# 4th Grade Engineering – Building Upon the Curriculum of Science, Math, and Creativity to Inspire the Next Generation of Engineers (Evaluation)

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Proceedings of the ASEE 2019 Annual Conference
June 16-19, 2019, Tampa, Florida, USA

# 4TH GRADE ENGINEERING – BUILDING UPON THE CURRICULUM OF SCIENCE, MATH, AND CREATIVITY TO INSPIRE THE NEXT GENERATION OF ENGINEERS (EVALUATION)

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**Abstract**

*The standard fourth grade curriculum of math, science, and creativity (in the name of art, composition, and music) equips students with all of the basics that they need to do simple engineering activities. Over the course of the last several years, this principle has been leveraged at St. Thomas Aquinas School in East Lansing, MI to present students with a brief overview of the engineering profession. More than just a show-and-tell of the career, the "4th Grade Engineering" sessions have sought to immerse the students in engineering activities to actually let them experience many facets of the field in a hands-on fashion. During a fast moving period, the fourth graders get to try their hands at design, system analysis, lab testing, and collaborative thinking. All the while, subtle elements are incorporated into the presentation to promote the engineering profession as inclusive, creative, open to all genders, and a force for societal / humanitarian innovation. The initiative is motivated in part by a desire to attract a broader audience of potential engineering candidates to the profession, particularly from underrepresented populations. Because the format of the classroom activities pack a large amount of content into a short time span, the sessions can easily be replicated at other schools, fitting in and complimenting existing learning objectives without much schedule disruption.*

*This paper reports on the approach that has been taken for these "4th Grade Engineering" sessions, the content of the presentations, details on the in-class activities, and qualitative observations based on student and parent reactions. The paper seeks to answer the question of whether brief short span classroom interventions can impact student perceptions on the engineering career. Furthermore, survey results are included which seek to demonstrate quantifiably the impacts that the engineering outreach has had on the students over the past four years. A survey was administered to about 150 students; roughly half of which have participated in the in-class engineering activities and half of which have not. The questions were designed to gage how much impact the sessions have had regarding knowledge of and attitudes toward the engineering profession. Both objective and subjective question forms were utilized.*

**Motivation**

Writing on Dartmouth College's achievement of awarding more than half of its undergraduate engineering degrees in Spring 2016 to women, Dean of Engineering Joseph Helble stated "We need to educate increasing numbers of talented and creative engineers, drawn from all corners of society" [1]. That is absolutely true. To reach those far corners, recruitment of diverse engineering candidates cannot happen just during freshman year of college, or even during high school. Many researchers have demonstrated that perceptions of technical careers in general, and engineering specifically, are formed by students from a very early age. It was thus the intent of the authors to contribute to the reshaping of preconceptions early in the student's academic careers and to introduce entire classes of fourth graders to the engineering profession at a young age. The paper at hand documents those efforts and provides evidence as to the outcomes of those initiatives.

Engineers are an important part of our economy and work force. It is hard to point to any product, service, or human-made surrounding that we utilize in our everyday lives that was not touched by an engineer at some point during its design, manufacture, or distribution. In an age of growing fears regarding national competitiveness, rising technical complexity, and homeland security concerns, the ability to maintain a strong pipeline of promising candidates into the engineering profession is imperative. Yet, there continues to be a struggle to attract diverse populations to consider pursuing engineering as a career option. Moreover, engineering in general lacks the widespread awareness which is needed in order to have the career even be a consideration for young people beginning to make life choices. As our survey results will demonstrate later in this paper, most of the students involved with the efforts documented here report not knowing a single engineer and most cannot say what an engineer does. This is in the state of Michigan; a state that is in the top 25% of the country in terms of number of engineers and scientists per capita [2].

Both authors have a personal stake in the matter at hand as well. At the time this initiative was first conceived, both authors had young daughters currently in the fourth grade. One of the authors was the fourth grade teacher (specializing in math and science) at the school that this work has been trialed at, while the other is a professional engineer and former mechanical engineering professor. What began as a one-time trial to introduce the students to engineering has grown into an annual series.

