

# Elementary Teachers' Understandings of Engineering and Technology

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Although people spend over 95% of their time interacting with the human-made world, few can articulate how our designed world came to be (engineering) and how the products that we have developed to meet our needs (technology) function. This is largely due to the fact that the disciplines of engineering and technology are not studied in the majority of schools in the United States.

To produce a technologically literate society, we believe that *all* students should engage with the disciplines of engineering and technology. Furthermore, we believe children's exposure to these disciplines should commence when they begin their schooling—elementary school provides a setting ripe for explorations into technology and engineering. However, introducing these subjects can prove challenging, not least because the education of the vast majority of elementary school teachers (like the bulk of our population), did not include engineering or technology activities or information. To integrate engineering into the classroom, not only do the preconceptions and learning of students need to be considered, but also those of teachers.

The importance of teacher knowledge and its impact on teaching has been widely researched. [1, 2]. Grossman [3] has identified four general areas as the cornerstones of knowledge for teaching: general pedagogical knowledge, subject-matter knowledge, pedagogical content knowledge, and knowledge of context. Infusing engineering into classrooms will require new forms of both subject-matter knowledge and pedagogical content knowledge related to engineering and technology. Previous studies have explored the influence of teachers' subject-matter knowledge on teaching practice practice [4-8].

What do elementary teachers know about engineering and technology? Knowledge of teachers' background knowledge, conceptions, attitudes, and comfort related to engineering and technology is important information that should shape engineering curriculum development, teacher resources and materials, and teacher professional development. However, to date there has been very little research investigating teachers' conceptions of engineering and technology and virtually none of it has been focused on elementary teachers. The International Technology Education Association (ITEA) has conducted one study of adults' thinking about technology and engineering [9]. This paper takes an early step and focuses on very basic subject-matter understanding that teachers hold related to science and engineering.

### **Methods**

This study grew from and extended two studies that probed students' conceptions of engineering [10, 11]. As part of a curriculum and teacher professional development project, we have collected 106 surveys from teachers most from Massachusetts—the state where we conducted initial research and development. The teacher survey collected background information about the teacher, such as how many years of teaching experience s/he had, the amount of time they spend teaching science, and their work and learning experiences with science, technology, and engineering.

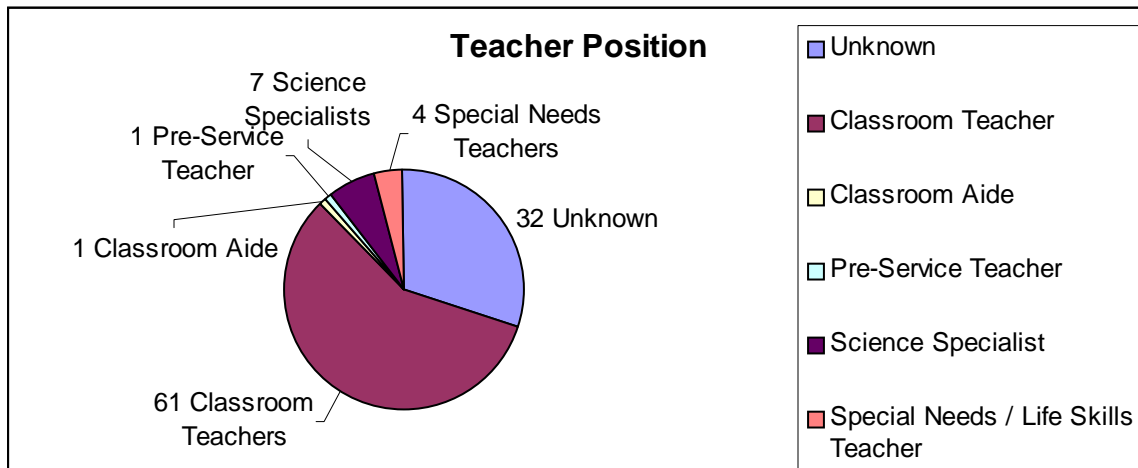
Additionally, we asked some of the teachers who completed the survey to complete two instruments that we had developed to measure students' understandings of technology and engineering: the *What is Engineering* and *What is Technology* instruments [10] (see Appendix A for copies of these instruments). The *What is Technology* instrument contains 16 images and

descriptions and asks respondents to circle those items that were technology and to respond to one of the two open-ended questions “How do you know if something is technology?” or “What is technology?” in writing. Similarly, the *What is Engineering* instrument consists of table with 16 images and descriptions of people at work and asks respondents to circle the kinds of work that engineers do. Respondents are also asked to either complete in writing the phrase “An engineering is a person who ...” Or to answer the open-ended question “What is engineering?” Six months after we began to collect data using this instrument, we adjusted it—replacing some items with less canonical “engineering” examples, such as “Design a better bubble gum” and “Figure out ways to track luggage”. Results from both versions of the *What is Engineering* instrument are reported here.

