Kiyıcı, 2019; Hammack et al., 2020; Lopez et al., 2012; Pleasants et al., 2020).

The DAET can provide valuable insight into students' and teachers' thinking about what engineering is and what engineers do, but there are limitations inherent in the instrument. One is the analytical difficulty in interpreting responses to such an open-ended task. Multiple coding systems have been developed to analyze DAET responses (e.g., Thomas et al., 2020; Weber et al., 2011), but those systems do not necessarily chart a clear course for drawing inferences about respondents' perceptions of engineering as a field. The system developed by Weber et al. (2011), for instance, includes codes for physical objects present, the location, and level of detail of the drawing. Descriptive codes can help summarize DAET data but are difficult to connect to respondents' broader views of engineering. More generally, researchers have questioned the validity of making inferences about respondents' views based on the drawings they produce. Minor changes to the format of drawing tasks have been found to influence responses in unexpected ways (Losh et al., 2008; Reinisch et al., 2017). In addition, the decision-making processes that underlie what respondents choose to draw are more complex than they are often assumed to be (Finson, 2002, 2009; Reinisch et al., 2017). In short, making claims about an individual's thinking about engineering based on a single drawing, even when accompanied by written descriptions, is beset by difficulties.

One way to avoid the interpretive challenges of an instrument such as the DAET is to use methods that produce more in-depth and expansive responses. Semi-structured interviews, for instance, have been used to explore teachers'

understanding of the nature of engineering work (e.g., Berland et al., 2014). Recently, Kaya (2020) and colleagues (Deniz et al., 2020) developed the Views on Nature of Engineering (VNOE) instrument, modeled on the Views on Nature of Science (VNOS; Lederman et al., 2002) that is frequently used to assess views on the nature of science. The VNOE includes a set of open-ended written items that are intended to elicit respondents' views on a range of dimensions. Like the VNOS, Kaya (2020) recommends conducting follow-up interviews with respondents to clarify their views. For each dimension, responses are holistically scored using rubric categories that range from "uninformed" to "fully informed." The detailed data generated by the VNOE provide a more detailed view of how respondents think about engineering than the DAET. A drawback, however, is that open-ended instruments that involve participant interviews are necessarily time-consuming both to administer and to interpret, making them impractical for certain settings.

Surveys featuring closed-choice items offer advantages in terms of ease of implementation and the generation of quantitative data that are amenable to statistical modeling. One widely used survey that targets respondents' perceptions of engineering is the What is Engineering? (WiE) survey developed by Cunningham et al. (2005, 2006), which has been used with both students and teachers (e.g., Hammack & Ivey, 2017). Although the WiE survey can provide useful insights, prior research has identified significant limitations with the instrument. Pleasants and Olson (2019b) found that while some of the survey items functioned as intended, a substantial number of respondents interpreted survey questions in ways that undermined the instrument's validity. The survey items were also not grounded in a cohesive conceptual framework. An alternative is the Design, Engineering, and Technology (DET) survey, developed by Yaşar et al. (2006) and used by later researchers (e.g., Hsu et al., 2011), which includes items that address teacher familiarity and confidence with teaching engineering as well as several items that target teachers' perceptions of engineers. The perception items include ones that elicit teachers' views on the characteristics of engineers (e.g., the extent to which they do well in science and math or have communication skills), but also include several that ask teachers to rate their agreement with items such as, "Most people feel that female students can do well in DET" (Yaşar et al., 2006, p. 209). Evidence is provided for the reliability of the DET survey, but the authors do not describe any clear framework for how the perception items were chosen; that lack of framework is reflected by the wide variety of items that are included among the perception items. Individual items on the DET survey might be informative, but it is limited in its ability to provide deeper insights into teachers' thinking about engineers and engineering.

In sum, there is a substantial need for the development of additional instruments that target perceptions of engineering. The SOES, presented in this study, addresses several of the methodological limitations of extant survey measures while also being more firmly grounded in a theoretical framework (NRC, 2001). As a quantitative measure, it enables the collection of data from a large number of participants and is amenable to statistical analysis. From the outset, teachers were the target population for the instrument; as described above, several existing instruments were designed for students and were only subsequently used with teachers. Finally, an important consideration is that the SOES was not modeled on a pre-existing instrument from science education (e.g., the Draw-A-Scientist-Test or the VNOS). Instead, it was built on a theoretical framework (NRC, 2001) rooted in the philosophy of engineering and the specific needs of pre-college teachers of engineering.

Theoretical Framework for the SOES

The goal of the SOES is to provide insight into teachers' perceptions of engineering that are useful for teacher educators and researchers. "Perceptions of engineering," however, is a broad construct that could include views on the kinds of work that engineers do (Cunningham et al., 2006; Pleasants & Olson, 2019b), the ways that engineers engage in their work (Berland et al., 2014; Kaya, 2020), the characteristics and traits of engineers (Yaşar et al., 2006), or the kinds of people who can be engineers (Yaşar et al., 2006). The instrument developed in the present work does not aim to address all of these aspects, but instead focuses more narrowly on the "scope of engineering," which is conceptualized as a question of demarcation: what kinds of activities fall under the umbrella of "engineering," and which do not (Pleasants & Olson, 2019a, 2019b). The rationale for targeting this particular construct, and specifically *teachers'* views of it, is its relevance for instructional practice. Of central importance to classroom engineering activities is that they provide students with *authentic* engineering experiences that accurately reflect the discipline (ASEE, 2020). Teachers who hold misunderstandings about the scope of engineering can easily, and unintentionally, implement activities that are engineering in name only (Guzey & Aranda, 2017; Whitworth & Wheeler, 2017). For example, a teacher might mistakenly view an arts-and-crafts activity as engineering based on an inaccurate view of the scope of engineering, and though the activity might be engaging for students, labeling it as engineering is problematic (ASEE, 2020). In contrast, teachers who hold accurate views regarding the scope of engineering are in a much better position to design and implement *authentic* engineering instruction in their classrooms.

The conceptualization of the scope of engineering presented here is rooted in scholarly investigations of the engineering disciplines, particularly the philosophy of engineering. At the same time, the construct is defined in a way that is sensitive to the needs of pre-college teachers. While teachers require accurate conceptions of the scope of engineering in order to make informed classroom decisions, they need not be well-versed in all of the details and complexities that are of interest to philosophers. A similar logic applies to teachers of science: science teachers need a working understanding of what separates science from pseudoscience, but they do not necessarily need to concern themselves with the thorny philosophical issues raised by attempts to cleanly separate the two. Thus, in the description of the scope of engineering construct that follows, care is taken to simultaneously leverage scholarly accounts of the engineering field while also taking a practical, teacher-oriented perspective.

Defining the Scope of Engineering

Engineering is fundamentally a technological activity, but not all technological activities are included within the scope of engineering; for instance, the work of a car mechanic or a construction worker is not generally regarded as engineering. Educational documents typically make this distinction by defining engineering as technological design and development rather than fabrication, repair, or use (ASEE, 2020; International Technology and Engineering Educators Association, 2020; NAE & NRC, 2009; NRC, 2012). Thus, an engineer might draw up the plans for an electrical system in a building but will not be the one to physically install that system or repair it when components break. Philosophers, too, also highlight the distinction between the work of technological designer versus the technician or craftsperson (Dym & Brown, 2012; Kroes, 2012; Mitcham, 1994).

Although the above cases might be clear enough, more complicated situations indicate that a straightforward definition of engineering as “technological design and development” cannot handle all demarcation issues. Consider the long and sustained debate around the question of whether software engineering is deserving of the “engineering” label, or whether it should instead be called programming or software development (cf. Bogost, 2015; Davis, 1996; Wayne, 2021). Developing software seems to align with the basic definition of engineering in that programmers are clearly engaging in technological design. Individuals who have been trained in a more traditional engineering field and later move into programming often see their work as engineering (Wayne, 2021). However, software development occurs outside of formal engineering institutions, which some argue is an essential criterion for inclusion (Bogost, 2015; Davis, 1996). More importantly, software development covers a wide range of activities, including some that appear “crafts-like” (e.g., developing a website), some that resemble repair work (e.g., debugging code), and others that are more akin to more traditional notions of design (e.g., designing high-level security systems) (Wayne, 2021).

The question of whether software engineering is “true” engineering will not be answered here. The example is raised primarily to illustrate that a simple definition of engineering is unlikely to satisfactorily address the question of demarcation. In fact, stating a definition or putting forward a set of criteria for demarcation that can handle a wide variety of cases tends to be extremely difficult, if not impossible. This has been well established within the philosophy of science, where the problem of demarcation proved intractable despite years of concerted effort (cf. Laudan, 1983; Pigliucci, 2013). One reason why a clear distinction between engineering and non-engineering is so elusive is that various subfields of engineering exist, each of which have unique ways of engaging in technological development (Banse & Grunwald, 2009; Daly et al., 2012). Furthermore, while technological design is usually regarded as the “core” of engineering practice (Brophy et al., 2008; Dym & Brown, 2012; Kroes, 2009, 2012; Mitcham & Schatzberg, 2009), engineers also engage in a variety of other related activities, such as investigating technological failures, researching technological systems, and analyzing performance (Banse & Grunwald, 2009; Bucciarelli, 2009; Figueiredo, 2008; Trevelyan, 2007; Vincenti, 1990). Such activities ought not be excluded from the scope of engineering, but establishing a simple definition of engineering that accounts for that variety while avoiding being overly permissive is likely not possible (Davis, 1996; Pawley, 2009).