**Preceding Investigations**

The engineering profession began with almost exclusively male practitioners and has been left to struggle with that legacy to present day. Cohen and Deterding point out that most professions began with few women among their ranks, but engineering is rare in its degree of retention of these effects [3]. The engineering workforce continues to suffer from a lack of diversity and gender inclusion with underrepresented groups appearing at much lower rates compared to the general population. As recently as 1995, the percentage of engineering degrees granted to women in the United States was just 17%. By 2004, nearly twenty years later, this number had barely budged, coming in at 21% [4]. Now, over another decade has past, and the latest numbers indicate progress has stalled, with only 21% of engineering bachelor's degrees going to women in 2016 [5]. Through the years, many have speculated that engineering schools suffer from a retention problem; students lose interest part way through their pursuit of an engineering degree. Contemporary evidence though suggests that engineering has a recruitment problem – the under-represented populations, particularly young women, never set foot in the engineering schools to begin with [3]. Dartmouth's accomplishment notwithstanding, there is still much work to be done in terms of attracting a broader audience to the engineering profession.

The dilemma of how to attract a larger and more diverse group of young people to the engineering profession has been debated and studied for years. To address these issues, countless outreach programs have been initiated to raise awareness of the engineering profession and to encourage students to consider it as a possible career path. A majority of these efforts to date have targeted high school students [6]. However, educational researchers have found that critical decisions made by students that could eliminate engineering as a career option are made much earlier. Children as young as middle school may begin down paths that will either prepare them or not for technical careers as they progress through their academics [7]. Moreover, many students, particularly girls, lose interest in subjects related to engineering – science, math, and technology – in grades as low as fourth through sixth [8], [9]. It is thus imperative that students in elementary school be exposed to the engineering profession simply to raise awareness of it being a viable career option, before their decisions remove it as a feasible choice.

It is simple to write off engineering as being an unappealing career to young people because of the traditional stereotyping of math and science being just for "nerds". However, researchers that have dug deeper found that engineering does not merely suffer from a lack of allure, it is more of a complete unfamiliarity with the field. Repeatedly, studies have shown that elementary school students are likely to conflate engineers with auto mechanics and construction workers [6], [10]. (The former is thought to be a result of word association; young children assuming that an *engineer* is one who works on *engines*.) Only a minority of those same students correctly identify an engineer as a professional who designs and creates things [6]. With such a lack of basic understanding then, it is not difficult to imagine why so few students start down roads that would lead them toward careers within engineering disciplines. Furthermore, other sciences such as biology, chemistry, and physics are taught as subjects in elementary through high school whereas engineering traditionally is not [3]. This only erodes engineering's pull even more.

**Survey of Students**

Following up on the research noted above, it was decided to evaluate the specific population of students at the school being studied in these outreach efforts. The results of this survey have further informed the introductory engineering activities planned for the students. In the fall of 2017, a brief survey was completed by 156 students enrolled in St. Thomas Aquinas School in East Lansing, MI. Those students in grades 4 through 8 answered predominantly open-ended questions with the intent of gauging the student's understanding and opinions of the engineering profession.

It is well documented that one of the strongest indicators of choosing a STEM profession is for a young person to personally know somebody already working in that field [3]. Whereas students regularly come in contact with teachers and doctors in their everyday life, and they see actors, athletes, and musicians in the media, unless they know an engineer or technologist, those professionals tend to be behind-the-scenes and out of the public eye for most young people. The first survey questions thus asked simply do you know any engineers and if so who. More than half (56%) reported not knowing any engineers. These results are interesting, because the state of Michigan as a whole has one of the largest per-capita populations of engineers in the country. Yet, the greater Lansing metropolitan area is a bit of an exception to that trend, with very few technology based employers. That is reflected in this data, with only 14 students reporting that their parents are engineers. The majority of those responding that they knew an engineer tended to cite a more distant relationship both in terms of bloodline and geography.

Many of the survey questions focused on student perceptions of what do engineers do, and what does it take to become an engineer. These questions illustrated a wide range of understanding on all related measures. Some students could explain quite accurately what engineers do, while others were way off in their descriptions. The typical conflations of engineering with auto mechanics and construction workers were well represented in student responses. It was widely understood by a majority of students that engineers needed to attend some form of advanced schooling to become an engineer, even if those details were vague.

Students were asked "What kind of special skills or talents do engineers need?" Of all of the questions posed in the survey, the responses to this question were the most accurate. Even those students that indicated very little understanding of what an engineer does still had a sense that knowing math and science are important to the field. These responses do highlight one cautionary note though. The three most common responses were knowledge of math, science, and in general being smart. These perceptions, although accurate in some sense, can be a means of students self-selecting themselves out of the profession. The survey responses can indicate that a student thinks not just that an engineer needs to be smart, but only *the smartest* person in the class is cut out to be an engineer. Similarly, not only are math and science important, but only *the smartest* student in our class at science and math can make a living doing it. Most practicing engineers would argue that creativity, problem solving, and team work are just as important as those other attributes, but the students have given those far less significance in their answers.