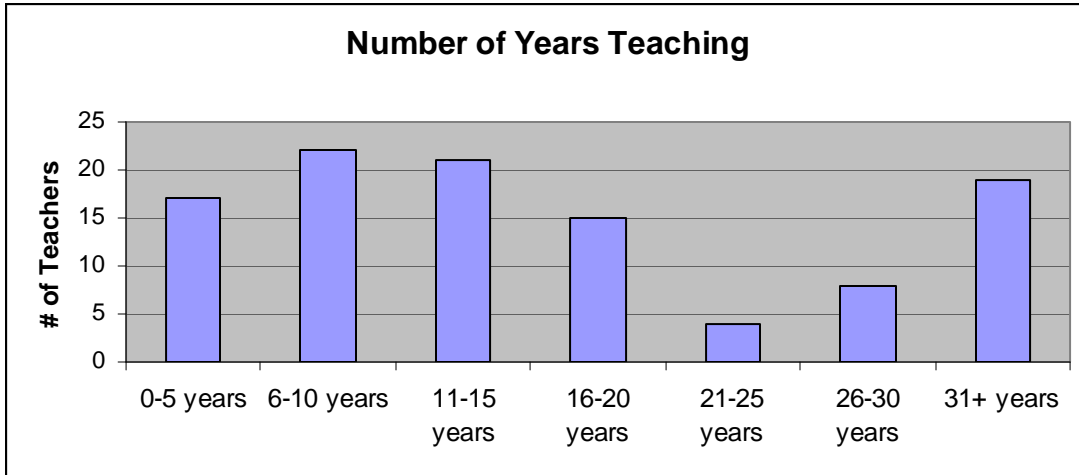
The teachers were also asked to explain in their own words the differences and similarities between science and engineering. These written explanations were coded, and are reported below.

### **Sample Demographics**

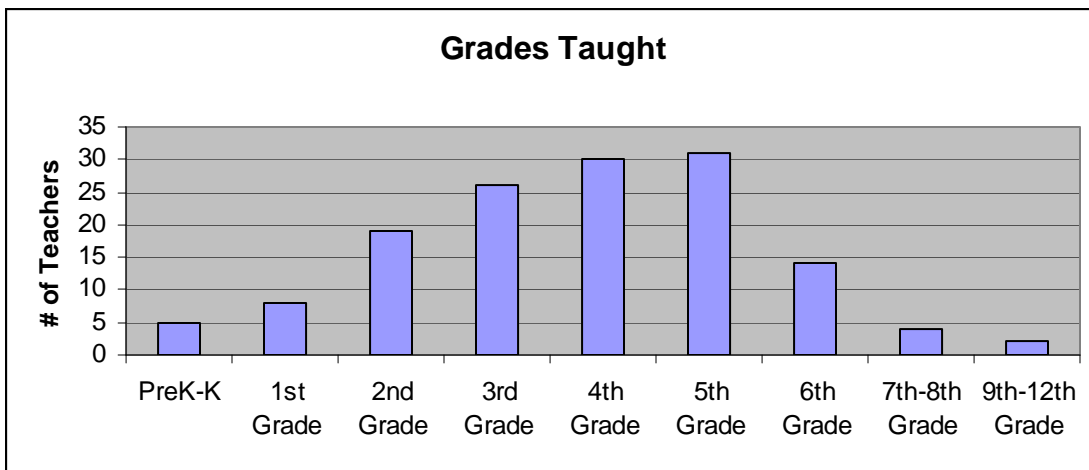
Our survey sample of 106 teachers includes mostly elementary school teachers, with the vast majority being female (more than 90%). All but 7 teach in Massachusetts – the others hail from Connecticut and South Dakota. About 90% of these teachers are regular classroom teachers, with the rest being special needs teachers, science specialists, or other specialists.