One productive way out of this conceptual thicket is to conceptualize the scope of engineering as a continuum rather than as a binary (Pleasants & Olson, 2019b). In this approach, there does not necessarily exist a clear point of separation between what is and is not engineering; rather, the question is one of a “strength of association” or a Wittgensteinian “family resemblance” (Wittgenstein, 1953). One end of the continuum would include canonical examples from well-established fields of engineering (e.g., the design of mechanical or aeronautical systems). Those examples are not linked together by definitional criteria, but rather by a set of characteristics that, while not universally shared, represent common features. A non-exhaustive list of characteristics that have been emphasized in the literature include: a focus on the development of the functional (rather than aesthetic) aspects of technological systems (Kroes, 2012; Mitcham, 1994; Pawley, 2009); the use of theoretical knowledge from the natural sciences and mathematics, in addition to knowledge bases specific to engineering and technology (Bucciarelli, 1994, 2009; Figueiredo, 2008; Houkes, 2009; Kroes, 1995, 2012; Meijers & de Vries, 2009; Vincenti, 1990); attention to contextual details, including a sensitivity to cost and contexts of use (Figueiredo, 2008;

Kroes, 2009; Vermaas et al., 2008; Vincenti, 1990); and attention to professional standards, including ethics and relevant regulations (Bucciarelli, 1994; Davis, 1996; Dym & Brown, 2012; Robison, 2013).

At the other end of the continuum are unambiguous non-examples of engineering that share few, if any, of the core characteristics of engineering (e.g., giving a religious sermon, interpreting a literary text). Any activity, even unambiguous non-examples, might share at least *some* characteristics with engineering. Preparing a stock portfolio, for instance, involves mathematical reasoning just as engineering does. Yet the overlap is limited, and the association is sufficiently weak that making investment choices is very unlikely to be mistaken for engineering (or vice versa). In the middle of the continuum lies a broad spectrum of activities, some of which show strong connections to engineering despite not necessarily demonstrating all of the core characteristics. An individual who is developing quality assurance methods for a manufactured product, for instance, is not directly engaging in technological design or development. Yet this is an activity that is not far removed from the core activity of technological development and would therefore be strongly associated with engineering; indeed, it as an activity often undertaken by engineers within certain subdisciplines (Banse & Grunwald, 2009). The case of software development would also occupy an intermediate place on the continuum, its proximity toward the “engineering” end depending on the specific nature of the programming task.

An important question is where scientific inquiry ought to be placed on the continuum. This is a particularly crucial issue for science teachers who are including engineering as part of their instruction, as they will need to attend to the ways in which engineering is distinct from science while also acknowledging their similarities (McComas & Burgin, 2020; Pleasants, 2020). At the level of practice, science and engineering utilize many overlapping methods, techniques, and knowledge bases (Hansson, 2007; Houkes, 2009; Figueiredo, 2008). Complicating matters is the existence of the “engineering sciences,” a collection of research fields that are differentiated from traditional natural sciences (e.g., biology or chemistry) primarily in that they take technological systems as the objects of study rather than the natural world (Banse & Grunwald, 2009; Bucciarelli, 2009; Mitcham & Schatzberg, 2009). Furthermore, in complex research and development projects that involve multidisciplinary teams, distinctions between scientific and engineering activities can become blurred (Tala, 2013; Vincenti, 1990).

Despite the existence of activities and fields that straddle engineering and science, there are nevertheless more “pure” forms of scientific inquiry that can be more clearly distinguished from engineering. Pure science differs from engineering in terms of its overarching goals and purposes. Unlike engineering, pure science is not overtly oriented toward specific technological applications, but rather is aimed at generating context-general, theoretical knowledge that can be used to explain natural phenomena and processes. To the extent that engineering is concerned with developing knowledge, that knowledge has a different character in that it is knowledge directed toward how to accomplish certain practical aims or achieve certain outcomes (Kroes, 1995; Meijers & de Vries, 2009; Mitcham, 1994; Vincenti, 1990). A technological design, for instance, can be viewed as knowledge of how to create an artificial system to achieve a specified function within a certain set of parameters (Kroes, 2012). For classroom teachers, conceptualizing how the purer forms of science stand in relation to engineering is what is most practically relevant. At the pre-college level, most teachers will not be addressing concepts from the engineering sciences, instead focusing on natural science concepts derived from pure scientific investigation. Although it is important to acknowledge the shared characteristics that exist, maintaining a separation between science and engineering in the classroom supports the authenticity of activities that are labeled “science” or “engineering” (McComas & Burgin, 2020; Pleasants, 2020).

To make the conceptualization of the scope of engineering more concrete, Figure 1 gives two examples, one of which represents a more informed understanding and the other of which represents a less informed understanding. In providing an example of a “better informed” continuum, the intent is not to make definitive claims about where certain activities ought to be placed on such a continuum. The activities could be placed somewhat differently from how they are presented in Figure 1 and nevertheless represent reasonably informed views. For instance, it is possible that studying animal behavior ought to be more strongly associated with engineering than planning a carpentry project. Or perhaps the space between studying the performance of materials and designing an electrical system ought to be smaller. On the other hand, the “less informed” continuum demonstrates several clearly problematic views. Planning a carpentry project, for instance, ought not to be the activity most closely associated with engineering.

Design and Development of the SOES

Having laid the conceptual foundation for the scope of engineering construct, the following sections detail the development process for the SOES and provide evidence of the reliability and validity of the data produced by the instrument. Guiding the development process were the following overarching design goals:

1. Teachers (pre-service and in-service) are the target population for the SOES.
2. The SOES should produce primarily quantitative data; qualitative items should support quantitative interpretations.
3. The SOES should be capable of being completed in a short period of time (~15 minutes).

Figure 1. Two contrasting examples of a scope of engineering continuum.

The survey targets teachers because, as discussed above, the scope of engineering is particularly crucial for teachers to understand if they are to effectively incorporate engineering into their classrooms. The other design decisions were made out of a concern for practicality and usability. To make the SOES practical for use with large numbers of respondents and non-research contexts (e.g., a methods course), a format was selected that would reduce the time investment required for both generating and interpreting the data. Like all design decisions, the choices above come with certain trade-offs, and the limitations of the SOES are addressed in the Discussion section.

The development of the SOES occurred in two main design phases, each of which targeted different design decisions and called for different types of data collection and analysis. Figure 2 summarizes the different development phases, and the final version of the SOES that was used in the large-scale field test is provided in the Appendix. The decisions made during each phase of design are described in the following sections. The discussion of the first design phase is relatively brief, focusing on the rationales underlying key design decisions made rather than detailed discussions of all of the early forms and iterations of the SOES. The discussion of the second design phase is more extensive and detailed, because the evidence collected during that phase establishes the validity and reliability of the final form of the SOES.

Design Phase 1

To provide construct validity for the SOES, the initial design of the instrument was driven by the conceptualization of the scope of engineering described above. Operating on a continuum model for the scope of engineering, the core objective for the SOES was to elicit how respondents thought about different activities in relation to that continuum. A task was therefore

Figure 2. Development process for the SOES.

developed that asked respondents to express how strongly they associated different activities with engineering. Hereafter, this task is referred to as the “main survey task,” and can be seen in its final version in the Appendix. Various forms of the SOES, including its final version, also included open-ended questions that were used in support of the main survey task.

The main objective for the first phase of the SOES design was to make data-informed decisions about the form that the main survey task should take. Those decisions included choices about the wording of the task prompt, selection of the task format, and selection of the set of task items. To inform those decisions, an initial version of the SOES was prepared for use in a small-scale field test. The preparation of the initial version is described below, followed by a discussion of the initial field test results.

Main Survey Task Format

Two question formats were considered for the main survey task: a Likert format and a ranking format. Both formats were included in the version of the SOES used in the initial field test. In the Likert format, participants were shown 21 different activities on 5-point scale and asked to “rate each according to how much you associate it with the work of an engineer.” The scale points were labeled to facilitate consistent interpretations of the task (Alwin, 2007), beginning with “not at all associated with engineering” to “strongly associated with engineering.”

In the ranking format, participants were asked to consider a set of activities and rank them from “most strongly associated with engineering” to “least strongly associated with engineering.” While a ranking task allows respondents to express more nuance because they are not limited a set number of scale points, the tasks are often more difficult to complete, especially when the number of items becomes large (Krosnick, 1999; Ovadia, 2004). In light of that, the ranking task used a subset of 13 items drawn from the 21 items used in the Likert format.