An interesting question asked of the students was whether they had ever participated in any engineering related activities. This was a bit of a trick question because it is known that at the time, at least two grade levels worth of students (about 40% of the total) had gone through the "4$^{th}$ Grade Engineering" sessions. Encouragingly, 89% of the students in those grade levels did report having some exposure to engineering, and some explicitly mentioned 4$^{th}$ Grade Engineering. Similarly, at this point, those same two cohorts had been participating in weekly STEM activities as part of the normal 5$^{th}$ grade curriculum which had recently been introduced. Only half (51%) of the students explicitly referenced the in-class STEM activities. 11% of students reported no engineering experience or that they were unsure of their experience. This could indicate that those students are not making the connection between the acronym "STEM" and the words "Science, Technology, *Engineering*, and Math".

A common mechanism by which to measure students' perceptions of a profession is to ask them to draw a picture of a person participating in that career [6], [10]. Subtle elements such as what gender the drawn figure is, is the person working alone, are they outside, are they using tools, and what the person is doing can all help fill in details on what the survey respondent perceives about a given job. Students were thus asked in this survey to draw an engineer. All of the instruction they received was “In the box below, draw an engineer doing their work”.

In published papers reporting on the use of this tool, students commonly stumble into two pitfalls. Students will often draw a car mechanic working on a car, or a person driving a train. Both of these are thought to be simple word associations. In one case, when asked to draw an “engineer”, it is interpreted as “one who works on engines”; i.e. a mechanic. In the other case, the alternate usage of “engineer” as a “train driver” is another logical conclusion. The St. Thomas Aquinas students were very likely to fall for the automotive mechanic trapping. In fact, drawing a person working on a car was the most common submission. The second most frequent appearance was trades people constructing buildings or houses. Those two alone accounted for nearly half (48%) of the drawings. Train drivers were much less prevalently drawn in this survey population.

The most striking tendency here was that even students which indicated a firm grasp of an engineer using science and math to design things or to solve problems through their previous answers still fell into the trap of sketching automotive technicians. This may simply be an outcome of students not knowing what “designing” or “analyzing” looks like, so they regress to sketching “fixing” which is better known to them. For all of the misrepresentations of the engineering profession noted above, there were a handful of sketches that were remarkably good. One of the best is shown here as Figure 1, depicting an engineer working on a computer, performing calculations on a white board, and displaying a design drawing on an easel. The coffee cup and what might be a diploma hanging on the wall really added to the accuracy of the picture.

