121st ASEE Annual Conference & Exposition
Indianapolis, IN
June 15-18, 2014
Paper ID #9024

Boys and Girls Engineering Identity Development in

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Boys and Girls Engineering Identity Development in Early Elementary Before and After Hands-On Engineering Learning Classroom Experiences

Research to Practice

Despite many calls to increase the number of students who pursue engineering as a potential career, particularly those of diverse backgrounds[1,2], the disparity between the number of males and females that go into engineering continues to persist.[3] In 1991, women accounted for 15.5% of U.S. bachelor degrees in engineering; twenty years later, this had grown dismally to 18.4%.[4] As pointed out by others, the motivation behind increasing the number of women and traditionally under-represented groups who are engaged in engineering has become more than a moral responsibility, but also one of economic necessity.[5]

Recent educational reforms have sought to increase the future engineering, and more broadly STEM, workforce and grow a more STEM literate society. There is hope that with Next Generation Science Standards (NGSS)[6], children from all different backgrounds will have meaningful, hands-on learning experiences with engineering beginning in early elementary. According to the National Academy of Engineering and the National Research Council, one of the rationales for the inclusion of engineering in K-12 curriculum is to inspire learners.[7] A desirable outcome is that more girls and young women would choose to pursue engineering as a career.

Career Development of Young Students

Early opportunities for authentic engineer learning are essential to creating a more diversified engineering workforce. In addition, there is a need to research how diverse groups respond to the engineering experiences and whether there are differences in how well they can identify with the work of engineers. There is evidence that children begin ruling out career options as early as the 5th grade.[8] Other researchers have found that this process begins in elementary school and by the 8th grade, students have decided which careers are not for them.[9] Some career theorists have suggested that career choice is based on developmental stages that children progress through into adulthood. For example, Gottfredson's Theory of Circumscription and Compromise states that individuals experience stages during which their career focused thinking changes and develops.[10] Gottfredson states that in early elementary years, children's notions about careers tend to be based on gender stereotypes. However, the most significant and influential stages where children begin to consider what types of careers are possible for them also occur at the primary grade levels. This creates a small, vital window of time in which to integrate engineering into the list of potential careers that young learners are entertaining. It is essential that elementary and middle school students have exposure to authentic, meaningful engineering opportunities before they prematurely foreclose engineering as "not for me".

Extending the identity theoretical framework of Gee[11], Capobianco[12] termed the concept of engineering identity development as a way to describe how one comes to view herself as the kind of person who could be an engineer. Capobianco originally conceptualized the term in relation to undergraduate women, and later, with others, applied the framework to the study of elementary students.[13] The theory implies a process by which students come to see themselves as potential future engineers and realistically entertain the idea of pursuing professional engineering. According to the framework, in order for students to begin to identify, or see themselves as potentially being an engineer, they must 1) perceive themselves as belonging in their school, 2) perceive themselves as performing well in their courses, 3) understand the work of engineers, and 4) see the work of engineers as desirable for them. This framework is complimentary to Gottfredson's Theory in that both theories describe how young students begin to view themselves with respect to potential careers. Research related to early elementary students' engineering identity development can provide insight into students' thoughts about their potential to be engineers. This information can be used to assess how well students respond to engineering lessons and more specifically, whether gender disparities occur after students have exposure to engineering activities. A previous study[14] on a small sample of boys and girls in 4th grade found that there were no differences between genders in engineering identity development prior to or after students had engineering lessons in their classroom.

The purpose of this study is to examine gender differences in 2nd, 3rd, and 4th graders' engineering identity development, prior to and after engineering lessons were integrated into their classrooms. The research questions are: (1) Prior to engineering exposure in the classroom, what differences exist between elementary boys and girls in their engineering identity? (2) After exposure to engineering lessons, do elementary students experience significant gains in their engineering identity development? and (3) Are there significant differences between elementary boys' and girls' rate of growth in engineering identity development after exposure to engineering lessons?

Background

As part of an NSF five-year grant, the Institute for P-12 Engineering Research and Learning (INSPIRE) at Purdue University partnered with a large school district in south-central U.S. to provide professional development in engineering to elementary (grades 2-4) teachers. The goal of the project was to examine the impact of elementary engineering professional development on teacher change and student achievement. The focus of the professional development was for teachers to be able to: 1) convey a broad perspective of engineering, 2) articulate differences between engineering and science thinking, 3) develop a level of comfort in discussing engineers and engineering with elementary students, and 4) use problem-solving processes to engage in open-ended problem solving. An on-site teacher liaison provided ongoing support to teachers during the school year through brief workshops and individual consultation.

