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Parents as Critical Influence: Insights from Five Different Studies

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Abstract

Broadening participation in engineering, increasing students interest in engineering, and increasing technological literacy are concerns that engineering programs and engineering education researchers continue to address. One important group to consider in this process is parents. Parents play a number of roles in engineering education: they can motivate interest in engineering in early childhood, they can provide support when their child is in the process of selecting a major at college, they can provide experiences for learning engineering concepts and skills, and can serve as role models if they themselves are engineers. Using multiple case study analysis, this paper examines different roles parents play in engineering education through five distinct studies. In these five studies, participants range from parents of young children up to high school age, in a variety of different settings. The collection of these five studies provides unique insights into a more comprehensive understanding of the ways that parents are engaged in engineering education.

Introduction

In recent years there has been a need for increased STEM awareness, partly to increase interest in STEM majors & STEM careers, but also to develop an overall more technologically literate populace. Additionally, there is a concern that engineering should better reflect the national population. Increasing diversity amongst engineering practitioners is important both from an equity perspective as well as a workforce development perspective (a more diverse population means more diverse perspectives are represented, leading to innovation; also, to attract a sufficient workforce we will need to attract women and underrepresented minorities). Research suggests that a majority of engineering undergraduates have a parent or another close family member who is an engineer, and that this is especially true for women.[1] Therefore if we are concerned with increasing awareness of engineering, and increasing participation in engineering, it is important that we understand the ways that parents can promote awareness of, understanding of, and interest in engineering.

Parents can play a tremendous role in their children's learning experiences as children typically spend more than 80% of their waking hours outside of school settings.[2] Research suggests that children develop critical and lasting attitudes towards science at young ages[3], and at this age children spend much of their out-of-school time with their parents. Additionally, this is further supported by research that has shown that parents' involvement in their children's education is most important in these early school years.[4,5]

Prior work in engineering and science education suggests that parents can play a variety of roles that can promote engineering learning. To begin, the tendency for "occupational inheritance" (i.e. for children of engineers to become engineers) is not unique to engineering; it has also been observed in the medical community, [6,7] with lawyer families,[8] politics[9] and even in NASCAR[10] (Groothuis, 2008). A review of parents' roles in engineering and science education helps us to further understand *why* the occupational inheritance phenomenon occurs. Some of the roles that parents play include: an “Engineering Career Motivator,” “Engineering Attitudes Builder,” “Student Achievement Stimulus,” and “Engineering Thinking Guide”.[11]

Engineering Career Motivator

One role parents can play is as an engineering career motivator.[11] Several empirical studies have shown that parents play a significant role in the occupational aspiration and career goal development of their children, and that children have more understanding of the parents’ occupations than other occupations. Through research involving students, teachers and university deans, studies show that parents’ own beliefs and aspirations have been found to be important factors in children’s career and academic aspirations. After asking students why they selected engineering majors and careers, Alpay et al. (2008) found that parents are the largest influence as children select engineering as a major,[12] and Trenor et al. (2008) likewise discovered that parents are the most frequently used information sources in that selection process.[13] Teachers also perceive parents as important role models, inspiring children to consider an engineering career,[14] and engineering deans believe informal advising from parents and teachers is one of the greatest factors in profession selection.[15] Other studies involving undergraduate engineering students not only from the United States[16] but also South Africa[17] provide additional support for the idea that parents are the primary and initial motivation for their children’s motivation to participate in engineering.

Engineering Attitudes Builder

Parents can also play the role of an “engineering attitudes builder.”[11] Even though attitude is a complex concept with many definitions, in nearly all definitions, attitude refers to the growth of feelings and emotions attached to a particular action or thought which are related to behaviors.[18] Parents can help their children begin, grow, and change their attitude towards engineering. In fact, research shows that both parents and children can change viewpoints about engineering. After workshops, programs, or workshops, Lam et al. (2008) showed significant attitude changes of both students and parents where each group developed more positive attitudes about STEM education and parents influenced students’ interest.[19] When it comes to improvement in retention of freshman students, Budny and Paul (2003) found that frequent interaction between parents and students was very important for promoting positive parent attitudes which then impacted students’ attitudes.[20]

Student Achievement Stimulus

A third role that parents may play is as a stimulus for student achievement[11], a theme that considers parents as one of the most important stimuli to improve students’ academic achievement. Jacobs and Harvey (2005) found that parental expectation improves children’s academic achievement.[21] In addition, not only do parents believe in the importance of their own involvement in their children’s education, but teachers and principals also acknowledge the need for parents’ involvement.[22] In an investigative study of K-12 engineering-oriented student competitions, Wankat (2007) concluded that students with supportive parents had higher performance at the competition, and parent involvement was effective in focusing students and increasing enthusiasm for the project.[23] Retrospective studies have also revealed that parents are a significant motivator, especially for low socio-economic students to enter into engineering and that parents' influence on children depended on the parents' motivational beliefs in helping the child succeed in school.[24] In summary, research indicates that parental involvement and expectations are important for children's academic achievement.