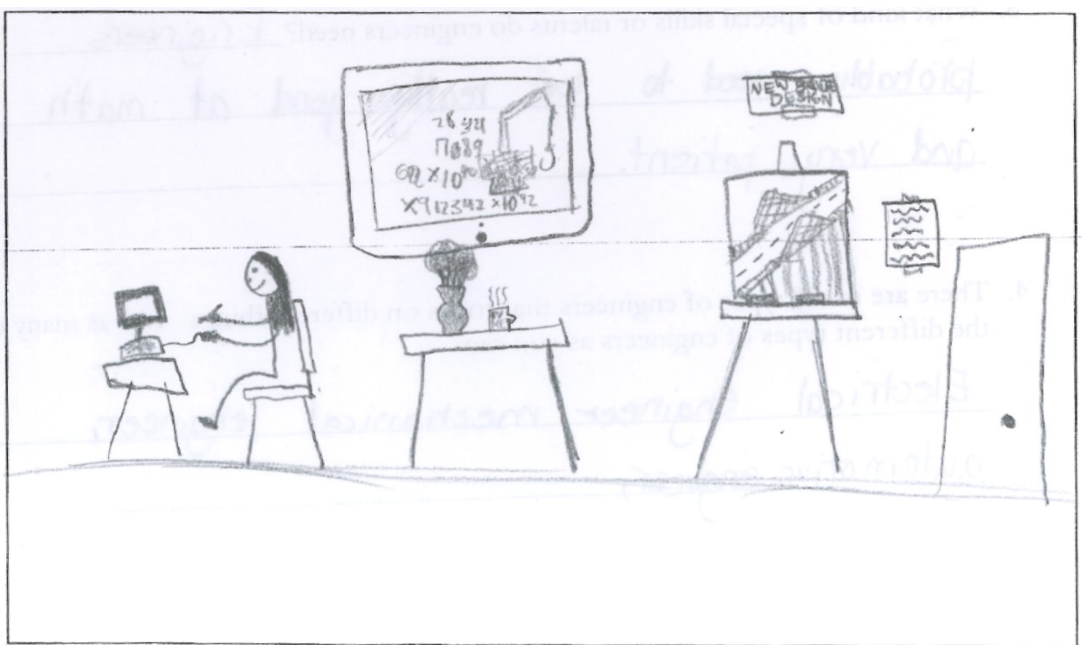

*Figure 1. Sample illustration submitted in response to the survey prompt “Draw an engineer doing their work”.*

Overall, the survey responses indicate a quantifiable impact that the “4$^{th}$ Grade Engineering” sessions and in-class STEM activities were having on students’ perceptions and understandings of the engineering profession. Compared to the students that were not exposed to those same engineering elements, their understanding of engineering related careers was more complete and accurate.

## In-Class Presentation Overview

The "4th Grade Engineering" sessions that are the subject of the paper at hand comprised just a single class period each year lasting approximately 1.5 to 2.0 hours. This is significantly less ambitious than the outreach programs that other authors have documented which extend to six or even eight sessions spread out over the course of an academic year [11], [12], [13]. At this point, this pilot project is in its fourth year, and the "4th Grade Engineering" classroom activity has been repeated 10 times for a total of approximately 150 to 160 students.

*Introduction to Engineering*

To directly address the already noted identity issue that engineering suffers from, the "4th Grade Engineering" sessions begin directly by answering the question "what is an engineer?" A broad definition is presented that "Engineers use creativity, science, and math to solve problems and make the world a better place." The discussion moves into a brief history lesson, describing how at the turn of the previous century, the profession of "engineer" as we know it today did not exist yet, so many of the inventors that they are already familiar with would be considered engineers today – Henry Ford, Thomas Edison, and the Wright Brothers. The students are told that the modern field of engineering is very broad, and this leads into a discussion of some of the major disciplines of engineering. Those discussed specifically include: mechanical, civil, electrical, chemical, biomedical, and manufacturing. For each discipline noted, a general overview of what those types of engineers focus on is provided along with some of the typical systems that they may design. The fields chosen were selected based on the most prevalent degrees awarded in recent years. Based on ASEE statistics, those six engineering disciplines accounted for more than two-thirds of the degrees awarded (65%) in the United States during the 2015 academic year [14]. (Also note that beyond these six disciplines, the remaining engineering types each individually account for less than 5% of the total degrees awarded.) The class is then told that many other fields of engineering are available that go beyond these basics, some of which are specializations of the categories already noted.

*Design Process and Concept Generation*

Immediately after the engineering profession has been introduced, the presentation moves quickly to having the students *do* engineering related activities. The early stages of the design process are introduced (namely the "problem statement" and "concept generation" phases) and the students dive into the process by being given a design task. A scenario is described in which they are working for a fictitious start-up company, and they need to design a machine to move and lift boxes from one conveyor system to another. The basic system is illustrated as shown in Figure 2 on the following page. The dark rectangle along the bottom of the figure represents the warehouse floor upon which their machine should sit. A box is sitting on one platform, and their machine needs to be able to move the box to the other platform in the upper left corner of the picture. This is actually based on a class project that was used in college level computer aided engineering courses when one of the authors was teaching sophomore level CAD/CAE [15].

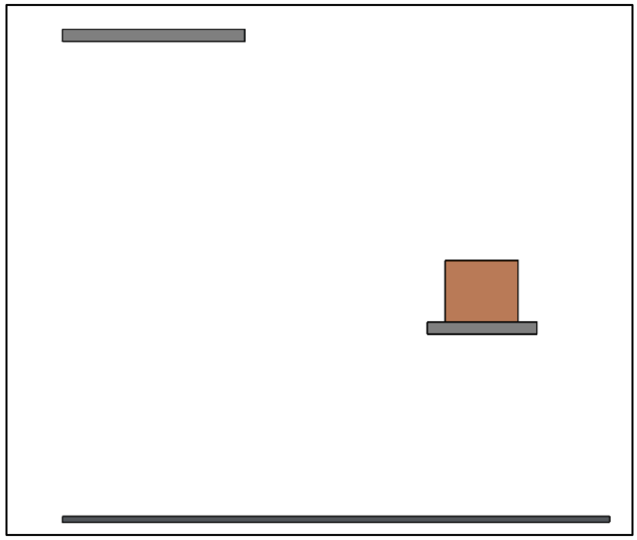

*Figure 2. Depiction of box handling system design task.*

The students are given 5 to 10 minutes to sketch a machine that they think will accomplish the task at hand. As they are working, they are encouraged to add in as many details as they can think of, and to add clarifying notations to help explain their design. The designs range in complexity, practicality, and creativity. Students have depicted conveyors, robotic arms, suction devices, teleportation systems, and many others.