Main Survey Task Items

An initial set of 21 task items was generated with the intent of representing a broad range of the scope of engineering continuum. Activities were included that were considered unambiguous non-examples of engineering (e.g., analyzing the themes of a novel) as well as unambiguous examples of engineering design (e.g., creating the plans for a new computer chip). Also included were activities associated with basic science (e.g., modeling the migration pattern of birds), the engineering sciences (e.g., developing a theory of how airplane wings work), and activities often erroneously associated with engineering (e.g., installing wiring in a building).

Table 1
Questions used during phase 1 field test.

Survey questions(In order seen by respondent)	Task description/rationale
1. What is an engineer?	Orient respondent to the survey; not intended for analysis.
2. Main survey task: Likert format	Respondent rates (from 1 to 5) 21 different activities in terms of how strongly they associate each activity with engineering.
3. How did you decide which items to rate as “strongly associated with engineering”?	Provide information about respondents’ thought processes as they rated the items. Provides evidence of the validity of the survey task. Also provides information about respondents’ thinking that is potentially valuable in its own right.
4. How did you decide which items to rate as “somewhat associated with engineering”?	
5. How did you decide which items to rate as “not at all associated with engineering”?	
6. Main survey task: ranking format	Respondent ranks 13 different activities from most strongly associated with engineering to least associated with engineering.
7. You just completed a Rating task and a Ranking task that had similar sets of activities. Which task do you think better allowed you to express your thinking about engineering?	Respondent provides feedback on the two different formats.
8. Explain why you preferred one of the tasks over the other.	

Additional Questions

In addition to the main survey task, several open-ended questions were used to elicit further information about respondents’ reasoning as well as feedback about the survey itself. Table 1 describes all of the questions used on the initial survey as well as how and why each was included.

Design Phase 1—Field Test

The initial draft of the survey was field-tested using 79 respondents who were participants in a professional development project aimed at incorporating engineering into elementary science classrooms (see Pleasants et al. (2020) for a description of the project). Respondents included 34 elementary student teachers, 35 elementary classroom teachers, and 10 graduate students in engineering. The survey was administered electronically using Qualtrics. Follow-up cognitive interviews (Peterson et al., 2017; Willis, 2004) were conducted with 10 respondents (4 student teachers, 4 classroom teachers, and 2 engineering graduate students were randomly chosen from within the three participant groups), during which respondents were presented with their survey responses and asked to describe their thought process for both formats of the main survey task. The cognitive interviews provided additional evidence regarding how the respondents interpreted the survey tasks.

Phase 1 Field Test Results

Likert Versus Ranking Participants’ responses on the two forms of the main survey task were first compared to see if the format had any effect on how participants expressed their thinking. For each of the items that appeared on both tasks, the average Likert rating and the average rank position were calculated across all participants. A correlation between average rating and average ranking was then calculated for those items and found to be very high: $r = 0.97$. In general, therefore, the format did not significantly affect how participants expressed their thinking about the different main survey task items. On average, items that were rated highly using the Likert scale were also assigned high ranks. In addition, when participants were asked which format allowed them to better express their ideas, no overall preference was found, with 51% preferring the ranking task, 46% preferring the rating task, and 3% indicating no preference. Based on those findings, the Likert format was selected for future iterations of the survey. The main advantage of the rating format is that it allows for a larger number of activities to be included on the instrument. Items added to a Likert task make the survey longer without adding much complexity; in contrast, adding items to a ranking task can cause the task to become unmanageable for participants to complete (Ovadia, 2004).

Use of Full Likert Scale Given the choice to use the Likert format for the main rating task, there was a need to more deeply investigate participants’ use of the rating scale. The items on the main survey task were selected to represent a broad range of the scope of engineering continuum, and those items should therefore encourage respondents to use the full range of the Likert scale. Use of the full rating scale across participants is desirable because it means that they are using the end points of the scale to anchor their judgements in similar ways (Tourangeau & Bradburn, 2010). Of the 79 field test responses, 59 of them (75%) used the full rating scale, 18 (23%) used only four of the five points of the scale, and the remaining 2 (2%) used only one of the points on the scale (i.e., they rated all activities the same). Of the 18 respondents who

used *nearly* the full rating scale, half did not use the highest rating and the other half did not use the lowest one. Overall, these results indicate that the set of rating task items reasonably represented a broad range of the scope of engineering continuum; however, the addition of more unambiguous examples and non-examples of engineering would likely increase the use of the full Likert scale.

Indicators of Main Survey Task Validity The open-ended items on the SOES asked participants to give justifications for their responses, and those justifications were examined for evidence that the main survey task was being interpreted as intended. The rationales expressed by participants varied widely, but overall indicated that the task was working as intended. All participants indicated that they judged the task items based on their internal conceptualization of what makes something “engineering.” For example, a common rationale given for assigning high ratings was “if there was some kind of problem that needed to be solved.” Many participants indicated that they gave low ratings to activities that “did not require an understanding or application of science.” The cognitive interviews further confirmed those findings. All of the participants that were interviewed communicated that they completed the tasks by evaluating each task item with respect to certain characteristics and qualities that they associated with engineering.

For the purposes of the field test, participants’ rationales were not analyzed in detail; the fact that participants provided the intended kinds of rationales was sufficient for the goal of supporting the validity of the main survey task. However, it was noted that participants’ rationales were themselves an interesting and worthwhile data source. Future versions of the SOES therefore retained the open-ended questions asking for participants’ rationales to preserve a potentially rich source of data.

Design Phase 2

The second design phase focused on refining the set of items used on the main survey task. As described above, the initial pool of activities was primarily intended to reflect a wide range of the scope of engineering continuum. The field test results indicated the need for additional items to better reflect that range. In addition to expanding the set of items, an important consideration during this phase of development was how responses to the rating task would be interpreted.

Respondents’ ratings of individual items are potentially informative, but to facilitate interpretations, a revised set of task items was structured around *categories* of activities that were identified as being of particular interest. Previous investigations have indicated that K-12 teachers and students erroneously associate repair and construction work with engineering (Capobianco et al., 2011; Cunningham et al., 2005, 2006; Montfort et al., 2013; Pleasants & Olson, 2019b). A category was therefore constructed to include items describing the work of a *Technician* rather than an engineer. A category for *Natural Science* items was also created on account of its relevance within the theoretical framework and prior findings that K-12 teachers and students have difficulty differentiating science and engineering (Antink-Meyer & Meyer, 2016; Deniz et al., 2020; Karatas et al., 2011). A category of *Non-Technological* items was created to represent the “not at all associated” end of the scope of engineering continuum, and a category of *Technological Design & Development* items was created to represent the “strongly associated” end of the continuum. One final category included activities associated with the engineering sciences rather than technological design; that category was labeled *Technological Analysis*.

By structuring items around categories, the intended method of interpreting SOES responses is to calculate each respondent’s average rating across the activities within each category to produce a “category rating.” The category rating represents the extent to which the respondent associates that category of activities with engineering. Differences between category ratings can be particularly informative. For instance, if a respondent assigns low ratings to the Technician category but high ratings to the Technological Design & Development, then that provides evidence that the respondent differentiates the work of a technician from that of an engineer. Such a differentiation is consistent with an accurate view of the scope of engineering. In contrast, a respondent with very similar category ratings for Technician and Technological Design & Development would be demonstrating an inaccurate view that fails to differentiate engineers and technicians.

Activity Category Development

The goal during item development was to create five items per category with high internal reliability (DeVellis, 2003) as well as content and construct validity (American Educational Research Association, American Psychological Association, & National Council on Measurements in Education [AERA, APA, & NCME], 2014). In concrete terms, the items within each category needed to be associated with one another and clearly tied to only the conceptual category to which they belong. Furthermore, all of the developed items needed to be sufficiently unambiguous such that respondents generally interpreted the items in non-idiosyncratic ways.

To develop items that met those objectives, an initial set of five items were developed for each category, using the theoretical framework to provide clarity around the meaning of each category. To establish the content validity, the items

Table 2
Activity categories and associated items.