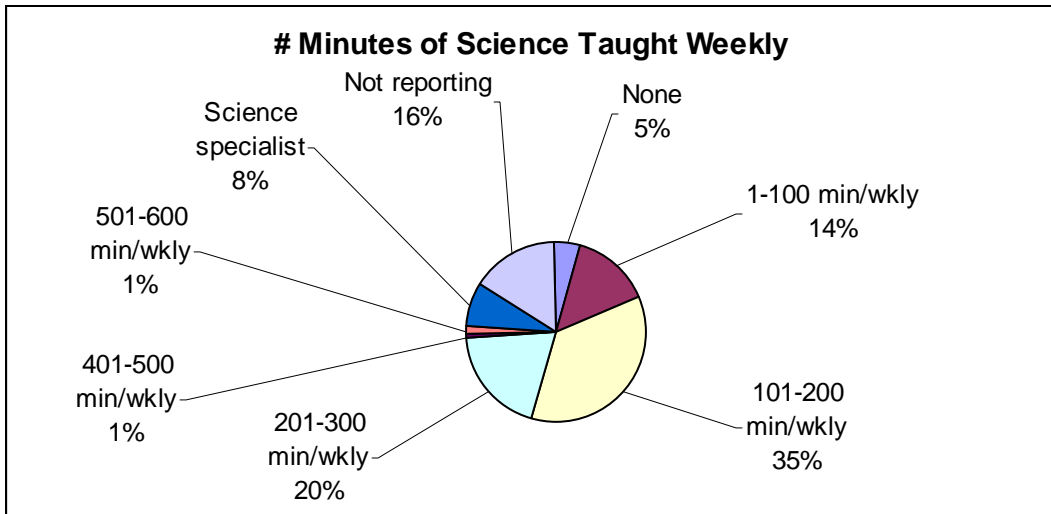
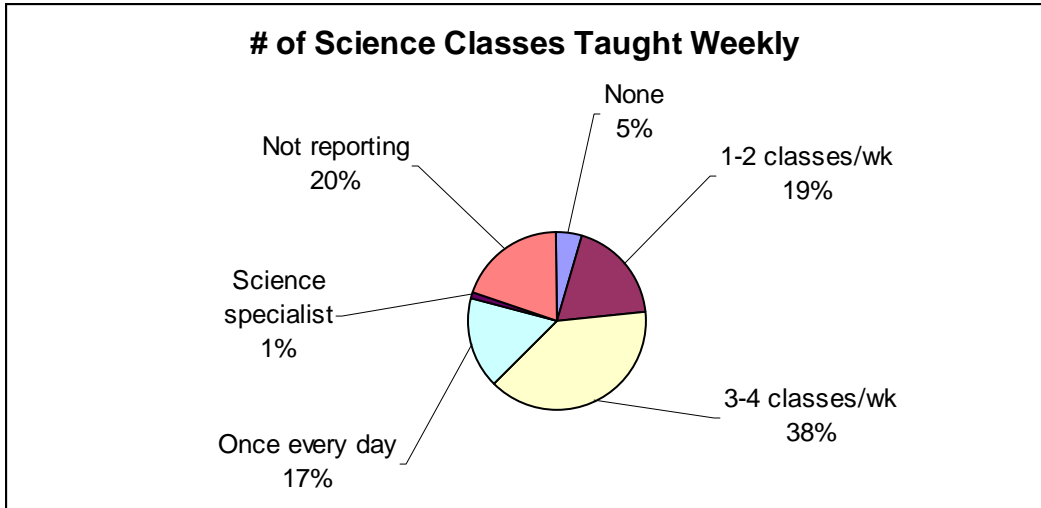
These teachers have a range of experience, from 1 to 37 years of teaching. The average number of years teaching is 16 years, with a median of 15 years. Teachers with 6-16 years of experience were our most common respondents, though we also had many veteran teachers responding.