Each year, a new cohort of teachers committed to implementing engineering lessons for a minimum of two years. They attended a week-long academy where they learned about technology, the work of engineers, and the engineering design process. They were prepared to implement a series of introductory engineering lessons (i.e. What is technology?, What is engineering?, Introduction to the engineering design process) and one *Engineering is Elementary* (*EiE*) unit[15], consisting of four lessons. After a year of implementation, teachers attended a three-day follow-up academy designed to answer teachers' questions and provide further support and development. Teachers had discretion over when they taught the lessons and to what extent they integrated engineering into their classroom beyond the given lessons. There was variation between classrooms on the timing and duration of the lessons.

Methods

Students

Students in this study included 818 (423 male and 395 female) students, with 237, 262, and 319 students in grades 2, 3, and 4, respectively. Of the 818 participants, 9 identified as Indian/Alaskan, 88 as Asian/Pacific Islander, 154 as African-American, 246 as White, 12 as multi-ethnic (selecting two or more options), and 26 did not provide a response. Only students who had no prior classroom exposure to engineering were included in this sample.

Engineering Identity Development Scale

This study uses the Engineering Identity Development Scale (EIDS)[13], which measures engineering identity development among pre-adolescent students. The scale includes 20 items that reference two factors: engineering career and academic. The total possible score for the engineering career factor is 33; the total score possible for the academic factor is 15. Sample "engineering career" items are: "Engineers solve problems that help people", "Engineers are creative", and "When I grow up I want to be an engineer". . Some sample "academic" items include: "I do my school work as well as my classmates", "I am good at solving problems in mathematics", and "I am good at working with others in small groups". In the version of EIDS administered to grades 3-5, the items are rated by the students on a scale of 1-3, with 1 = "no", 2 = "not sure", and 3 = "yes". An altered version of the scale is administered to students in grades 1 and 2, with enlarged text and smiling, neutral, and frown faces in place of the options 1, 2, and 3, respectively[13].

Data Analysis

Students' academic and career scores on the EIDS from before and after the classroom engineering intervention were analyzed and compared. To analyze differences between boys' and girls' EIDS scores, multivariate analysis of variance (MANOVA) was performed on pretests between genders for each grade level. EIDS scores were analyzed using a paired sample t-test for all students, by grade level, to examine changes in engineering identity over the course of the school year. To explore any potential differences in the rates of engineering identity development between boys and girls after exposure to engineering lessons, multivariate analysis of covariance (MANCOVA) was performed for each grade level.

Results

Table 1 shows the means and standard deviations (SD) of the initial scores for the engineering career and academic factors. The means for both boys and girls on the pretests for both factors are high, indicating that the young children feel overall positively about their identity in school and towards engineering. On average, boys and girls did not significantly differ in their initial scores on the engineering career factor in the second ($F(1,235) = 0.426$, $p > 0.05$), third ($F(1,260)$

= 0.00, p>0.05), or fourth (F(1,317) = 0.168, p>0.05) grade. However, there were significant differences of small effect size between boys and girls in second grade in their initial academic factor scores (F(1,235) = 6.90, p < 0.01, r = 0.17). On average, girls scored 0.59 higher on the academic factor than boys. There were no significant differences between boys and girls in third (F(1,260) =1.03, p >0.05) and fourth grade (F(1,317) = 0.156, p>0.05) in their initial academic factor scores.

Table 1. Boys' and Girls' Pre-Scores of the Engineering Identity Development Scale

Grade	2nd		3rd		4th	
	Mean	*SD*	Mean	*SD*	Mean	*SD*
Pre-Academic						
Boys	12.82	1.89	12.71	1.49	12.96	1.68
Girls	13.41	1.51	12.91	1.73	12.88	1.70
Pre-Engineering						
Boys	25.46	4.36	25.48	3.70	25.62	3.33
Girls	25.81	3.79	25.45	3.79	25.46	3.27

Table 2 shows the mean scores and standard errors (SE) of pre and post scores of both academic and engineering career factors, by grade. On average, second (t (236) = -6.44, p<0.001, r = 0.39), third (t (261) = -4.31, p<0.001, r = 0.26), and fourth (t(318) = -7.45, p<0.001, r = 0.39) grade students significantly increased their engineering career factor scores after a school year where engineering lessons were integrated into their classrooms. However, overall, second (t(263) = 2.31, p>0.05), third (t (261) = 1.72, p>0.05) and fourth (t(318) = 1.08, p>0.05) grade students did not show significant changes in their academic factor scores after engineering instruction during the school year.