At the conclusion of their design period, volunteers are asked to share their creations with their classmates, explaining how they plan to transport the boxes from platform to platform. The variety of solutions are pointed out to the class, emphasizing how diverse teams arrive at more varied solutions, and that there is no single "right" or "best" answer. (A notion that the students are not entirely comfortable with.) This segment wraps up by showing the class CAD generated computer animations that sophomore engineering students had created when working on this same challenge as an end-of-semester design project [15].

*Engineering Analysis*

The next two segments of the presentation are coupled together – engineering analysis and testing. The students are introduced to a system that consists of a wooden beam, with fixed supports at both of its ends, and a load supported from its midpoint. It is explained that this could very well be a component - a drive shaft, wrist pin, or support member of the box transport system that they just conceptualized. A schematic of the setup is shown below as Figure 3.

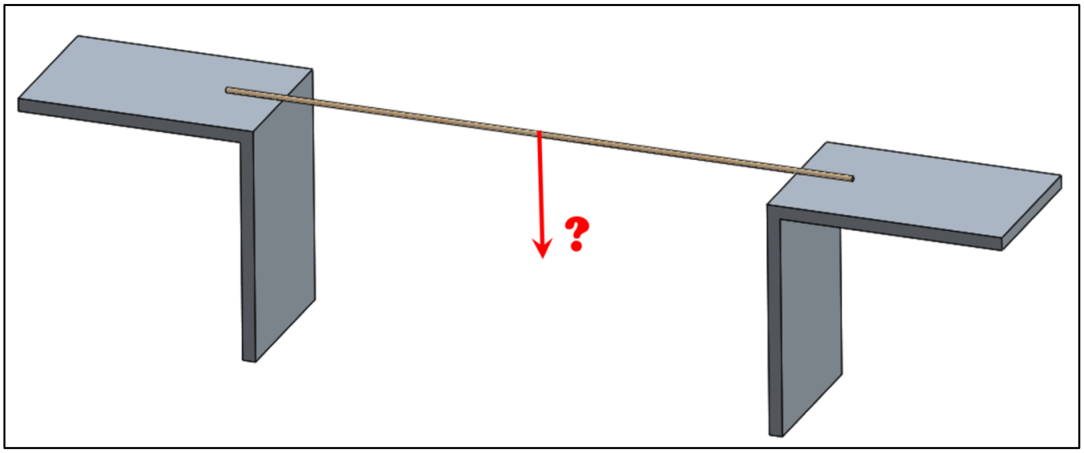


*Figure 3. Schematic showing the experimental setup that is the subject of the analysis and testing portions of the sessions.*

As suggested with the "?" that appears in Figure 3, the students are told that their objective is to calculate how much load will be required to fail the beam. Once the calculations are complete, then the physical test is conducted to see how close the predicted values have come to reality.

This opportunity is taken to describe to the classes briefly how engineers use science and math to derive equations that model physical systems. They are told that for a common loading scenario like this, an existing equation can be found in a textbook, which is then presented to them in the form of Equation 1 below.

$$\sigma \times \pi \times d^3 = 4 \times m \times \ell \times g \tag{1}$$

In this equation, **σ** is the bending stress or the strength of the material of construction in this context. Because a round wooden dowel is being used, **d** is the diameter of the beam. The mass required to fracture the beam is **m**, **ℓ** is the length of the beam between its two supports, and **g** is the gravitational constant.

As noted earlier, the fourth graders have already learned about variables in their math classes. Thus, most students find Equation 1 to be intimidating, but they understand the basic principle that each variable has a value. (A brief description of Greek letters is typically warranted at this point as well.) It is explained that we know the value of each variable except for the mass **m**, which is the value of interest, and when they learn about algebra in a few years, they will find out that any equation with just one unknown variable is preferable.

