Influencing Elementary Students Perceptions about the Work of an Engineer

Juliana Utley, Drew Gossen, and Toni Ivey
Oklahoma State University

Abstract

Most of pre-college engineering curricula is designed to increase students' understanding of engineering and change their perceptions about the work of engineers. The purpose of this study was to explore students' potential changes in perceptions of the work of engineers after participating in Engineering is Elementary (EiE™) curriculum and instruction. While findings revealed a significant increase in students' conceptions of engineering with large effect sizes for general knowledge of what is engineering and what is technology, the influence on students' conceptions about the work of an engineer, as measured using the modified Draw an Engineer Test (Thomas, Colston, Ley, DeVore-Wedding, Hawley, Utley, and Ivey, 2016), and how engineers use mathematics was a small effect. These results suggest that the use of a single EiE™ curriculum unit with elementary aged students can significantly enhance students overall understanding of the work of engineers; however, does not have as much impact on their perceptions of how engineers apply mathematics in their work and the depth of their knowledge about the work of engineers is not as strong.

Key Words:

Elementary Students, Pre-College Curriculum, Conceptions of Engineers

Introduction

There is a growing call for increasing the role of engineering in school curriculum alongside the disciplines of science, mathematics, and technology. The inclusion of engineering is based on the need to advance innovation in the United States, produce capable and creative graduates who can excel in STEM fields, and improve technological and scientific literacy among all students regardless of their eventual occupation (Honey, Pearson, & Schweingruber, 2014). Additionally, with the advent of the Next Generation Science Standards (NGSS) and the subsequent adoption of NGSS or modified versions of NGSS by many states, engineering practices have become a part of the science curriculum (NGSS Lead States, 2013). This addition has increased students' opportunities to develop the skills that are necessary to meet the demands of a competitive STEM college degree and career.

Many adults and children do not demonstrate an awareness of what engineering is as a profession. Students' portrayal of engineers often reveal that they don't have an understanding of what engineers do (Gibbons, Hirsch, Kimmel, Rockland, & Bloom, 2004). The reasoning behind student conceptions is complex, but often forms because of a personal connection to an engineer or to how they see engineers portrayed in the media (Bevins, Brodie, and Brodie, 2005). The Draw-an-Engineer-Test (DAET) has been widely used to gain an understanding of student conceptions of engineers (Knight & Cunningham, 2004), and it can be an effective tool to assess how interventions affect engineering awareness in students. This study uses the mDAET, a modified version of the DAET, which provides a tool to help us further understand students' conceptions of engineering (Thomas, Colston, Ley, DeVore-Wedding, Hawley, Utley, and Ivey, 2016).

Therefore, there is a need to gain a deeper understanding of what influences young students' conceptions of engineers as well as whether they are malleable. Teachers can choose from a variety of engineering education curricula for use in their classroom. Most of these curricula are designed to increase students' understanding of engineering and change their perceptions about the work of engineers. Thus, the purpose of this study was to explore students' potential changes in perceptions of the work of engineers after participating in Engineering is Elementary (EiE™) curriculum and instruction. The research question guiding this study was: How does EiE™ curriculum influence student understanding about the work of an engineer?

Background Literature

The use of the DAET has revealed a set of misconceptions that students have about engineering and engineers. Students often do not correctly describe the work of an engineer, they have gender biases, and they cannot connect the use of science and mathematics accurately to engineering. The following section provides a brief review of the research literature that is pertinent to this study. First, we examine misconceptions about engineering. Second, we explore different engineering education curriculums for use in the elementary classroom. Finally, we examine the use of drawings to explicate student understanding of engineering.

Student Misconceptions about Engineers. Trevelyan (2019) states that "engineers are people with technical knowledge and foresight who conceive, plan, and organize delivery, operation, and sustainment of man-made objects and systems. These objects and systems enable people to do more with less effort, time, materials, energy, uncertainty, health risk, and environmental disturbances" (paragraph 5). However, many elementary students struggle with understanding what the work of an engineer actually entails. Common descriptions depict engineers as fixers, mechanics, laborers, or technicians, while only a small percentage of students describe engineers as designers (Capobianco, Deemer, & Lin, 2017; Capobianco, Diefes-dux, Mena, & Weller, 2011; Chou & Chen, 2017; Newley, Kaya, Yesilyurt, & Deniz, 2017; Reeping & Reid, 2014). Additionally, students tend to represent engineers predominantly as males rather than females or groups working together (Chou & Chen, 2017). These misunderstandings about the work of an engineer are common among students who have received little to no introduction to engineering in school. The majority of the conceptions students have come from the media, where there are few good examples of engineers, or from contact with family or adult friends who are engineers (Bevins, Brodie, & Brodie, 2005; Chou & Chen, 2017; Jacobs & Scanlon, 2002).