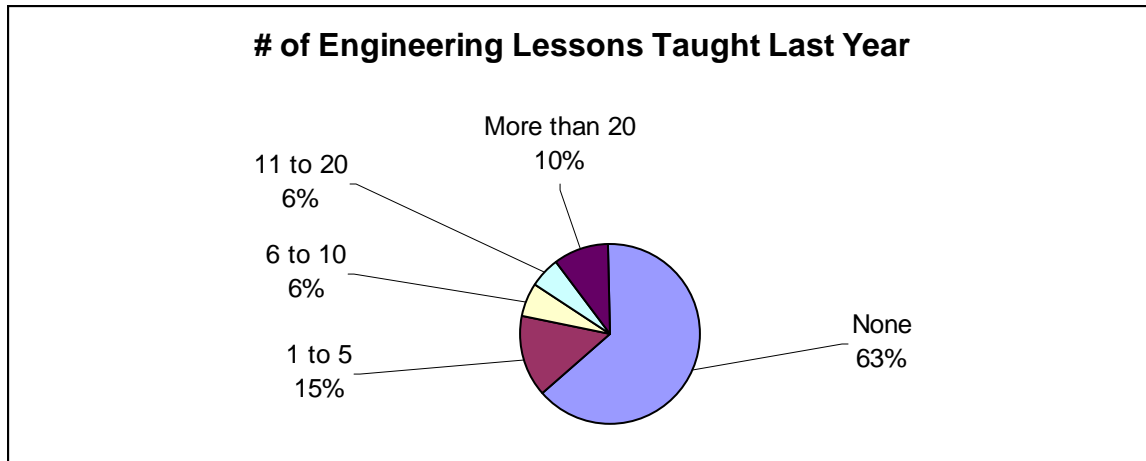
Most of our survey respondents were elementary school teachers—not surprising, since the professional development workshops where we distributed these surveys were offered for “elementary school engineering”. Of teachers responding, 86% taught grades 2 through 6. A few high school special needs teachers also participated.



Teachers reported a range of time spent teaching science in their classrooms. Most teachers reported spending 3-4 class periods, or 100-200 minutes per week, teaching science. Approximately 20% reported spending more time teaching science, and approximately the same percentage of teachers reported spending less time.



For the most part, teachers had little or no experience teaching engineering lessons to their students. Sixty-three percent of teachers reported that they did not teach any engineering lessons in the prior school year. Only 10% reported that they taught more than 20 engineering lessons in the prior year; many of these teachers were science specialists.