To keep the math at an accessible level for the fourth graders, some of the system parameters have been devised such that the arithmetic becomes relatively simple and the units are taken care of without consideration. For example, the beam is set up so that the length ℓ happens to be 1 meter. Other variables are rounded so as to maintain simplicity. The geometric constant pi is approximated as 3, the ¼ inch diameter beam (6.35 mm) is assumed to be 6 mm, and the gravitational constant is rounded to an even 10 $m/s^2$. The wooden dowels are sold as being made of oak. The strength of wood is inherently variable, but it has been found through the repeated running of this experiment that a strength value of 140 MPa for **σ** typically yields accurate results. With those values specified, Equation 1 reduces to Equation 2 below.

$$140 \times 3 \times 6^3 = 4 \times m \times 1 \times 10 \qquad (2)$$

With some guidance, the students have proven to be capable in performing the necessary multiplication operations to reduce the equation to:

$$90720 = 40 \times m \qquad (3)$$

With some algebraic help, the classes are told that the value of **m** can be calculated by performing the long division operation:

$$m = 40\overline{)90720} \qquad (4)$$

The final calculated result is that a mass of 2268 grams is predicted to fail the wooden beam. At every step of the way in the above development, all equations are carried out step-by-step on the white board in front of the class, lagging behind the point at which most of the students have already arrived at that step correctly on their own. All of the students are required to do their own work at their desks on paper. The first student to correctly calculate **m** is awarded with a prominent role in the next phase of the class session.

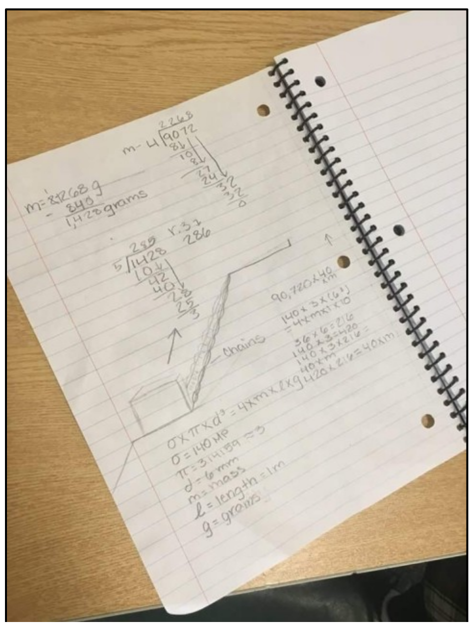

*Figure 4. Photo of a student's notebook showing both their concept generation sketches and engineering analysis work.*

*Testing*

The in-class activity then moves toward physically testing the system that was just analyzed. Students always respond well to this as they enjoy the hands-on aspect of the experiment, and breaking things is universally considered to be fun. For most of the students, this is the first exposure they have to the concept of destructive testing – learning from planned failures.

A steel can is hung from the center of the beam that is supported by two desks or two tables in the classroom. Wooden fixtures have been constructed to act as fixed beam supports at each end. These fixtures not only provide sturdy anchoring points for the beam loading, but they also incorporate steel eye bolts just big enough to tightly grip the wooden dowels. The steel can has heavy-duty magnets affixed to its bottom to not only provide added mass, but also to help contain the rest of the load ballast in the can. Altogether, the can, magnets, and support wire contribute a mass of 840 grams to the beam loading. The class is told that the remainder of the mass will be made up of steel ball bearings. A representative bearing has been evaluated to have a mass of 5 grams (rounding slightly like before). The students are asked to do the arithmetic, finding how much of the total required mass needs to be made up from the bearings, and then how many bearings are required to put in the can. In the end, it is determined that approximately 286 bearings are needed.

The student that first calculated the required mass during the analysis section of the presentation is brought to the front of the room. All students are fitted with safety glasses, which contributes to the experimental atmosphere of the proceedings and adds a perceived element of danger. Each student has counted out 20 bearings into their own plastic cup, and then in turn, brings that cup up to the front of the classroom for the lead student to pour into the can hanging on the beam. This process gives all of the students a chance to be involved with the experiment, and it slows things down enough to allow for time to point out how the beam is deflecting and to make observations such as listening for the creaking of wood indicative that failure is imminent.

*Figure 5. Photos of students counting steel bearings to load the wooden beam with during the testing portion of the class session.*

Most of the time, the beam will break in a fairly dramatic fashion. The wood tends to tear apart under the critical load at a speed that is fast enough to be exciting to watch, yet not so fast as to happen instantaneously. Once the beam breaks, the loaded can at the center of the dowel crashes to the floor with a loud thud, and most of the bearings remain contained within, owing to the magnets.