Interventions. The lack of accurate conceptions about the work of an engineer along with the absence of good engineering models for students provides a rationale for programs that introduce engineering concepts in the schools. There are many programs that provide engineering curriculum to elementary students, such as Engineering is Elementary™ and iSTEM™, that show promise in increasing student awareness about the work of an engineer and the engineering design process. Some studies introduced interventions that increased students' views of engineers as designers and the overall work of an engineer (Capobianco et al., 2017; Farland-Smith & Tiarani, 2016). Other work demonstrated the ability of engineering curriculum to help students learn how to use the engineering design process, but not necessarily improve student conceptions about the work of engineers (Hammack, Ivey, Utley, & High, 2015; Douglas, Moore, Johnston, & Merzdorf, 2018).

Use of Drawings to Explicate Student Understanding. Due to an array of misconceptions held by students, it can be difficult to measure students' perceptions about the work of an engineer. While many instruments are available for this task, the Draw-an-Engineer-Test (DAET) has been used in many studies because of its ability to discern the tasks and environments that make up the work of an engineer in students' minds. Part of the usefulness of this tool is that it allows for interpretation of students' thoughts about the use of math and science in engineering, the role of gender and collaboration, and what an engineer does (Capobianco et al., 2011; Chou & Chen, 2017; Farland-Smith & Tiarani, 2016; Newley et al., 2017). The current study uses the modified Draw-an-Engineer-Test (mDAET) (Thomas, Colston, Ley, DeVore-Wedding, Hawley, Utley, and Ivey, 2016), which expands on the DAET by increasing the number of drawings collected and providing a specific scoring rubric.

Additionally, the work of engineers involves the application of science and mathematics as creative tools they use to design and develop economical solutions to global problems that benefit society. While many design challenges attempt to integrate the STEM subjects, there is often not sufficient application of each subject, and math especially is not emphasized regularly (Honey et al., 2014). Furthermore, design challenges are sometimes prepared in a way that do not require students to use any science or math content, and do not promote learning of new science or math content (Fortus et al., 2004; Mehalik et al., 2008). As a result, students lack an understanding of the connection between the subjects and instruction that does not explicitly point out this connection will result in a lack of understanding of the role of mathematics and science in the work of engineers (Guzey et al., 2016).

Context for Study

As a part of the Rural Readiness for Engineering Education (RREE) project, authors engaged 20 elementary (grades 2 - 5) teachers from the state's most comprehensive regional education cooperative that includes 15 school districts across several rural counties, many with high Native American student populations in a one-day engineering education workshop. The workshop followed the prescribed *EiE* 6-hour workshop format indicated in their professional development materials. To assist in the easy integration and eventual adoption of the materials, researchers selected *EiE* kits matched to Oklahoma grade-level science standards. The teachers were split into two groups where second and third grade teachers received training on the *Best of Bugs: Designing Hand Pollinators* (n = 7) and the fourth and fifth grade teachers received training on *Water, Water Everywhere: Designing Water Filters* (n = 13). Although the kits were different according to training session and grade level, it is important to note that *EiE* workshops emphasize that although the science content may change from one *EiE* curriculum kit to the next, the philosophies behind understanding the nature of technology and the engineering design process are consistent across kits. Further, each *EiE* curriculum kit follows the same structure, which makes it easy for teachers to learn one kit and then translate this knowledge to another. Additionally, during the workshop session, all teachers participated in introductory activities designed to insure teachers understood what is understood technology and the work of engineers. To maximize shared resources, the purchased kits and refill materials were made available for checkout at the Interlocal Cooperative so participating teachers could continue to implement the lessons with their students after the funding period. Following the workshop, the participating teachers received a stipend incentive for completing the *EiE*™ curriculum unit in their respective classrooms. Eleven teachers across six elementary schools taught their unit and allowed authors to collect pre-post assessments with their students.

Methods

Participants. Participants in this study included 174 rural elementary students from six different elementary schools. In terms of gender about half were male (n = 91; 52.3%) and half were female (n = 83; 47.7%). Students represented grades three (n = 62; 35.6%), four (n = 26; 14.9%), five (n = 75; 43.1%) and sixt (n = 11; 6.3%).