Activity category	Items
Non-Technological	Analyzing the themes of a novel Planning a seating arrangement for a party Trying out a new recipe in a kitchen at home Taking a photograph of a landscape to hang on an office wall Designing the graphics that will appear on a product's package
Technician	Installing wiring in a building Assembling a laptop computer using a set of instructions Performing the maintenance on a sewer system Repairing a broken mobile phone Operating a crane at a construction site
Natural Science	Developing a new theory of gravity Categorizing different types of galaxies using a telescope Studying the migration patterns of birds Observing volcanoes to figure out what causes them to erupt Studying the life cycles of different insects
Technological Analysis	Calculating the environmental impact of a new factory Determining how the composition of cement affects performance Analyzing the performance of a city's highway system Determining why a piece of equipment did not operate correctly Researching how different types of tire treads perform
Technological Design & Development	Creating the plans for a new computer chip Developing a new type of siding to use on houses Finding ways to improve the durability of a prosthetic limb Finding ways to make football helmets safer Designing the production process for a chemical

along with descriptions of the categories were sent to a group of expert reviewers for feedback. Reviewers included faculty in engineering as well as faculty with expertise in engineering from science, science education, and philosophy. Reviewers were asked to provide feedback on the clarity of the items, the conceptual links between item and category, and suggest additional items that they felt should be included in each category. Feedback from the expert reviewers was used to create a revised set of five items for each of the identified categories, shown in Table 2.

Design Phase 2—Field Test

After developing the set of items in Table 2, a large-scale field test of the SOES was conducted to provide evidence of the reliability and validity of the items and categories that were developed. In addition, the field test was used to establish baseline data against which future applications of the SOES could be compared. It also provided an opportunity to evaluate the SOES in terms of its design goals—particularly whether the amount of time participants took to complete the survey was within the desired range. The SOES used during this field test is included in the Appendix.

To conduct the field test, the SOES was administered to 249 pre-service elementary and secondary teachers from four different institutions located in four different regions in the United States, including the Northeast, Midwest, Gulf Coast, and Mountain West. Of these, 78 were elementary education students enrolled in a course on science and engineering practices; 49 were students in an elementary science methods course; 10 were students in a secondary science methods course; and 112 were students taking a science content course geared towards elementary education students. The SOES was administered during spring of 2020, fall of 2020, and spring of 2021. Students completed the survey as part of normal classroom instruction and were assigned to complete the survey outside of class time. Only students who gave consent for their responses to be used in the field test research were included. The survey was assigned to students either at the beginning of the course or immediately preceding explicit instruction on engineering. The SOES was administered using Qualtrics survey software. Important to note is that the field test was *not* conducted to make any comparisons between the different groups of students who were included in the sample. Rather, the intention was simply to gather a large number of responses from a range of individuals within the intended population to gather information about the functioning of the SOES.

The field test sample was skewed toward pre-service elementary teachers for accessibility reasons; simply, at most institutions there are far more elementary education students than there are secondary science education students.

Also important to note regarding the sample is that the SOES is intended for use with pre-service and in-service teachers. Pre-service teachers were the focus here because they were a more accessible population in terms of obtaining a large number of responses. Future field tests should therefore confirm that the findings obtained here are similar across different populations. Although the field test sample had limitations, it also had a number of strengths. By drawing participants from multiple institutions and from multiple types of courses, the sample represents students with a relatively large range of backgrounds and preparation.

A primary analytical objective of the field test was to examine whether the 25 activities in the main survey task can indeed be grouped into the five categories used to generate them. The category structure is important because analyzing responses at the category level, rather than the level of individual items, facilitates the interpretation of SOES data. Two sets of analyses were conducted to examine the category structure of the main survey task items. First, a factor analysis was conducted. Factor analysis enables the reduction of a large number of variables to a smaller number of distinct factors (Tabachnick & Fidell, 2013). If the five activity categories represent a good way to structure the activities, then a factor analysis should return a simple five-factor structure, corresponding to each of the five categories. Second, internal reliability statistics were calculated for each category, operating on the assumption that each category is a separate scale composed of the five associated items.

The field test also provided an opportunity to collect further evidence regarding the validity of the activity categories. A question was added to the field-tested version of the SOES for use as a cross-reference of the Natural Science category. That category was regarded as particularly important because differentiating science and engineering is especially relevant for teachers who are teaching the two fields in the same classroom. After respondents completed the main survey task, they answered the question, "In your understanding, how similar/different do you think science and engineering are?" Respondents then selected from a list of six options, ranging from "Science and engineering are essentially the same" to "Science and engineering are completely different." If the main rating task functions as intended, then respondents' ratings for the Natural Science category should be associated with their answers to that question. More specifically, respondents who indicate that they view science and engineering as being essentially the same should also give high ratings of association to the activities in the Natural Science category. Respondents who view science and engineering as very different should likewise give low ratings to the activities in the Natural Science category.

Phase 2 Field Test Results

Summary Statistics Table 3 provides summary statistics for each of the items on the main survey task, based on the 249 responses gathered during the field test. A rating of "1" corresponds to "not at all associated with engineering" whereas a rating of "5" corresponds to "strongly associated with engineering."

As discussed above, one goal for the set of items on the main survey task was for respondents to utilize the full range of the rating scale. For the version of the SOES used in the design phase 2 field test, 83% respondents used the full range of the rating scale, 14% did not use either the highest or lowest scale point, and the remaining 3% used a smaller range of the scale. That constitutes an improvement over design phase 1 in that a higher percentage of respondents used the full scale.

Completion Time A design goal for the SOES is that it be able to be completed in a relatively short time frame. Table 4 provides descriptive statistics summarizing the distribution of completion times. The majority of respondents completed the survey within a time frame of about 15 minutes, but an unexpectedly large number of respondents logged lengthy completion times. However, those long times can likely be attributed to the online format in which the survey was administered. Respondents completed the survey on their own and did not need to complete it in a single sitting. Long completion times can therefore most likely be attributed to students who began the survey, left it incomplete, then completed it at a later point in time. It should also be noted that the form of the SOES given during this field test included several questions beyond the main survey task, including several open-ended items. If those questions were not included, the completion time would likely be substantially reduced. Overall, the length of the survey met the design goal given that 75% of responses were completed in about 16 minutes or less.

Factor Analysis The exploratory factor analysis was conducted using SPSS Version 24. The data were found to be suitable for factor analysis in that the Kaiser–Meyer–Olkin measure for these data was 0.863, exceeding the recommended value of 0.6 (Kaiser & Rice, 1974). A five-factor solution was found to best fit the data. Five factors were extracted with eigenvalues exceeding 1.0, and an examination of the scree plot indicated a clear break after the first five factors (Cattell, 1966). Those factors explained 15.3%, 13.1%, 12.2%, 10.1%, and 9.4% of the total variance, respectively (58.9% in total). The varimax rotation method was used to generate the loadings of each of the items onto the five factors. That orthogonal rotation method was selected based on the factor correlation matrix. Because all factor correlations were

Table 3
Summary statistics for main survey task items.

Activity category	Item	Mean rating	Standard deviation
Non-Technological	Analyzing the themes of a novel	1.47	0.90
	Planning a seating arrangement for a party	2.08	1.17
	Trying out a new recipe in a kitchen at home	1.92	1.12
	Taking a photograph of a landscape to hang on an office wall	1.47	0.94
	Designing the graphics that will appear on a product's package	2.76	1.38
Technician	Installing wiring in a building	3.99	1.16
	Assembling a laptop computer using a set of instructions	3.75	1.25
	Performing the maintenance on a sewer system	3.23	1.34
	Repairing a broken mobile phone	3.58	1.16
	Operating a crane at a construction site	2.81	1.29
Natural Science	Developing a new theory of gravity	2.99	1.30
	Categorizing different types of galaxies using a telescope	2.11	1.20
	Studying the migration patterns of birds	1.76	0.99
	Observing volcanoes to figure out what causes them to erupt	2.32	1.25
	Studying the life cycles of different insects	1.86	1.07
Technological Analysis	Calculating the environmental impact of a new factory	3.43	1.28
	Determining how composition of cement affects performance	3.67	1.20
	Analyzing the performance of a city's highway system	3.62	1.21
	Determining why a piece of equipment did not operate correctly	4.36	0.88
	Researching how different types of tire treads perform	3.62	1.21
Technological Design & Development	Creating the plans for a new computer chip	4.55	0.81
	Developing a new type of siding to use on houses	4.11	1.09
	Finding ways to improve the durability of a prosthetic limb	4.57	0.73
	Finding ways to make football helmets safer	4.20	0.99
	Designing the production process for a chemical	3.96	1.21

Table 4
Completion times for SOES.

	Percentile						
	5	10	25	50	75	90	95
Completion time (minutes)	4.6	5.4	7.3	10.1	16.1	25.0	44.0

small (less than 0.32), oblique rotation methods were deemed unnecessary (Tabachnick & Fidell, 2013). The rotated factor analysis solution is shown in Table 5.

Overall, the factor analysis provides evidence that the categories function as intended. With a handful of exceptions, which are discussed in detail below, Table 5 shows a simple structure for the majority of the items and factors (Thurstone, 1947). Each of the five factors aligned with a different activity category and most of the items within each category loaded only onto the same intended factor. Of the five activity categories, the Non-Technological category showed the weakest overall factor loadings. That is not surprising given that the five items in that category are related to each other not in what they *are*, but in what they *are not*. In contrast, the strongest evidence for a simple structure was obtained for the Technician category, which had strong factor loadings and no instances of cross-loaded items.