Table 2. Descriptive Statistics of the Pre and Posttests on the Engineering Identity Development Scale

Grade	2nd		3rd		4th	
	Mean	SE	Mean	SE	Mean	SE
Pre-Academic	13.12	0.11	12.81	0.10	12.92	0.09
Post-Academic	12.77	0.12	12.58	0.11	12.79	0.11
Pre-Engineering	25.64	0.26	25.47	0.23	25.54	0.18
Post-Engineering	27.66	0.24	26.71	0.21	27.17	0.16

Table 3 shows the means and standard deviations of the initial and final scores for the engineering career and academic factors, by gender and grade level. After controlling for students' pretest scores on the academic and engineering career factors, gender was not significant in students' posttest scores in second (F(2,232) =1.46. p>0.05), third (F(1,262) = 0.900, p>0.01), or fourth (F(1,319) = 1.53, p >0.05) grade.

Table 3. Descriptive Statistics of Engineering Identity Scale Scores by Gender

Grade	2nd		3rd		4th	
	Mean	SD	Mean	SD	Mean	SD
Pre-Academic						
Boys	12.82	1.89	12.71	1.49	12.96	1.68
Girls	13.41	1.51	12.91	1.73	12.88	1.70
Post-Academic						
Boys	12.82	1.68	12.57	1.98	12.71	1.95
Girls	12.72	2.02	12.59	1.66	12.87	1.87
Pre-Engineering						
Boys	25.46	4.36	25.48	3.70	25.62	3.33
Girls	25.81	3.79	25.45	3.79	25.46	3.27
Post-Engineering						
Boys	27.33	3.93	26.49	3.48	27.35	2.84
Girls	27.96	3.41	26.92	3.43	26.91	3.00

Discussion

Elementary boys and girls in this school-district, on average, have similar levels of identification with engineering prior to exposure to engineering in the classroom and afterwards. This was a surprise finding considering that engineers are more prevalently male and career theorists such as Gottfredson[10] state that young children base career aspirations on gender stereotypes. It is also interesting that the levels of engineering identity development were quite high, even on the pretests, despite not having prior classroom exposure to engineering. One potential explanation is that children at this age level tend to score more positively on surveys.[16] Another potential explanation is that students may not have had enough exposure to engineering previously to really know what engineers are or do, let alone that the majority of engineers are male. Another potential explanation is that as U.S. culture is rapidly changing, young children may not be as bound to gender-based stereotypes of career as previous generations.

Boys and girls both significantly improved in their identification as potential engineers after experience with hands-on engineering lessons. This is an encouraging finding as one of the main rationales for inclusion of engineering in K-12 grade levels is for the purpose of inspiring learners.[7] Despite low levels of exposure to engineering in comparison to other subjects, students did increase in their ability to see themselves as potential engineers. In addition, on average, boys and girls experienced similar levels of gain in their engineering identity development. This is an important finding for evaluation of whether hands-on design projects are meaningful to both genders. After gaining a broad exposure to engineering and fields of engineering, elementary girls identify with engineering to the same extent as boys; both groups started out positive towards engineering and increased further.

Students in all three grades decreased in their scores on the academic factor of EIDS, indicating that students felt more positively about themselves in school at the beginning of the year, than at the end. The engineering lessons were not designed specifically to improve how students' view themselves in relation to their school work or school environment; therefore, this result is not considered to be due to the engineering lessons. Previous research with the EIDS has found similar results when administered at the beginning and end of a school year.[14]

Limitations

As with all research, this study has limitations. The first is related to measurement. While the EIDS was able to detect a significant change after classroom intervention, there is an unknown potential of social desirability, considering the high mean scores on the pretests. Measuring elementary students' attitudes through a quantitative assessment is quite difficult.[16] Young children tend to answer in ways that they believe are "correct" or would please their teacher.[16]

A second limitation is that the data from this study were collected from one school-district. It is unknown how well the results generalize to young students who live in diverse parts of the U.S.

Implications and Future Research

There is a great potential to engage young boys and girls with authentic engineering lessons before they prematurely foreclose engineering as a career option. In addition, as students age through high school, there is a need for continued engineering curriculum to keep students open to fields of engineering. Future research should consider the potential impact that continuous exposure to engineering through middle school would have on students' career pursuits. Corroborating student measures with other research methods, such as teacher interviews or direct observation, would provide a richer understanding of how boys and girls are experiencing the engineering lessons in relation to their career objectives.

Acknowledgement

This work was made possible by a grant from the National Science Foundation DLR 0822261. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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