Data Sources. In order to assess changes in participants' understandings of engineering education, we utilized existing assessments from *Engineering is Elementary*™ curriculum kits. The *What is an Engineer?* (Capobianco, Diefes-dux, Mena, & Weller, 2011) instrument contains 19 yes/no items used to measure student understandings of the work of engineers. The *What is Technology?* (Lachapelle, Hertel, Jocz, & Cunningham, 2013) contains 20 pictures that instructs students to circle items that represent technology and is used to measure student understanding of technology, the human-designed world. Additionally, students completed the modified Draw an Engineer Test (mDAET; Thomas, Colston, Ley, DeVore-Wedding, Hawley, Utley, and Ivey, 2016). The mDAET includes both a drawing and narrative responses. On a legal-sized piece of paper divided into thirds (horizontally), students were prompted to draw a picture of an engineer at work. Then, students responded to four questions related to providing a narrative about what the engineer is doing, how they are using math and science, and to describe the gender of the engineer. Next, students repeat this process two more times.

Data Collection and Analysis. In order to maintain continuity in data collection, a graduate assistant collected data from all classrooms. Pre- and posttests were conducted around EiE™ curriculum delivered by the classroom teachers. A percent correct score was calculated for the What is Technology? and What is Engineer? instruments. Researchers scored student drawings using the mDAET rubric (Thomas, Colston, Ley, DeVore-Wedding, Hawley, Utley, and Ivey, 2016) that includes four criteria measured along a continuum including work of an engineer (0-3), gender stereotypes (0-3), use of mathematics (0-2), and use of science (0-2). The Shapiro-Wilk test of normality revealed all data sets were not normally distributed thus the non-parametric Wilcoxon Signed-Rank Test was used for all analysis.

Findings

Results of the Wilcoxon Signed-rank Test revealed a statistically significant increase in students' conceptions of engineering (see Table 1). Examination of the effect size of results revealed a large effect in students understanding of both technology and for what engineering encompasses through the What is Engineering? instrument and the overall mDAET. However, effect sizes for the conceptions of the work of an engineer and how engineers use mathematics had only a small effect. These results suggest that while the use of a single EiE™ curriculum unit with elementary aged students can significantly enhance students overall understanding of the work of engineers; however, particularly for how engineers apply mathematics in their work is not as strong.

Table 1

Summary statistics for students' (n = 174) pre- and post-measures

	Pretest			Post Test			Z	p	r
	Min	Max	Mdn	Min	Max	Mdn			
What is Engineering?[1]	5.26	78.95	47.50	5.26	100.00	68.42	-10.254	<.001	.78
What is Technology[1]	35.00	100.00	45.00	25.00	100.00	97.5	-10.010	<.001	.76
mDAET – Overall[4]	0.33	5.67	2.33	0.67	8.00	3.00	-6.868	<.001	.52
Engineering Conceptions[2]	0.00	1.67	0.50	0.00	2.67	0.67	-2.933	.003	.22
Gender[2]	0.33	2.33	1.33	0.33	3.00	1.67	-6.016	<.001	.46
Use of Math[3]	0.00	1.67	0.33	0.00	2.00	0.33	-2.615	.009	.20
Use of Science[3]	0.00	1.67	0.00	0.00	1.33	0.33	-4.985	<.001	.38

[1]Percent correct scores; [2]Scores and range from 0 to 3: [3]Scores range from 0 to 2; [4]scores range from 0 to 10

Summary and Conclusions

This study provides a quick look at the impact of students' perceptions about the work of engineers using drawings and questionnaires. Results indicate some promise for the use of a single engineering education curriculum unit to expose and increase understanding of elementary aged students from rural communities about the work of engineers that do not typically have exposure to engineers in their daily lives. This is critical, as research has shown that the development of interest in STEM fields including engineering by the eighth grade increases the likelihood that students will pursue a STEM career in college (Maltese & Tai, 2010).

While this study revealed a significant increase in students' perceptions of the work of an engineer, the question remains about whether this increase sustained across time. Thus, additional studies should be conducted that not only measures influence pre to post intervention but also at an additional point after the intervention has been over for a period of time. Future analysis should explore whether the particular kit they were taught has an impact as well as the fidelity and quality of implementation of the curriculum. Additionally, research should explore whether there was any impact differences based on gender and grade level.

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References

Bevins, S., Brodie, M., and Brodie, E. (2005). "*A study of UK secondary school students' perceptions of science and engineering*." Paper presented at the European Educational Research Association Annual Conference, Dublin.

Capobianco, B., Deemer, E., and Lin, C. (2017). "Analyzing Predictors of Children's Formative Engineering Identity Development." *International Journal of Engineering Education, 33*(1(A)), 44-54.

Capobianco, B., Diefes-dux, H. A., Mena, I., and Weller, J. (2011). "What is an engineer? Implications of elementary school student conceptions for engineering education." *Journal of Engineering Education, 100*(2), 304-328.