Six items showed complex structure in that they loaded onto two factors. Two items loaded more strongly onto a different factor from that which was intended: "Taking a photograph of an outdoor landscape to hang on an office wall" and "Calculating the environmental impact of a new factory." In both cases, the items loaded onto the intended factor but had a slightly stronger loading on the factor aligned with the Natural Science items. Four other items showed evidence of complex structure in that they loaded onto multiple factors, although the strongest loading was on the intended factor. "Finding ways to make football helmets safer," for instance, loaded most strongly onto the factor aligned with the other Technological Design & Development items, but also showed a weaker but substantial loading onto the factor associated with Technological Analysis. Similarly, "Designing the production process for a chemical" mainly loaded onto the Technological Design & Development factor but also more weakly onto the Natural Science factor. Because the intended method of interpreting SOES responses is to characterize participants' ratings of categories rather than individual items,

Table 5
Rotated factor matrix for main survey task items.

Item	Rotated factor coefficients					Communalities
	1	2	3	4	5	
Analyzing themes of a novel	0.136	0.080	0.255	0.140	0.486	0.345
Planning a seating arrangement	0.034	0.268	0.232	0.018	0.710	0.632
Trying out a new recipe	0.088	0.079	0.134	0.023	0.697	0.518
Taking a photo of a landscape	0.385	0.291	0.172	0.088	0.349	0.392
Designing graphics for a product	0.099	0.291	0.381	0.184	0.478	0.503
Installing wiring in a building	0.212	0.804	0.092	0.151	0.042	0.724
Assembling laptop components	0.072	0.708	0.020	0.039	0.051	0.511
Performing sewer maintenance	0.133	0.675	0.063	0.281	0.249	0.619
Repairing a broken mobile phone	0.115	0.791	0.155	−0.080	0.157	0.694
Operating a crane	0.153	0.751	0.034	0.088	0.275	0.672
Developing a theory of gravity	0.709	0.126	0.260	0.056	0.135	0.608
Categorizing galaxies	0.804	0.232	0.010	0.080	0.062	0.711
Studying migration of birds	0.738	0.086	0.012	0.171	0.294	0.668
Observing volcanoes	0.732	0.105	0.046	0.269	0.091	0.630
Studying insect life cycles	0.806	0.112	0.038	0.087	0.092	0.679
Calculating environmental impact	0.507	0.099	0.210	0.419	0.093	0.495
Studying cement composition	0.290	0.013	0.416	0.543	0.200	0.592
Analyzing a highway system	0.303	0.081	0.163	0.665	0.185	0.602
Determining why equipment failed	0.092	0.242	0.238	0.691	0.188	0.636
Researching tire tread performance	0.214	0.058	0.258	0.659	0.009	0.550
Designing plans for a computer chip	0.194	0.178	0.654	0.055	0.170	0.529
Developing a new type of siding	0.001	0.055	0.683	0.280	0.135	0.566
Improving durability of prosthetics	0.057	0.024	0.731	0.261	0.017	0.607
Improving football helmet safety	0.021	0.018	0.646	0.462	0.159	0.657
Designing production process	0.352	0.014	0.636	0.164	0.196	0.594

Note. Major factor loadings (>0.32) are shown in bold.

Table 6
Internal reliability of activity categories.

Activity category	Number of items	Mean inter-item correlation	Min. inter-item correlation	Max. inter-item correlation	Cronbach's α
Non-Technological	5	0.256	0.135	0.510	0.632
Reduced version ^a	3	0.306	0.166	0.510	0.570
Technician	5	0.519	0.397	0.614	0.844
Natural Science	5	0.548	0.420	0.644	0.858
Tech Analysis	5	0.408	0.280	0.538	0.775
Reduced version ^a	3	0.422	0.409	0.434	0.687
Tech Design	5	0.432	0.316	0.569	0.792
Reduced version ^a	3	0.398	0.311	0.452	0.665

^aThe reduced version of each category obtained by removing the items that were cross-loaded in the factor analysis.

the cross-loaded items are problematic. While those items can still provide insights into respondents' thinking if considered individually, they cannot be associated with a single category.

In sum, the factor analysis provides evidence that the activity categories are an appropriate way to structure participants' responses to the main survey task items. Interpreting participants' responses using category ratings is supported, but the six items that showed complex structure should not be used as part of those category ratings.

Internal Reliability of Categories Analyses of the internal reliability of the five categories build on the results of the factor analysis. Table 6 provides a summary of the internal reliability measures for each of the activity categories. Measures are provided for the set of all five items within each category as well as the "reduced set" of items, obtained by eliminating from the categories the six items shown by the factor analysis to have complex structure.

For all of the activity categories, except for the Non-Technological category, the inter-item correlations are all positive and of moderate to large size, which provides evidence of their internal reliability (DeVellis, 2003). The α statistics for the Technician and Natural Science categories show high internal reliability; the Technological Analysis and Technological Design & Development categories are somewhat lower, but still acceptable (DeVellis, 2003). Similar to the results from the factor analysis, the Non-Technological category of items showed the lowest internal reliability. That is not surprising for the same reasons described above: those items were placed into the category not because of their similarities but rather because of their shared *dissimilarities* from engineering. Even though the internal reliability is relatively low for that category, the items still show positive inter-item correlations, albeit of a weaker magnitude than the other categories.

The inter-item correlation statistics were largely similar for the five-item and reduced versions of the categories. The reduced versions of the categories, however, showed somewhat lower values for α . That reduction in α is due to the fact that α is a function of the number of items in a given category; in general, α can be increased by adding more items, provided they are intercorrelated with the others (DeVellis, 2003). That property of α is what accounts for the lower values obtained for the reduced versions of the categories, as the items that were eliminated were correlated with the others in the category. Overall, the α values for the reduced scales are less than desirable. However, although higher internal reliability can be obtained by using the full set of five items in each category rather than the reduced set, the simple factor structure obtained by the reduced sets might outweigh that benefit.

Revised Category Ratings Results from the factor analysis support the calculation of category ratings using a reduced number of items for each category. On the other hand, the internal reliability analysis gives a more mixed picture; although the inter-item correlations are unchanged using the reduced sets of items, the α statistics for the reduced categories are lower than desired. The revised set of items associated with each activity category is shown in Table 7. Table 8 provides summary statistics for each activity category, using both the original set of five items for each category and the revised set of items. As seen in Table 8, the removal of the six items does not substantially change any of the summary statistics for any of the categories. Given that equivalence, the use of the reduced versions is recommended to take advantage of the simple factor structure offered by those categories.

Validity of Natural Science Category As discussed above, the Natural Science category is particularly important given that teachers are being asked to teach engineering alongside science. If that category functions as intended, then a respondent who views science and engineering as very similar (or perhaps not different at all) should assign higher ratings to the items in that category. A respondent who views science and engineering as being quite different should, in contrast, assign lower ratings to that category. To see if that is indeed the case, respondents were asked to indicate the extent to

Table 7

Revised set of items used to calculate category ratings.

Activity category	Items
Non-Technological	Analyzing the themes of a novel Planning a seating arrangement for a party Trying out a new recipe in a kitchen at home
Technician	Installing wiring in a building Assembling a laptop computer using a set of instructions Performing the maintenance on a sewer system Repairing a broken mobile phone
Natural Science	Operating a crane at a construction site Developing a new theory of gravity Categorizing different types of galaxies using a telescope Studying the migration patterns of birds Observing volcanoes to figure out what causes them to erupt
Technological Analysis	Studying the life cycles of different insects Analyzing the performance of a city's highway system Determining why a piece of equipment did not operate correctly
Technological Design & Development	Researching how different types of tire treads perform Creating the plans for a new computer chip Developing a new type of siding to use on houses Finding ways to improve the durability of a prosthetic limb

Table 8
Summary statistics for categories.

Activity category	Number of items	Mean rating	Median rating	Standard deviation
Non-Technological	5	1.94	1.80	0.71
Reduced version ^a	3	1.82	1.67	0.79
Technician	5	3.47	3.60	0.97
Natural Science	5	2.21	2.00	0.93
Tech Analysis	5	3.74	3.80	0.85
Reduced version ^a	3	3.87	4.00	0.87
Tech Design & Development	5	4.28	4.40	0.71
Reduced version ^a	3	4.41	4.67	0.68

^aThe reduced version of each category obtained by removing the items that were cross-loaded in the factor analysis.

Table 9
Summary of responses to question on science and engineering similarity.

Response option	Number of responses	% of total responses	Mean category rating for Natural Science
6—Essentially the same	6	2.4	2.90
5—Very similar, minor differences	51	20.6	2.46
4—More similar than different	127	51.4	2.30
3—More different than similar	48	19.4	1.85
2—Very different, minor similarities	12	4.9	1.38
1—Completely different	3	1.2	1.20

which, in general, they viewed science and engineering as being the same or different. They were given six options, ranging from “Science and engineering are essentially the same” (coded as “6”) to “Science and engineering are completely different” (coded as “1”). Table 9 provides the frequency of responses for each of the six options. Not surprisingly, few respondents gave responses at the extremes.