Engineering Thinking Guide

Finally, parents can provide scaffolding and other support as children learn engineering concepts and skills in the role of an "engineering thinking guide."[11] This can include activities that are pertinent to increase children's engineering learning, such as afterschool programs, homework assignments, museums, camps, and specialty fairs. For example, Rhoads, Walden, and Winter (2004) developed an afterschool program to introduce science and engineering activities while not burdening teachers and found that parents were the strongest support for their child's participation.[25] One-on-one parent-child interactions are also a vehicle for improving children's scientific reasoning and logical thinking skills. Parents are able to scaffold activities to support their child's unique developmental level, in order for the child to master a skill more readily than if the child was working independently.[26] In a study on parent-child interaction in a museum exhibit, Crowley et al (2001) found that children who interacted in the exhibit with their parents had more opportunities to build concrete scientific thinking skills that similar peers without parents.[27]

The goal of this paper is to investigate the ways that parents adopt these roles and enact other roles that promote children's awareness of, understanding of, and interest in engineering across the pre-college lifespan. This paper provides a foundation for future research on the effects of parents in the larger engineering education eco-system.

Methodology

The methodological framework for this study is multiple case study analysis. This section will describe our application of this framework, the context of the study and data collection from the five studies, and our method for the collective analysis. A case study is an in-depth exploration of a contemporary phenomenon,[28] in this study: *the ways in which parents interact in the engineering education of their children.* Yin defines case study research as an "all encompassing" method, which converges the logic of design, data collection techniques, and approaches to data analysis.[28] Thus, for this paper, as we examine five independent research studies, case study is both the data collection tactic and the design feature[28,29], specifically called multiple case study analysis.

A multi-case study allows us to examine how a phenomenon performs in different environments, or how parents interact with their children's engineering education across a diverse set of contexts.[30] This form of collective case study research endeavors to address an issue (research question) while contributing to the literature base, and conceptualizing a theory.[31,32] Our research aims to be, as case study research is generally, more exploratory than confirmatory,[32] relying on multiple sources of evidence that will converge in a triangulating fashion among all five included studies.[28] The collective case design of these five studies, or cases, will enable greater transferability to a larger context of understanding of the ways in which parents interact in the engineering education of their children.

Study Context, Data Collection, & Data Analysis

This section will describe the study context, data collection, and data analysis methods. There are five independent studies presented in this paper as individual cases. The studies were identified because of the observed common thread of parent engagement across various studies within a research group at a large Midwestern university. However, a more compelling reason for the slection of these five studies as five cases is the fact that the studies span parent engagement with children across the spectrum of childhood: preschool through high school (see Table 1).

Table 1. Children's' age range for the five different studies.

Study	Age of Children
Interviews with Parents who Help their Children Learn Engineering	All Ages (17m-29yr)
Parental Engagement while Reading an Engineering Storybook	Preschool
GRADIENT (Gender Research on Adult-child Discussions within Informal ENgineering environmenTs)	Preschool & Elementary
Informal Pathways to Engineering	Middle School
Examination of High School Female's Experiences in Engineering	High School

For the purpose of the overarching study represented by this paper, we present each study as its own case with its own findings and/or themes. Each study has its own context and method of data collection briefly explained in the individual case introductions. Our approach to data collection for this paper required the individual researchers to contribute a brief summary of their research study for the single case descriptions you will see in a later section.

The purpose of the cross case analysis presented in the discussion section is to make assertions from the collective themes of the individual cases, facilitating a broader characterization, representative of the true diversity of the interaction of parents in the engineering education of their children. Each author reviewed the five cases individually and assertions were discussed and agreed upon as a group. The assertions are articulated in the discussion section, and proposed as conceptualized theory.