During the numerous times that this experiment has been run in the classroom, quite a bit of variation has been observed in how close the initial calculated mass value is to the real-world critical load. This is to be expected when taking into consideration the variability of the natural wood material, the size and shape variations of the dowels, and the amount of rounding that went into the calculations. Beams have failed at light loads of 100 or less bearings, while others have survived beyond the collection of 500 bearings that are on hand. Quite a few times the experimental result is within +/- 10% of the calculated values. In any case, the results provide a topic of discussion immediately after the proverbial dust has settled from breaking the beam. For those cases where the math has predicted the experimental value well, it is a good time to recap all of the science and math that led to that determination. In cases where the prediction was way off, it is an opportunity to discuss the sources of error (many just noted here) that likely contributed to the discrepancies. This is usually followed up by an observation that civil structures are rarely constructed from wood anymore in part due to its variability compared to metals or engineered concrete.

An important point is made as to why the analysis was required at all. Students have often asked some variation of "why not just do the test and skip the math"? A brief discussion covers how in a real design setting, it is impractical to test all systems to failure. For example, nobody is going to build a suspension bridge and load it until it fails before building another bridge to be put into service.

The conversation circles back around to the engineering design cycle that initiated the hands-on activities. Documentation and implementation phases are briefly described before moving on to concluding remarks.

*To Learn More*
At this point during the session, excitement levels in the classroom are high, and most of the kids are eager to run another experiment (which there is typically not time for). This enthusiasm is leveraged toward pointing the students to further opportunities that they can pursue on their own to learn more about engineering and to participate in engineering related activities. Returning to a traditional lecture style format, a series of ideas are provided to the class. The students are told about weekend and summer engineering camps run by the local college of engineering. Television shows like "Mythbusters", "Modern Marvels", and "How It's Made" are discussed as showcasing engineering topics in an entertaining manner. The engineering aspects of some of their toys that they already have including Legos, K'Nex, and Tinker Toys are pointed out to them. Finally, some regional engineering destinations that students can visit with their families are highlighted – science labs that offer tours, factories that have visitor centers, and STEM related museums in the area are highlighted.

**Subtle Inclusions**
Drawing from the literature that addresses what should be done to attract a broader population to the engineering profession, the content of "4th Grade Engineering" has been carefully assembled to include subtle cues to that effect without ever explicitly mentioning any of them. For

example, during the introductory presentation that gives an overview of what an engineer *is*, that is taken as another opportunity to frame what an engineer *looks like* whenever photographs of engineers are shown. As such, more women engineers are shown throughout the slides than men, and across genders, those engineers pictured also represent a diverse range of ethnic backgrounds.

To that same point, researchers have noted the significance of having female engineering mentors involved in their outreach efforts citing the greater effectiveness at reaching out to young women. This can be current female engineering students, graduate students, or practicing engineers [13]. Doing so offers yet another subtle element to help reshape the perception of engineering like those noted above with the benefit of providing the elementary students with role models. Beginning in the third year of these initiatives, young women that are professional engineers just a couple of years out of college were invited to take part in the "4th Grade Engineering" sessions. Their involvement has had obvious impacts on the overall effort, with students reacting well to their stories and participation.

In a similar fashion, with the discussion of each engineering discipline comes another chance to answer the question "what do engineers do"? All too often in the past, engineering has been marketed to young white males by showcasing engineers as the designers of racecars, robots, and roller coasters. In the presentations used in the fourth grade classrooms, the subject matter for engineering is intentionally drawn from all aspects of life. Electrical engineers are shown designing the newest iPhone, mechanical engineering is depicted through wind turbine optimization, biomedical engineers are shown developing artificial limbs for amputees, and food production is presented as an application of chemical engineering. Moreover, all engineering disciplines are portrayed as a means toward accomplishing humanitarian initiatives – energy efficient devices, cultural development, public health and safety, and environmental impact. What was intentionally omitted from the conversation was the well-worn selling point that "engineers make a lot of money". Referring again to Dean Helble's op-ed, he writes "What we sought to create instead was an environment and a culture that exposed the broadest and most diverse group of students – male and female – to the beauty of engineering as a way to tackle the world's challenges" [1].