## **Findings**

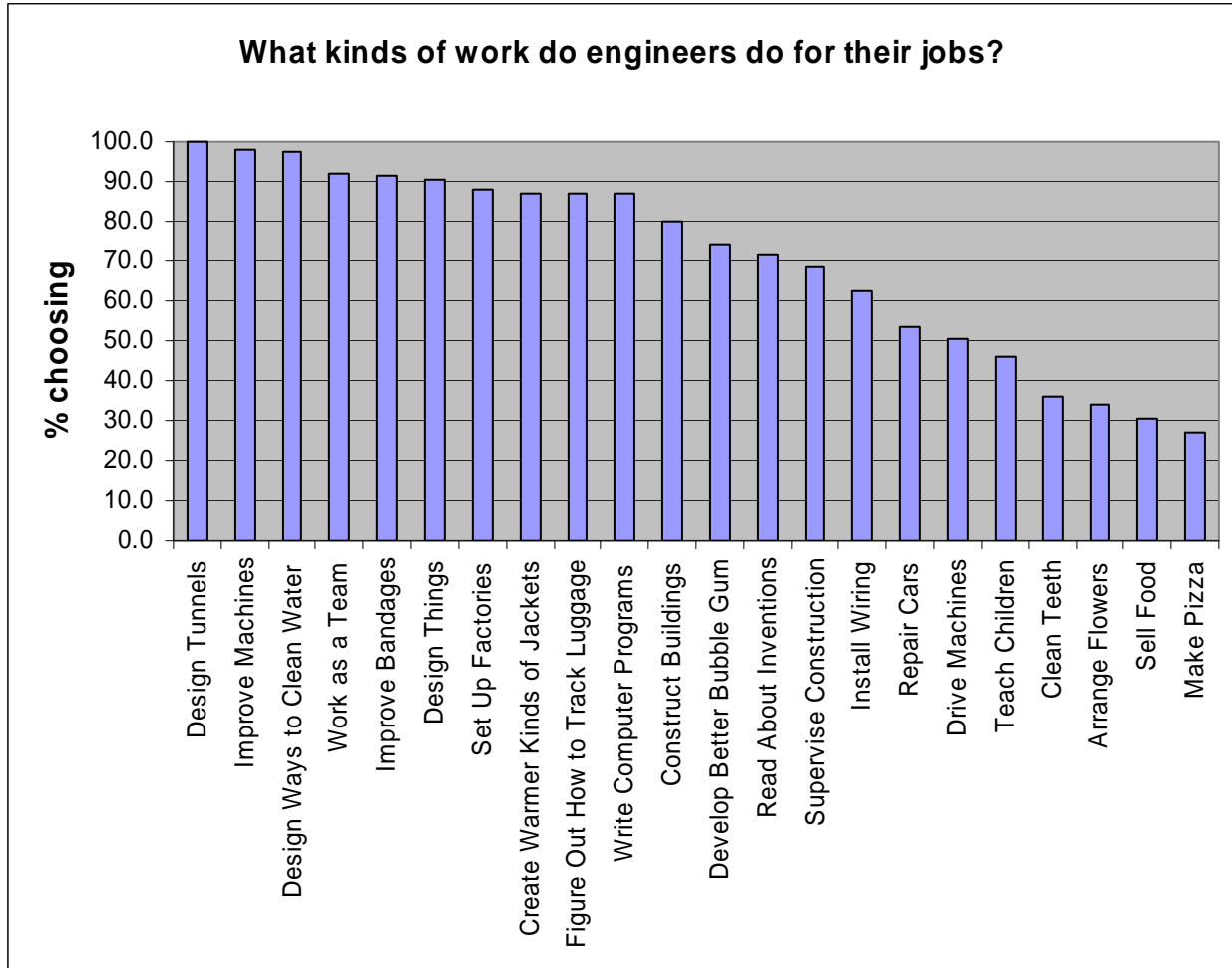
### **What is Engineering?**

“Engineer” is defined at <http://www.wordreference.com> as “a person who uses scientific knowledge to solve practical problems”. On their website, ASEE says that “Engineers are problem solvers who search for quicker, better, and less expensive ways to use the forces and materials of nature to meet today’s challenges.” (cite: [http://www.engineeringk12.org/students/what\\_is\\_engineering/default.htm](http://www.engineeringk12.org/students/what_is_engineering/default.htm)). These definitions are broad in the sense that they can include many different fields for “problems” or “challenges” involving human convenience, human needs, knowledge of chemistry, biology, or physics. These definitions also suggest constraints on the sorts of work that engineers do; they use “scientific knowledge” or knowledge of “the forces and materials of nature” to solve “practical problems” or “today’s challenges”.

We have found, when we ask students and teachers to identify the kinds of tasks that engineers do for their work, they often have ideas that are congruent to the definitions supplied by the dictionary or by ASEE. Unlike their students [10], teachers were much more able to identify which tasks were those an engineer would conduct. Over 90% of teachers correctly identified that engineers might design tunnels, improve machines, design ways to clean water, work as a team, improve bandages, or design things. Over 80% of teachers indicated that engineers set up factories, create warmer kinds of jackets, figure out how to track luggage, and write computer programs. Teachers responding in this way seem to understand that engineers design and improve technological solutions to human problems. As some teachers explained in response to the open-ended question on this assessment, an engineer is a person who: “uses materials and ideas to help man;” “designs new things;” or “designs or works on inventions in our lives that help us.”

However, many teachers do hold common misconceptions about the work of engineers. The most common misconception (held by 80% of teachers) is that engineers construct buildings (illustrated, on our instrument, by a construction worker using a riveter on the frame of a steel building). In fact, teachers were more likely to believe that engineers construct buildings than that they supervise the construction. Over half of the teachers held other misconceptions that

mirrored those of their students—that engineers install wiring, repair cars, and drive machines. Teachers, like students, are very likely to believe that engineers are the people who construct and repair technology. Some of these teachers explained that engineers: “design and build bridges, roads and tunnels;” “operate or supervise technical equipment”.



Between 25-35% of teachers also selected that engineers clean teeth, arrange flowers, sell food, and make pizza—tasks that are not performed by engineers at work. All the teachers who chose these options selected most, if not all, of the 16 items presented. In working with teachers in professional development workshops, we always ask teachers to answer this question aloud, and we have had many responses that indicate why. First, some teachers have the understanding that “engineers design things”. What they mean by “design”, however, is very broad – hence the answers “arrange flowers” or “make pizza”. As one of these teachers answered in response to the open-ended question at the bottom of the page asking what engineers do for their jobs: “If they build, design Anything!” Another explained that an engineer “works with design materials and improvises on them or designs materials.”

A third misunderstanding that teachers appear to hold is that engineers are people who use any sort of technology for their work. This leads them to believe that pretty much anyone is an engineer—as these teachers explained, after choosing most or all 16 options, an engineer: “uses

technology to create/work.” “Uses mechanical instruments as a main way to get a job done, esp design and construction project.”