The mean category ratings shown in Table 9 do indeed display the anticipated pattern: participants who indicated that engineering and science are more different tended to give lower ratings to the Natural Science category. To test the statistical significance of that apparent pattern, an ordinal logistic regression (Cohen et al., 2003) was conducted with the response option shown in Table 9 as an ordinal response variable and Natural Science category rating as a continuous predictor variable. The ordinal logistic regression model tested whether participants who had higher ratings of the Natural Science category were more likely to select a response indicating a greater similarity between science and engineering. The regression model showed that the Natural Science category rating is indeed a significant predictor of response option ($t = -4.894, p < 0.001$). More specifically, for every one point increase on a participant’s rating of the Natural Science category, the analysis shows that they are 1.97 times more likely to indicate a higher level of similarity between science and engineering (e.g., to select one of the response options coded as 4, 5, or 6 versus one of the options coded as 1, 2, or 3). In sum, participants’ ratings of the Natural Science category show the expected relationship to the separate measure of their views on the similarity between science and engineering. This finding provides evidence of the validity of the Natural Science category rating.

Discussion and Recommendations for Use of the SOES

The data presented here provide strong evidence of the utility of the SOES for learning about teachers’ views of the scope of engineering. The field test data indicate that the main survey task produces valid and reasonably reliable measures of how strongly respondents associate five different categories of activity with engineering. The field test also indicates that, as desired, the SOES can be completed by participants in a relatively short period of time. The SOES has a range of potential uses for both teacher educators and researchers. Below, recommendations for the use, scoring, and interpretation of the SOES are presented, as well as a discussion of the instrument’s limitations.

Administering the SOES

The form of the SOES shown in the Appendix was the one given during the phase 2 field test. It is recommended that the main survey task be used in the form shown in the Appendix, as alterations to the set of items could affect the reliability of

the task, particularly in terms of the activity categories. The additional questions that surround the main survey task, however, can and should be customized to the specific context of use. As mentioned above, the open-ended questions that ask for respondents' rationales underlying their ratings are useful for ensuring that respondents are interpreting the task as intended. Although not examined extensively here, participants' responses to those questions are interesting sources of data in their own right. Future work might explore the different ways that teachers justify their ratings and how those justifications relate to the ways that they complete the main survey task.

Scoring and Interpreting SOES Responses

The scope of engineering is conceptualized as a continuum, which means that examining a respondent's rating of any single item in isolation is unlikely to be informative. Instead, the ratings that a respondent assigns to the different activities ought to be considered as constituting that respondent's continuum and should therefore be examined in relation to one another. Analyzing a participant's responses to the full set of individual items is possible, but it is recommended that the activity categories be used instead as they provide a more concise overview of how a respondent views the scope of engineering continuum. Table 7 provides the items that are recommended for use within each category, and it is recommended that average ratings across those items be calculated to generate category scores for each respondent; Table 8 provides baseline data for category scores, based on the phase 2 field test data.

When interpreting category scores, insights are best gained by examining the *difference* between a respondent's scores on two categories of interest, again because those ratings make the most sense in relation to one another. From an informed view of the scope of engineering, the two categories that ought to occupy positions closest to the "engineering" end of the continuum are Technological Design & Development and Technological Analysis. Therefore, examining the difference in category score between those two categories and the others can indicate whether the respondent holds informed perceptions or possible misconceptions. For instance, an informed response would have a higher category score for Technological Design & Development than for Technician. However, for some field test participants, the Technician category actually had a higher category score than the Technological Design & Development category—evidence of a common misconception about what engineers do (Capobianco et al., 2011; Cunningham et al., 2005, 2006; Pleasants & Olson, 2019b). The difference between the Technological Design & Development and the Natural Science categories is also informative, as it indicates the extent to which the respondent differentiates scientific inquiry from engineering design.

Many separate contrasts can, of course, be drawn between the different category scores. Those of most interest will depend on context, but to aid with decision-making, Table 10 provides examples of category score differences that are indicative of more informed perceptions versus less informed ones. While not an exhaustive list, teacher educators could use the contrasts indicated in Table 10 as a diagnostic tool when working with pre-service or in-service teachers. Teacher educators or researchers might examine how certain differences between category scores change as a result of different interventions.

Use With Other Populations

The SOES was designed for use with teacher populations, and important to note is that the field test data reported here included responses only from pre-service teachers. Although there is little reason to suspect that the SOES would function differently for in-service teachers, care should always be taken in applying an instrument to new populations. In particular, it is best practice to recheck factor structures and reliability measures when utilizing an instrument in a novel context (AERA, APA, & NCME, 2014; DeVellis, 2003). While not specifically designed for use with student populations, the form of the SOES does not preclude its use with older K-12 students. Provided that steps are taken to confirm its validity and reliability

Table 10
Example category score contrasts indicative of more- or less-informed perceptions.

Contrasts consistent with informed perceptions	Contrasts consistent with less-informed perceptions
Tech Design & Development >>> Non-Tech	Technician > Tech Design & Development
Tech Design & Development >> Technician	Technician $\approx$ Tech Design & Development
Tech Design & Development > Natural Science	Natural Science > Tech Design & Development
Tech Design & Development $\approx$ Tech Analysis	Technician > Tech Analysis
Tech Analysis >>> Non-Tech	Tech Design & Development >>> Tech Analysis
Tech Analysis >> Technician	Natural science $\approx$ Tech Analysis
Tech Analysis > Natural Science	

Note. The magnitude of the difference between category ratings is represented by the number of ">" symbols present.

for new contexts, the SOES could indeed prove to be a useful tool across a range of contexts, including use with K-12 students.

Limitations

The SOES provides insights into a specific dimension of teachers' perceptions of engineering, but it does not provide a complete view of teachers' thinking. The quantitative and brief nature of the SOES means that it is necessarily limited in terms of the breadth of information that it can provide. To gain a more comprehensive understanding of teachers' thinking, more open-ended approaches are necessary. Further, a concern with any quantitative survey instrument is that the thought processes used by participants to generate their responses always remain largely hidden from view. The open-ended items on the SOES address that issue to an extent, but there always remains the possibility that a respondent interprets the survey items in unanticipated or idiosyncratic ways. The evidence of the validity and reliability of the SOES presented here does not (and can never) assuage those concerns. One shortcoming of the instrument that emerged from its analysis is that, when using the reduced set of items for the different activity categories, the internal reliability of those categories is not as high as desired. The construction of additional items in those categories to replace those that were eliminated would likely address that issue. Finally, as discussed above, a need does exist to further validate the SOES with additional populations.

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References

- Alwin, D. F. (2007). *Margins of error: A study of reliability in survey measurement*. Hoboken, NJ: John Wiley & Sons.
- American Educational Research Association, American Psychological Association, National Council on Measurement in Education. (2014). *Standards for educational and psychological testing*. Washington, DC: American Educational Research Association.
- American Society for Engineering Education. (2020). *Framework for P-12 engineering learning: A defined and cohesive educational foundation for P-12 engineering*. Washington, DC: American Society for Engineering Education.
- Antink-Meyer, A., & Meyer, D. Z. (2016). Science teachers' misconceptions in science and engineering distinctions: Reflections on modern research examples. *Journal of Science Teacher Education*, 27(6), 625–647. <https://doi.org/10.1007/s10972-016-9478-z>
- Banase, G., & Grunwald, A. (2009). Coherence and diversity in the engineering sciences. In A. Meijers (Ed.), *Philosophy of technology and engineering sciences* (pp. 155–184). Boston, MA: Elsevier.
- Berland, L., Steingut, R., & Ko, P. (2014). High school student perceptions of the utility of the engineering design process: Creating opportunities to engage in engineering practices and apply math and science content. *Journal of Science Education and Technology*, 23(6), 705–720. <https://doi.org/10.1007/s10956-014-9498-4>
- Bogost, I. (2015, November 5). Programmers: Stop calling yourselves engineers. *The Atlantic*. <https://www.theatlantic.com/technology/archive/2015/11/programmers-should-not-call-themselves-engineers/414271/>
- Brophy, S., Klein, S., Portsmore, M., & Rogers, C. (2008). Advancing engineering education in P-12 classrooms. *Journal of Engineering Education*, 97(3), 369–387. <https://doi.org/10.1002/j.2168-9830.2008.tb00985.x>
- Bucciarelli, L. (1994). *Designing engineers*. Cambridge, MA: MIT Press.
- Bucciarelli, L. (2009). Engineering science. In J. K. B. Olsen, S. A. Pedersen, & V. F. Hendricks (Eds.), *A companion to the philosophy of technology* (pp. 66–69). Malden, MA: Blackwell Publishing.
- Capobianco, B. M., Diefes-dux, H. A., Mena, I., & Weller, J. (2011). What is an engineer? Implications of elementary school student conceptions for engineering education. *Journal of Engineering Education*, 100(2), 304–328. <https://doi.org/10.1002/j.2168-9830.2011.tb00015.x>
- Cattell, D. F. (1966). The scree test for the number of factors. *Multivariate Behavioral Research*, 1(2), 245–276. https://doi.org/10.1207/s15327906mbr0102_10
- Chambers, D. W. (1983). Stereotypic images of the scientist: The Draw-a-Scientist Test. *Science Education*, 67(2), 255–265. <http://doi.wiley.com/10.1002/sce.3730670213>
- Cohen, J., Cohen, P., West, S. G., & Aiken, L. S. (2003). *Applied multiple regression/correlation analysis for the behavioral sciences* (3rd ed.). Mahwah, NJ: Lawrence Erlbaum Associates.