Finally, engineering is presented throughout the session as a career path that is accessible. Students need to hear that becoming an engineer is not a one-in-a-million shot like becoming a professional athlete or a pop star. This is done by pointing out all of the engineering colleges in the nearby vicinity. (East Lansing is fortunate to not only be the home of Michigan State University, but it is also within a one hundred mile radius of at least a dozen other engineering colleges.) Accessibility is further demonstrated by highlighting the engineering opportunities available to the students in the form of summer camps, engineering related places to visit in the state - science museums, assembly plant tours, and weekend engineering experience days hosted by some of the local engineering schools. Lastly, the fourth graders are told that many of the toys they are already playing with - Legos, Tinker Toys, K'Nex – are also very much in line with preparing them to become engineers.

In the least subtle pitch for the engineering profession throughout the entire presentation, "4th Grade Engineering" ends by displaying a quote that appears on the wall of the Michigan Science

Center in Detroit – "Engineers are not born…they are inspired" (see Figure 6). A fourth grader is well aware of what it means to be inspired.


*Figure 6. Inspirational engineering mural that hangs in the Michigan Science Center – Detroit, Michigan.*

**Lessons Learned**

The "4$^{th}$ Grade Engineering" sessions are currently in their fourth year. As with any repetitive activity, lessons have been learned through the years and the effort has evolved accordingly.

During the first iterations of the in-class lab activities, initially an attempt was made to get the students more involved with the experiment. The system parameters including the beam length, the beam diameter, and bearing masses were measured by the students in that pilot run. That seemed advisable because the students were learning about measuring and units in science at the time. However, only one or two students actually got the benefit of making the measurements during the class while the others just watched or lost interest. Additionally, the students were unfamiliar with the measuring devices, which slowed things down even further. Ultimately, it was decided to switch to providing the class with those values up front, and it appears to run much smoother in doing so.

With that being said, the students really enjoy taking part in the in-class experiment even if they do not all get a very active role. Between wearing safety equipment, intentionally breaking things in the name of science, and the suspense of whether the predicted values were calculated correctly, it all adds up to be an experience completely out of their routine classroom activities.

It has also been found worthwhile to do a certain amount of expectation setting before the analysis and testing activities. The fourth graders do not have a great deal of appreciation for the precision of a numerical answer. From most of their points of view, the predicted value is either right or it's wrong. Either the math was correct and the beam fails when loaded with exactly 286 bearings, or the math was wrong. This is now done by asking the class up front how many of the little steel ball bearings would need to be loaded on to the beam in order to break it. Their answers indicate, and understandably so, that they have no idea even what order of magnitude to guess. Their answers may range anywhere from 10 to 1,000,000. It is then emphasized in the end that the math predicted a value that was within 50 or 75 or whatever the error is for that specific experiment. The math and science based approach may not have arrived at *exactly* the right answer, but it yielded an estimate in the correct ballpark.

**Future Directions**

Experience has shown that one session is simply not enough to make a strong connection with the students. Engineering could certainly be showcased in a more comprehensive, less superficial manner if more class time could be devoted to the engineering class periods. However, within the confines of an already tight academic calendar and strict curriculum standards that must be adhered to, it is not trivial to squeeze any more content into the agenda. Perhaps a manageable middle step to growing the program would be to do single-session follow up engineering lectures similar to the fourth grade sessions already in place, but have one in fifth grade, and another in sixth, and so on. This would enable the benefit of reinforcing ideas that were already introduced in previous years while simultaneously accommodating the higher-level curriculum content of those higher grade levels. These possibilities are just now beginning to be explored.

Furthermore, it pays to recognize that none of the things mentioned in this paper are occurring in a vacuum. There are plenty of STEM efforts already underway at the school. Currently, these are all related, but not coordinated, activities. Coordinating the existing STEM initiatives and the proposed engineering specific content would be another way to enhance the effectiveness of each activity.

**Conclusions**

This paper has presented an effort that has been underway for several years to attract under-represented populations to the engineering profession by way of short in-class hands-on sessions performed with fourth grade classes. Fourth grade was chosen intentionally as the target age demographic since it offers the advantage of children having enough basic math and science background in order to do elementary engineering calculations, yet it is still early enough in the students' academic career to enable them to move towards a career in engineering if that becomes something that interests them. The students have responded well to the engineering content that builds upon the fourth graders' pre-existing math and science curriculum. Sufficient detail has been shared here regarding the activities done in the classroom to replicate the effort at other schools with little needed in the way of physical materials to do so. As with any classroom content, there exists room for improvement, and suggestion have been made as to how to make the "Fourth Grade Engineering" sessions more successful in their primary goal – to attract a larger, broader audience of candidates to the engineering profession.

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