A less common misunderstanding that would lead teachers to choose most or all of the options is that “engineer” is the term for any sort of specialist. This misconception may be fostered by common usage of such terms as “sanitation engineer” for trash collectors. As one teacher wrote, an engineer is a person who: “plans and directs certain jobs in a skillful way, a specialist in some area.”

Seventy-five teachers completed written responses to the open-ended question “An engineer is a person who...”. These responses were coded; up to five codes were assigned per response. Coding revealed that 65% percent of the respondents identified engineers as people who design or improve technologies, come up with new ideas, draft plans, and/or work toward goals. The next most common response, mentioned by 47% of respondents, referred to how engineers work: using their knowledge or skills in engineering, problem-solving, imagination, science, math, materials, teamwork, how things work, and/or the use of tools. An example of this kind of response: “someone who applies laws of mechanics, theories, aspects of science”. Twenty five percent of teachers indicated their perception that engineers solve (human) problems or improve life for people.

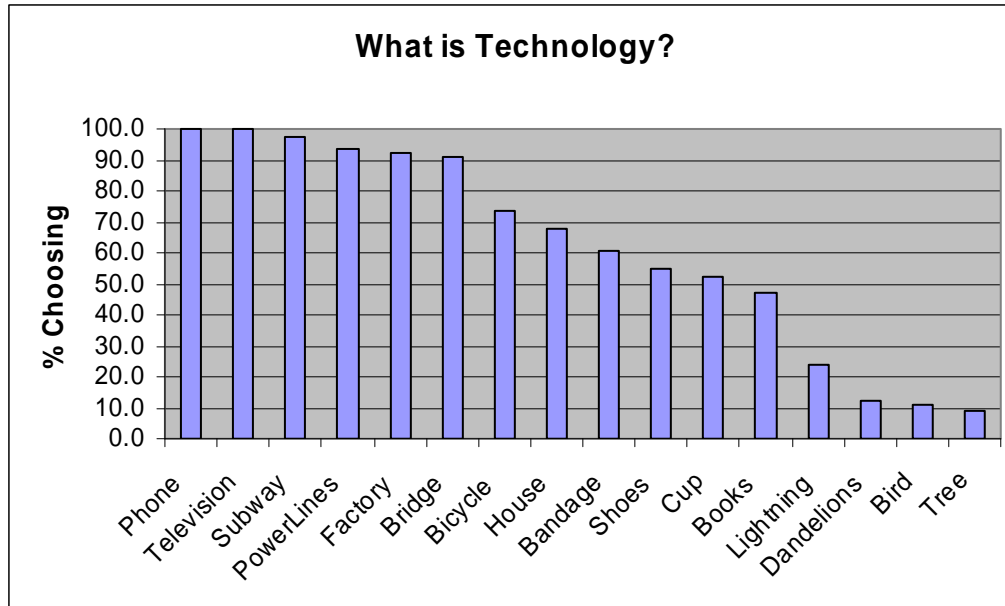
Almost as many respondents, 44%, indicated their misconception that engineers construct technologies, with some mentioning specific technologies such as infrastructure/construction. A few teachers responded that engineers fix technology (1%) or operate technology (4%). These misconceptions were expressed by nearly half of the teacher respondents.

Other, less common responses included references to the kinds of technologies that engineers work on (infrastructure, businesses—15%); features of engineers as people (educated, mechanically inclined, smart—11%); or their own self-knowledge or ways of knowing (I looked up the answer, I’m not sure, I’d ask them—5%). These kinds of responses are much more difficult to categorize—in some sense, they are all “correct”, but they are very limited ways of describing the work and characteristics of engineers. While these responses are not entirely incorrect, they show that these teachers, like many students, often focused on engineers as construction workers or technicians or focused on fields of engineering such as machines as a defining characteristic of engineering.

An engineer is a person who...	# people	% of respondents
(10) Respondent refers to features of engineer as a person	8	10.67%
(20) Respondent refers to self knowledge	4	5.33%
(30) Helps people/humankind	19	25.33%
(40) Designs/improves technologies	49	65.33%
(50) Constructs/makes technologies	33	44.00%
(60) Reference to object of engineer's work	11	14.67%
(70) Fixes technology	1	1.33%
(80) Operates technology	3	4.00%
(90) Respondent refers to how an engineer works	35	46.67%

### What is Technology?

All teachers identified a phone and a television as technology. Over 90% of teachers also indicated that subways, power lines, factories, and bridges are technology. Seventy three percent identified a bicycle as technology. Chosen by fewer teachers were the technologies house (68%), bandage (61%), shoes (55%), cup (52%), and books (47%). Interestingly, lightning was identified as a technology by almost a quarter of the teachers (24%).