- Cunningham, C. M., & Kelly, G. J. (2017). Epistemic practices of engineering for education. *Science Education*, 101(3), 486–505. <https://doi.org/10.1002/sce.21271>
- Cunningham, C., Lachapelle, C., & Lindgren-Streicher, A. (2005). Assessing elementary school students' conceptions of engineering and technology. *Proceedings of American Society for Engineering Education Annual Conference and Exposition* (Vol. 112). Portland, OR: ASEE. <https://doi.org/10.18260/1-2--14836>
- Cunningham, C., Lachapelle, C., & Lindgren-Streicher, A. (2006). Elementary teachers' understanding of engineering and technology. *Proceedings of American Society for Engineering Education Annual Conference and Exposition* (Vol. 113). Chicago, IL: ASEE. <https://doi.org/10.18260/1-2--200>
- Daly, S. R., Adams, R. S., & Bodner, G. M. (2012). What does it mean to design? A qualitative investigation of design professionals' experiences. *Journal of Engineering Education*, 101(2), 187–219. <https://doi.org/10.1002/j.2168-9830.2012.tb00048.x>
- Davis, M. (1996). Defining "engineer": How to do it and why it matters. *Journal of Engineering Education*, 85(2), 97–101. <https://doi.org/10.1002/j.2168-9830.1996.tb00217.x>
- Deniz, H., Kaya, E., Yesilyurt, E., & Trabia, M. (2020). The influence of an engineering design experience on elementary teachers' nature of engineering views. *International Journal of Technology and Design Education*, 30(4), 635–656. <https://doi.org/10.1007/s10798-019-09518-4>
- DeVellis, R. F. (2003). *Scale development: Theory and applications* (2nd ed.). Thousand Oaks, CA: Sage.
- Dym, C., & Brown, D. (2012). *Engineering design: Representation and reasoning*. (2nd ed.). New York, NY: Cambridge University Press.
- Ergün, A., & Kıyıcı, G. (2019). The effect of design based science education applications of science teacher candidates on their perceptions of engineering education and engineer. *Pegem Journal of Education and Instruction*, 9(4), 1031–1062. <http://dx.doi.org/10.14527/pegagog.2019.033>
- Figueiredo, A. D. (2008). Toward an epistemology of engineering. In D. Goldberg & N. McCarthy (Eds.), *Proceedings Workshop on Philosophy & Engineering [WPE 2008]* (pp. 94–95). London, UK: Royal Engineering Academy.
- Finson, K. D. (2002). Drawing a scientist: What we do and do not know after fifty years of drawings. *School Science and Mathematics*, 102(7), 335–345. <https://doi.org/10.1111/j.1949-8594.2002.tb18217.x>
- Finson, K. D. (2009). What drawings reveal about perceptions of scientists: Visual data operationally defined. In J. E. Pederson & K. D. Finson (Eds.), *Visual data: Understanding and applying visual data to research in education* (pp. 59–77). Rotterdam, The Netherlands: Sense.
- Guzey, S., & Aranda, M. (2017). Student participation in engineering practices and discourse: An exploratory case study. *Journal of Engineering Education*, 106(4), 585–606. <https://doi.org/10.1002/jee.20176>
- Hammack, R., & Ivey, T. (2017). Elementary teachers' perceptions of engineering and engineering design. *Journal of Research in STEM Education*, 3(1/2), 48–68. <https://doi.org/10.51355/jstem.2017.29>
- Hammack, R., Utley, J., Ivey, T., & High, K. (2020). Elementary teachers' mental images of engineers at work. *Journal of Pre-College Engineering Education Research (J-PEER)*, 10(2), 35–46. <https://doi.org/10.7771/2157-9288.1255>
- Hansson, S. O. (2007). What is technological science? *Studies in History and Philosophy of Science Part A*, 38(3), 523–527. <https://doi.org/10.1016/j.shpsa.2007.06.003>
- Houkes, W. (2009). The nature of technological knowledge. In A. Meijers (Ed.), *Philosophy of technology and engineering sciences* (pp. 309–350). Boston, MA: Elsevier Science.
- Hsu, M. C., Purzer, S., & Cardella, M. E. (2011). Elementary teachers' views about teaching design, engineering, and technology. *Journal of Pre-College Engineering Education Research*, 1(2), 31–39. <https://doi.org/10.5703/1288284314639>
- International Technology and Engineering Educators Association. (2020). *Standards for technological and engineering literacy: The role of technology and engineering in STEM education*. Author.
- Kaiser, H. F., & Rice, J. (1974). Little jiffy, mark IV. *Educational and Psychological Measurement*, 34(1), 111–117.
- Karatas, F. O., Micklos, A., & Bodner, G. M. (2011). Sixth-grade students' views of the nature of engineering and images of engineers. *Journal of Science Education and Technology*, 20(2), 123–135. <https://doi.org/10.1007/s10956-010-9239-2>
- Kaya, E. (2020) *Toward developing a valid and reliable assessment of learners' nature of engineering views* [Doctoral dissertation]. University of Nevada, Las Vegas.
- Knight, M., & Cunningham, C. (2004). Draw an engineer test (DAET): Development of a tool to investigate students' ideas about engineers and engineering. In, *Proceedings of American Society for Engineering Education Annual Conference and Exposition* (Vol. 111, pp. 4079–4089). Salt Lake City, UT: ASEE.
- Kroes, P. (1995). Technology and science-based heuristics. In J. C. Pitt (Ed.), *New directions in the philosophy of technology* (pp. 17–39). Dordrecht, The Netherlands: Springer.
- Kroes, P. (2009). Foundational issues of engineering design. In A. Meijers (Ed.), *Philosophy of technology and engineering sciences* (pp. 513–541). Boston, MA: Elsevier Science.
- Kroes, P. (2012). *Technical artefacts; Creations of mind and matter: A philosophy of engineering design*. Dordrecht, The Netherlands: Springer.
- Krosnick, J. A. (1999). Survey research. *Annual Review of Psychology*, 50(1), 537–567. <https://doi.org/10.1146/annurev.psych.50.1.537>
- Laudan, L. (1983). The demise of the demarcation problem. In R. Laudan (Ed.), *The demarcation between science and pseudo-science* (Vol. 21, pp. 7–35). Blacksburg, VA: Virginia Tech Center for the Study of Science in Society, Working Papers.
- Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching*, 39(6), 497–521. <https://doi.org/10.1002/tea.10034>
- Lopez, C. C. C., Echeverria, M. J. G., Lopez-Malo, A., & Palou, E. (2012). Eliciting Yucatan peninsula teachers' images of engineering and engineers. In, *Proceedings of IEEE Frontiers in Education Conference* (Vol. 42). Seattle, WA: IEEE. <https://doi.org/10.1109/FIE.2012.6462221>
- Losh, S. C., Wilke, R., & Pop, M. (2008). Some methodological issues with "Draw a Scientist Tests" among young children. *International Journal of Science Education*, 30(6), 773–792. <https://doi.org/10.1080/09500690701250452>
- McComas, W. F., & Burgin, S. R. (2020). A critique of "STEM" education. *Science & Education*, 29(4), 805–829. <https://doi.org/10.1007/s11191-020-00138-2>
- Meijers, A., & de Vries, M. (2009). Technological knowledge. In J. K. B. Olsen, S. A. Pedersen, & V. F. Hendricks (Eds.), *A companion to the philosophy of technology* (pp. 70–74). Malden, MA: Blackwell Publishing.
- Mitcham, C. (1994). *Thinking through technology: The path between engineering and philosophy*. Chicago, IL: University of Chicago Press.
- Mitcham, C., & Schatzberg, E. (2009). Defining technology and the engineering sciences. In A. Meijers (Ed.), *Philosophy of technology and engineering sciences* (pp. 27–63). Boston, MA: Elsevier.