The Five Studies

Interviews with Parents who Help their Children Learn Engineering

The first study began with a premise that parents with engineering backgrounds were the most likely group of parents to support their children's engineering education. To that end, interviews of 24 parents with engineering backgrounds who self-identified as parents who "help their children learn about engineering" were conducted and analyzed to capture a variety of approaches that parents have taken in order to shape their children's exposure to engineering. Participants included practitioners from industry (n = 8), engineering faculty (n = 14), and students (n =2), from twenty different engineering disciplines[33,34]. The 24 participants had a total of 50 children aged 17 months to 29 years-old; 39 of these children were between the ages of 2 and 18 (the primary focus age range for the study). The open-ended interviews included information about parents' background, interactions with children that led to engineering learning (content, strategies and reactions), parenting approaches, and parents' own understanding of engineering.

Two major points emerged from this study regarding engineering parents. First, even though they were recruited to participate if they self-identified as a parent who helped their children learn about engineering, most parents said that they did not explicitly talk about or do engineering activities with their children. Instead they focused on teaching fundamentals such as science and mathematics. Secondly, parents primarily reported helping their children learn about engineering through informal discussions, such as a conversation that might sprout up while driving around town. These conversations allowed the parent to share knowledge and were often initiated by the child asking a question. Some common locations included bedtime discussions, dinner table conversations and talking while in the car. Parents would also point out specific concepts to their child and even quiz them on previous knowledge. This one-on-one time could potentially serve as a source of (at times) unknown transfer of engineering occupational knowledge and warrants further research. The earlier papers on this study present additional information on these approaches and other strategies parents[33,34].

Parental Engagement while Reading an Engineering Storybook

The *Parental Engagement while Reading an Engineering Storybook* study looks at conversations between engineering parents and their young children (3-5 years) while reading an engineering storybook to discern strategies for facilitating the sharing of occupational knowledge of engineering. The focus of this study was specifically on engineers as the phenomena of occupational inheritance is common in engineering families[1], and the process by which it occurs has only been theorized. The study focuses on the use of storybooks as parents have reported books to be the most important tool for their child's development.[35] However, few studies have looked at the influence of media on the career development of children, though it has been implied as the primary source of occupational learning.[36] This premise is supported by a study that showed that even a short exposure to a book supporting women in non-traditional occupations was instrumental in changing kindergarten children's perceptions of women's career roles.[37]

A storybook was developed for the *Parental Engagement while Reading an Engineering Storybook* to portray current misconceptions of engineering (i.e. engineers fix cars like mechanics do), contain engineering imagery (e.g. turbine, blueprints), and to support the messages developed by the National Academy of Engineer's report "Changing the Conversation"[38].

Parents tended to focus more on relations of the illustration to the text, than the content itself - which is a common reading technique for children of this age. However, parents often didn't provide explanations when their children were unable to respond to the prompts deliberately planted into the storybook. One engineering parent didn't even correct the misconception (that engineers fix cars like a mechanic) put forth by the child when asked what an engineer does, and that same child was unable to name any engineers present in the child's life (though the parent personally identified as one).

GRADIENT (Gender Research on Adult-child Discussions within Informal ENgineering environmenTs)

The purpose of the (GRADIENT) study is to explore (1) how parent- child conversations and activity within informal engineering environments can contribute to the development of girls' interest and understanding in engineering and (2) gender differences in the development of early engineering interest and understanding within young girls. Building upon what was established with the parental interview data (from the *Interviews with Parents who Help their Children Learn Engineering* study*)*, the GRADIENT project closely examines parent-child conversation at the intersection of parents, children, and meaningful STEM learning within two different informal settings: a preschool program and an engineering exhibit at a large science museum.

For the preschool program, each parent-daughter dyad was asked to build a tower out of large foam blocks, followed by the construction of a tower with an unfamiliar set of materials (Dado squares). The second setting consisted of pneumatic ball run located within the engineering exhibit at a large science museum and focused on girls aged 6-11. Data for both settings includes audio and video-recordings of the design challenges, audio and video-recordings of the interviews with the children (as well as transcripts), and a modified version of the Parent Engineering Awareness Survey[39]. Thirty dyads were collected at each setting, with the parental gender distribution being equal.

Preliminary findings suggest that parents and children engage in several different types of roles throughout the activity. Parents also assist the child in the engineering process, as well as engage it in it themselves. We have also observed that parents often use questions as a way to elicit interactions with their child.[40] Further analysis will delve deeper into the differences between fathers and mothers in how they engage in the activities with their daughters.