Teachers' responses to the question "How do you know if something is technology?" illuminate some of the conceptions and misconceptions that people hold. The most common response (19% of responses) to this question was that technology meets a human need or makes life easier. However, almost as many teachers defined technology as involving computers, machines, or products that need power. Some teachers responded that technology was new or modern. And there was an interesting split as to whether technology was made of man-made materials or natural materials. A couple teachers also commented that technology could not be natural or living.

### What are some similarities and differences between science and engineering?

We coded teachers' responses to the questions "What are some similarities and differences between science and engineering?" Multiple codes could be assigned to each response. We found that the most common perception of the relationship between science and engineering (31% of respondents) was that engineering is, specifically, an applied science. As one teacher stated, "Science is the systematic study of the environment/living/nonliving things. Engineering is the application of science". Similarly, a sizable minority of teachers (12%) expressed the opinion that science is broader than engineering; that science includes engineering: "engineering is a branch of the broad category of science"; "engineering is a subgroup of the larger category of

science”. Other teachers answered that science and engineering have different purposes or goals (23%) or that they have different methods (20%). Some responses in these veins include: “science is the study of phenomenon and an inquiry into why things are the way they are. Engineering is finding solutions to problems that requires creative thinking.” “One (science) is for knowledge gain, the other is knowledge applied to solve problems to improve human life.” “Science studies things that happen. Engineering makes things happen.”

<b>What are some similarities and differences between science and engineering?</b>	<b># responses</b>	<b>% of respondents</b>
Engineering is applied science	20	30.8%
Science/Engineering have different purposes/goals	15	23.1%
Science/Engineering have different methods	13	20.0%
Science is broader than engineering/includes engineering	8	12.3%
Science/Engineering focus on different kinds of things to study/work on	4	6.2%
Science/Engineering have similar methods	4	6.2%
Science & Engineering work together	3	4.6%
Science & Engineering are the same/aspects of same field	2	3.1%

## **Discussion**

Not surprisingly, teachers are fearful about having to teach these topics. Interview data explore teachers’ expositions of their trajectories learning and teaching about engineering and technology.

One reason that teachers may have overly broad ideas about what engineers do for their work is that the definitions provided to teachers look vague to the non-specialist. For example, the Massachusetts Science and Technology/Engineering Curriculum Framework says that “engineering strives to design and manufacture useful devices or materials, defined as technologies, whose purpose is to increase our efficacy in the world and/or our enjoyment of it”. Such a definition might be construed as applying to the arts, the writing of history books, and “arranging flowers” by people who take “design” in the general sense, instead of in the specific sense of engineering design. Like adult confusion over what counts as “science”—evidenced by current debates over Intelligent Design—teachers, like all citizens, need to be educated as to what counts as “engineering”, whether professional or vocational.

Similarly, teachers’ sense of what counts as technology is often that of the non-specialist. Non-biologists often have a very different “sense” of what counts as a “fruit” than biologists do—a “sense” that grows from common usage in conversation and writing. In order for teachers to help students to understand the scientific definition of “fruit”, they need to know that definition and its ramifications. Similarly, many teachers have a “sense” of what counts as technology—some technologies, such as computers and cell phones, are more canonical examples than others. Without a specific definition a teacher’s idea of where to draw the line between “technology” and “not technology” can be murky indeed.

This paper reports results from a group of teachers who resided primarily in Massachusetts and who attended our professional development workshops. This year we are collecting well over 300 surveys of elementary school teachers from across the country from teachers who participated in our workshops. Although we have no specific reason to believe their responses will differ, to test generalizability of these results we will compare the results reported here from Massachusetts' teachers with those of the national population. Even so, the results may not be generalizable to all teachers; we are surveying a selected population of teachers who have chosen to attend our professional development workshops focused on engineering. These results could represent one tail of the teacher population—those who are already interested or intrigued by engineering. Nonetheless, these results of the research about teachers' conceptions and knowledge provide a starting point and should be valuable to anyone conducting professional development of teachers related to engineering and technology.

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