- Montfort, D. B., Brown, S., & Whritenour, V. (2013). Secondary students' conceptual understanding of engineering as a field. *Journal of Pre-College Engineering Education Research (J-PEER)*, 3(2), 1–12. <https://doi.org/10.7771/2157-9288.1057>
- Moore, T. J., Tank, K. M., Glancy, A. W., & Kersten, J. A. (2015). NGSS and the landscape of engineering in K-12 state science standards. *Journal of Research in Science Teaching*, 52(3), 296–318. <https://doi.org/10.1002/tea.21199>
- National Academy of Engineering & National Research Council. (2009). *Engineering in K-12 education: Understanding the status and improving the prospects*. Washington, DC: National Academies Press.
- National Research Council. (2001). *Knowing what students know: The science and design of educational assessment*. Washington, DC: National Academies Press.
- National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: The National Academies Press.
- NGSS Lead States (2013). *Next generation science standards: For states, by states*. Washington, DC: The National Academies Press.
- Ovadia, S. (2004). Ratings and rankings: Reconsidering the structure of values and their measurement. *International Journal of Social Research Methodology*, 7(5), 403–414. <https://doi.org/10.1080/1364557032000081654>
- Park, W., Wu, J. Y., & Erduran, S. (2020). The nature of STEM disciplines in the science education standards documents from the USA, Korea and Taiwan. *Science & Education*, 29(4), 899–927. <https://doi.org/10.1007/s11191-020-00139-1>
- Pawley, A. L. (2009). Universalized narratives: Patterns in how faculty members define “engineering”. *Journal of Engineering Education*, 98(4), 309–319. <https://doi.org/10.1002/j.2168-9830.2009.tb01029.x>
- Peterson, C. H., Peterson, N. A., & Powell, K. G. (2017). Cognitive interviewing for item development: Validity evidence based on content and response processes. *Measurement and Evaluation in Counseling and Development*, 50(4), 217–223. <https://doi.org/10.1080/07481756.2017.1339564>
- Pigliucci, M. (2013). The demarcation problem. A (belated) response to Laudan. In M. Pigliucci & M. Boudry (Eds.), *Philosophy of pseudoscience: Reconsidering the demarcation problem* (pp. 9–28). Chicago, IL: University of Chicago Press.
- Pleasant, J. (2020). Inquiring into the nature of STEM problems: Implications for pre-college education. *Science & Education*, 29(4), 831–855. <https://doi.org/10.1007/s11191-020-00135-5>
- Pleasant, J., & Olson, J. K. (2019a). What is engineering? Elaborating the nature of engineering for K-12 education. *Science Education*, 103(1), 145–166. <https://doi.org/10.1002/sce.21483>
- Pleasant, J., & Olson, J. K. (2019b). Refining an instrument and studying elementary teachers' understanding of the scope of engineering. *Journal of Pre-College Engineering Education Research*, 9(2), 1–18. <https://doi.org/10.7771/2157-9288.1207>
- Pleasant, J., Olson, J. K., & De La Cruz, I. (2020). Accuracy of elementary teachers' representations of the projects and processes of engineering: Results of a professional development program. *Journal of Science Teacher Education*, 31(4), 362–383. <https://doi.org/10.1080/1046560X.2019.1709295>
- Reinisch, B., Krell, M., Hergert, S., Gogolin, S., & Krüger, D. (2017). Methodical challenges concerning the Draw-A-Scientist Test: a critical view about the assessment and evaluation of learners' conceptions of scientists. *International Journal of Science Education*, 39(14), 1952–1975. <https://doi.org/10.1080/09500693.2017.1362712>
- Robison, W. L. (2013). Rules of skill: Ethics in engineering. In D. P. Michelfelder, N. McCarthy, & E. Goldberg (Eds.), *Philosophy and engineering: Reflections on practice, principles and process* (pp. 15–26). Dordrecht, the Netherlands: Springer.
- Tabachnick, B. G., & Fidell, L. S. (2013). *Using multivariate statistics* (6th ed.). Boston, MA: Pearson Education.
- Tala, S. (2013). The nature of technoscience. In M. P. Clough, J. K. Olson, & D. S. Niederhauser (Eds.), *The nature of technology: Implications for learning and teaching* (pp. 51–84). Rotterdam, The Netherlands: Sense Publishers.
- Thomas, J., Hawley, L. R., & DeVore-Wedding, B. (2020). Expanded understanding of student conceptions of engineers: Validation of the modified draw-an-engineer test (mDAET) scoring rubric. *School Science and Mathematics*, 120(7), 391–401. <https://doi.org/10.1111/ssm.12434>
- Thurstone, L. L. (1947). *Multiple factor analysis*. Chicago, IL: University of Chicago Press.
- Tourangeau, R., & Bradburn, N. M. (2010). The psychology of survey response. In P. V. Marsden & J. D. Wright (Eds.), *Handbook of survey research* (2nd ed., pp. 315–346). Bingley, UK: Emerald.
- Trevelyan, J. (2007). Technical coordination in engineering practice. *Journal of Engineering Education*, 96(3), 191–204. <https://doi.org/10.1002/j.2168-9830.2007.tb00929.x>
- Vermaas, P. E., Kroes, P., Light, A., & Moore, S. A. (2008). *Philosophy and design: From engineering to architecture*. Dordrecht, The Netherlands: Springer.
- Vincenti, W. (1990). *What engineers know and how they know it*. Baltimore, MD: Johns Hopkins University Press.
- Wayne, H. (2021, January 18). Are we really engineers? Hillel Wayne. <https://www.hillelwayne.com/post/crossover-project/are-we-really-engineers/>
- Weber, N., Duncan, D., Dyehouse, M., Strobel, J., & Diefes-Dux, H. A. (2011). The development of a systematic coding system for elementary students' drawings of engineers. *Journal of Pre-College Engineering Education Research (J-PEER)*, 1(1), 49–62. <https://doi.org/10.7771/2157-9288.1030>
- Whitworth, B. A., & Wheeler, L. B. (2017). Is it engineering or not? *The Science Teacher*, 84(5), 25–30.
- Willis, G. B. (2004). *Cognitive interviewing: A tool for improving questionnaire design*. Thousand Oaks, CA: Sage Publications.
- Wittgenstein, L. (1953). *Philosophical investigations*. Oxford, UK: Blackwell.
- Yaşar, Ş., Baker, D., Robinson-Kurpius, S., Krause, S., & Roberts, C. (2006). Development of a survey to assess K-12 teachers' perceptions of engineers and familiarity with teaching design, engineering, and technology. *Journal of Engineering Education*, 95(3), 205–216. <https://doi.org/10.1002/j.2168-9830.2006.tb00893.x>

Appendix: SOES Used During Phase 2 Field Test

In general, what kinds of things do you think engineers do?

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	☐	☐	☐	☐	☐
Creating the designs for a new computer chip	☐	☐	☐	☐	☐
Developing a new theory of gravity	☐	☐	☐	☐	☐
Finding ways to improve the durability of a prosthetic limb	☐	☐	☐	☐	☐
Planning the seating arrangement for a party	☐	☐	☐	☐	☐
Researching how different types of tire treads perform	☐	☐	☐	☐	☐
Studying the life cycles of different insects	☐	☐	☐	☐	☐
Assembling a laptop computer using a set of instructions	☐	☐	☐	☐	☐
Installing wiring in a building	☐	☐	☐	☐	☐
Determining why a piece of equipment did not operate correctly	☐	☐	☐	☐	☐
Trying out a new recipe in a kitchen at home	☐	☐	☐	☐	☐
Finding ways to make football helmets safer	☐	☐	☐	☐	☐
Designing the production process for a chemical	☐	☐	☐	☐	☐
Performing the maintenance on a sewer system	☐	☐	☐	☐	☐
Categorizing different types of galaxies using a telescope	☐	☐	☐	☐	☐
Determining how the composition of cement affects performance	☐	☐	☐	☐	☐
Calculating the environmental impact of a new factory	☐	☐	☐	☐	☐
Observing volcanoes to figure out what causes them to erupt	☐	☐	☐	☐	☐
Repairing a broken mobile phone	☐	☐	☐	☐	☐
Operating a crane at a construction site	☐	☐	☐	☐	☐
Taking a photograph of a landscape to hang on an office wall	☐	☐	☐	☐	☐
Designing the graphics that will appear on a product's package	☐	☐	☐	☐	☐
Developing a new type of siding to use on houses	☐	☐	☐	☐	☐
Analyzing the performance of a city's highway system	☐	☐	☐	☐	☐
Studying the migration patterns of birds	☐	☐	☐	☐	☐

How did you decide which activities to rate as highly associated (the top two categories) with engineering work?

How did you decide which activities to rate as weakly associated (the bottom two categories) with engineering work?

In your understanding, how similar/different do you think science and engineering are? Select the answer that is closest to your view.

- Science and Engineering are essentially the same
- Science and Engineering are very similar, with only minor differences
- Science and Engineering are more similar than different, but there are some clear differences
- Science and Engineering are more different than they are similar, but there are some clear similarities
- Science and Engineering are very different, with only minor similarities
- Science and Engineering are completely different