Chou, P., and Chen, W. (2017). "Elementary school students' conceptions of engineers: A drawing analysis study in Taiwan." *International Journal of Engineering Education, 33*(1), 476-488.

Cohen, J. (1988). "*Statistical power analysis for the behavioral sciences* (2nd ed.)." Hillsdale, NJ: Lawrence Earlbaum Associates.

Douglas, K. A., Moore, T. J., Johnston, A. C., and Merzdorf, H. E. (2018). Informed designers? Students' reflections on their engineering design process. *International Journal of Education in Mathematics, Science and Technology, 6*(4), 443-459. doi:10.18404/ijemst.440347

Farland-Smith, D., and Tiarani, V. (2016). "Eighth grade students' conceptions of how engineers use math and science in the field of engineering: A comparison of two cohorts." *Journal of Education and Training Studies, 4*(10), 182-192. doi:10.11114/jets.v4i10.186

Gibbons, S. J., Hirsch, L. S., Kimmel, H., Rockland, R., and Bloom, J. (2004). "*Middle school students' atttudes to and knowledge about engineering"*. Paper presented at the International Conference on Engineering Education, Gainesville, FL.

Guzey, S. S., Harwell, M., Moreno, M., and Peralta, Y. (2016). "The impact of design-based STEM integration curricula on student achievement in engineering, science, and mathematics." *Journal of Science Education and Technology, 26*(2), 207-222.

Hammack, R., Ivey, T., Utley, J. an High, K. A. (2015). "Effect of an engineering camp on students' perceptionso fengienering and technology." *Journal of Pre-College Engineering Education Research (J-Peer), 5*(2), 10-21.

Honey, M., Pearson, G., and Schweingruber, H. A. (2014). "*STEM integration in K-12 education: Status, prospects, and an agenda for research*." National Academies Press Washington, DC.

Jacobs, B. J., and Scanlon, C. (2002). "*Perceptions of Engineering-too little too late."* Paper presented at the 13th Annual Conference & Convention of AAEE Canberra.

Knight, M., and Cunningham, C. (2004). "*Draw an engineer test (DAET): Development of a tool to investigate students' ideas about engineers and engineering."* Paper presented at the ASEE Annual Conference and Exposition.

Lachapelle, C.P., Hertel, J.D., Jocz, J., and Cunningham, C. M. (2013). "*Measuring students' naïve conceptions about technology."* Paper presented at the NARST Annual International Conference, Rio Grande, Puerto Rico.

Maltese, A. V., & Tai, R. H. (2010). "Eyeballs in the Fridge: Sources of early interest in science. International Journal of Science Education", 32(5), 669-685. doi:10.1080/09500690902792385

Newley, A. D., Kaya, E., Yesilyurt, E., and Deniz, H. (2017). "*Measuring engineering perceptions of fifth-grade minority students with the Draw-an-Engineer-Test."* Paper presented at the ASEE Annual Conference & Exposition, Colombus, OH.

NGSS Lead States. (2013). "Next generation science standards: For states, by states. (978-0-309-27227-8)." Washington, DC: The National Academies Press Retrieved from https://www.nap.edu/catalog/18290/next-generation-science-standards-for-states-by-states

Reeping, D., and Reid, K. (2014). "Student perceptions of engineering after a K-12 outreach--A STEM academy.*"* Paper presented at the 2014 ASEE North Central Section Conference, Rochester Hills, MI.

Thomas, J., Colston, N., Ley, T., DeVore-Wedding, B., Hawley, L.R., Utley, J. and Ivey, T. (2016). "Developing a rubric to assess children's drawings of an engineer at work." Proceedings of the 123rd Annual Conference & Exposition of the American Society of Engineering Educators, New Orleans, LA.

Trevelyan, J. (2019). "The making of an expert engineer: Questions and Answers with Author James Trevelyan: Blog – Redefined engineering." Retrieved from https://jamesptrevelyan.com/2019/05/08/redefining-engineering/

Biographical Information

Juliana Utley is a professor of mathematics education and serves as the director for the Center for Research on STEM Teaching and Learning. Her research interests include beliefs and attitudes of teachers related to STEM content areas, mathematical knowledge of teachers, and engineering education.

Drew Gossen is a science education doctoral candidate and graduate research assistant for the Center for Research on STEM Teaching and Learning at Oklahoma State University. His research interests include K-12 engineering education and science education.

Toni Ivey is an Associate Professor of Science Education at Oklahoma State University. Her research interests include geoscience education; engineering education; preservice teacher education; and teacher professional development.