Informal Pathways to Engineering

The *Informal Pathways to Engineering* project investigates how informal engineering programs support engineering-related learning over time with middle school students and their support system of parents, teachers and other informal educators[41]. Building on Bandura's Social

Cognitive Career Theory (SCCT),[42] the study aims to look at how self-efficacy, interest, and access intersect to influence career thinking. Students with interest in STEM, particularly ones who like to build or create things, were recruited to participate in a three-year study where they are interviewed at the beginning, middle, and end of middle school and surveyed quarterly over a three-year period. Their parents, teachers, and informal educators are also interviewed to identify positive and negative factors within their support and social systems. In the first phase of the study, semi-structured interviews were conducted with approximately 50 parents of sixth and seventh grade students (n=25 boys, 25 girls) in Indiana and Massachusetts about what their informal activities are, how they are selected and supported, and what perceptions of engineering students and parents have. Parents were also asked how they discuss careers and whether engineering should be taught in middle school. Study participants were students representing traditional public, private, charter, virtual, parochial, and homeschool settings and come from families with diverse socioeconomic and career backgrounds.

To date there are four major findings from this study related to the parents. The first finding is that most parents could not articulate the difference between engineering and science or engineering and design. Even parents who were practicing engineers could explain what they specifically did for a living, but were not as successful or comfortable talking about engineering as a field and distinctions between engineering, science, and design. The second finding is that most parents say they support whatever career choice their child desires, but have not been intentional about career education and conversation by middle school. In reflection, some students choose a career early and are consistent while others change career aspirations regularly. Rather, discussions of career choices are spontaneous and parents provide opportunities for learning about careers after students have expressed interests in a particular career. Third, parents believe that middle school should teach STEM and would be excited about having schools introduce engineering earlier in the K-12 career, but are not always knowledgeable about what is being taught at school. Lastly, parents put much effort into keeping their children engaged in informal activities, but have limitations due to school and local options, finances, time, and knowledge of what informal activities are available. Often informal activities prior to middle school have fallen into athletic and artistic categories because those are well-publicized, parents depend on other parents and schools for information, and STEM activities are limited beyond museums, 4-H tracks, and initiatives of Boy and Girl Scouts.

Examination of High School Female's Experiences in Engineering

The final study is a multiple case study analysis of high school females' experiences in engineering using intersectional feminist theory, answering the question: How does race, class, gender, etc. influence high school females' experiences in engineering? Nine young women volunteered to participate. They all took a high school engineering course in the school year 2011-2012, and they had the same female teacher, an engineer. The study took place at a suburban high school in Central Texas teaching Project Lead the Way engineering curriculum. The students were observed in their engineering classes for the Spring 2012 semester, with bi-weekly interviews with the students, monthly interviews with teachers, and a single interview with the students' parents. The results from this study indicate that parents play a significant role in the engineering education of their daughters, and this can be described in two ways: influence, and support.

Parent careers and interests influence their daughter's interest in participating in engineering, as demonstrated by 78% (7 out of 9) of the participants. As evidenced in the literature, occupational inheritance is a common entry into engineering, specifically for females.[1] In this study, six out of nine of the participants have a parent (specifically only fathers) that work as a STEM professional. The other three participants were from low to middle class socio-economic status families with no parental occupational inheritance influence, however one of these three had a father that enjoyed designing and building things as a hobby. This influence seemed to be instrumental in Kaitlin's choice to enter into and remain in the high school engineering program, as she had nearly completed four years of the engineering program at the time of the study. The data from this study suggests that when a young woman has a parent with a STEM career or STEM interest, they are more likely to enter into a STEM focused high school pathway, in this school's case, a PLTW program.

The second parent related finding from this study demonstrates that parent or family support is vital to the female's pursuit of and success in engineering at a high school level. Support, as exhibited in these case studies, involved taking an active interest in their daughter's education (what she is learning and what grades she is earning), and active encouragement of finding a college/career path rather than just taking required courses (PLTW courses are electives). All but one of the participants in this study regularly discussed the support of their family for their education and career selection (89%, 8 out of 9). The outlier, Nicole, came from a low-socioeconomic family, with a mother that was struggling to get by, forcing the female teen to absorb many of the parent responsibilities at home with the other children. While Nicole did not say her mother was unsupportive, data indicated that time and availability played a factor in the mother's ability to be actively supportive, and in fact the mother was unable to make herself available for an interview in person, over the phone, or via email. The data from this study suggests that parental support is influential for a females' education and career selection in engineering.

In conclusion for the multiple case study analysis of high school females' experiences in engineering, the results indicate that parents play a significant role in the engineering education of their daughters, via career trajectory influence, and via support of education and a future career.

Discussion

These five studies have underscored the roles of parents from birth through completion of college as *engineering thinking guide*, *student achievement stimulus*, *engineering career motivator*, and *engineering attitudes builder*. Findings from all five studies show that parents were *engineering thinking guides* at some stage of their children's lives. From birth through high school, parents can serve as *engineering attitude builders*, and parents find a variety of ways to be *engineering career motivators* depending on the developmental stage of their children. GRADIENT, *Informal Pathways to Engineering*, and the *High School Female's Experiences in Engineering* study showed that *engineering career motivator* and *attitude builder* roles occurred in day-to-day interactions and through accessibility of parents who were confident or willing to investigate answers when children asked questions. Parents can be *student* *achievement stimulators* as students matriculate through their preK-12 career and into college. This role was implicitly evident in the interviews of parents who describe not directly discussing engineering topics, but worked on engineering foundational and related concepts such as science, mathematics, and technology. It can also be witnessed in the high school girls study where parents were actively engaged in the academic lives of their daughters. The impact of conversations is evident in GRADIENT, *Engineering Storybook*, *Informal Pathways to Engineering*, *High School Female's Experiences in Engineering*, and *Interviews with Engineering Parents*. These conversations make a parent an *engineering attitude builder*, *engineering thinking guide*, *student achievement stimulus*, and *engineering career motivator* simultaneously and can have positive and negative influence on their children's' engineering education and engineering career choice.

The authors of this paper believe that all of the roles could occur over the course of children's lives, but recognize that they will take different forms. Parents can continue to adopt the same roles throughout their child's life, or they may shift roles over time. Also, parents' background (including ethnic family culture, and implications of social capital or class[43]) and parenting style might impact the way that individual parents engage in these roles. Even if a parent only adopts one of the four roles, though, there is evidence that even that single role can support their child's learning of engineering.

An additional role that emerged from these studies is an **engineering engagement advocate**. From toddlerhood to college, parents have advocated engagement in activities that were mostly positive toward engineering education and career choice. In the GRADIENT study, parents participated in building activities informally with their daughters at an engineering exhibit at a science museum. Parents advocated engagement by selecting museums to visit that had an engineering exhibit. In the *Informal Pathways to Engineering* study, parents described working to support their children's interest but the challenge was in finding informal activities for their middle school children. The *High School Female's Experiences in Engineering* study showed parents engaged in the academic advocacy by looking at PLTW courses so their daughters could be prepared if they were interested in an engineering college major. The *Engineering Storybook* study is one example of a mix of positive and negative aspects of engineering engagement advocacy, in which the parent chooses to read an engineering storybook (positive), but instead of promoting the positive messages within the book, they perpetuated misconceptions (negative). In those cases, they are engaging in those important motivational conversations but missing the opportunity to be an accurate engineering thinking guide while simultaneously building an engineering attitude.

Since these cases underscore the critical nature of parents in engineering education and career choice, there are some ways for researchers and educators to support parents. Education of parents about STEM and design is vital because if parents cannot articulate what engineering is when children ask, they may be less likely to encourage their children to investigate it, unintentionally impact engineering attitude or they might perpetuate misconceptions about engineering. Since we know about high occupational inheritance, educators and researchers will need to provide resources and opportunities for informed parents who can engage in those spontaneous conversations that show lasting effect. Additionally, the types of support that the parents in these studies provided could be also be provided by teachers, guidance counselors, and other influences in students' lives. Therefore what we learn from the parents can be shared with these other agents.

Conclusion

As we as an engineering education community continue to address issues of recruitment and retention, as well as consider issues of who "gets" to participate in engineering, we need to recognize and continue to better understand the critical roles that parents play. Moving forward, we need to continue to investigate how these roles are important across engineering career selection and development and how parents and different parent roles continue to impact students through the college years. This paper lays a foundation for future studies to more systematically study differences between parents with and without engineering backgrounds as well as the experiences of students who receive more of the types of support described in these study compared to students who receive less of the types of support described in these studies. Finally, several of these studies provided unique insights into how parents support *girls'* development of awareness, understanding and interest in engineering. Research can be extended to investigate the impact of parents for other underrepresented groups.

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