Exploring Parents' Knowledge and Awareness of Engineering through Middle School Students' Summer Camps

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Abstract

Increasing student interest in science, technology, engineering, and math (STEM) is a recurring theme among the research community. The goal of these efforts is to create the next generation of diverse STEM professionals. Similarly, reform efforts have also focused on improving the quality of STEM education. While students' interests in engineering disciplines are shaped by a variety of factors, parents play a substantial role in enhancing children's interest. It is critical to understand parents' knowledge and awareness of the engineering concepts that will translate into their attitudes toward engineering. Parents' attitudes have a direct impact on students' attitudes toward engineering.

In this study, 32 middle-school student parents' knowledge and awareness with regards to engineering and engineering concepts are examined. Specifically, parents' knowledge of building automation and the Internet of Things (IoT) are explored. Data were collected at four different summer camps. In a three year long and NSF funded project, a research team of engineers and learning scientists designed four summer camps for middle grade students and implemented them in two different cities in Texas. At these camps, that each lasted one week, students planned, designed, and established a "Smart Home" by using 3D printers, computer-aided design (CAD) tools, and the IoT technologies. Parents were involved in the summer camp activities at different occasions. For example, parents brainstormed with their children and conducted research with them to complete the take-home assignments on engineering concepts and cutting edge technologies. Parents participated in the STEM Competition Night where the student groups presented their smart homes and their engineering designs.

To explore parents' knowledge and awareness of the engineering concepts, the Parents' Engineering Awareness Survey (PEAS) was administered to all parents who consented to participate. The PEAS survey included three constructs; engineering knowledge, attitudes toward engineering, and engineering behavior. The survey was a five-point Likert-scale instrument with twenty-five items. Eight items of the PEAS instrument focused on engineering knowledge. Ten items focused on attitudes toward engineering. Seven items focused on engineering behavior. This work reports the descriptive and inferential quantitative findings and meaningful correlations that emerged among the parents' knowledge and awareness of engineering and their students' summer camp learning experiences and outcomes. Because this study explores' parents' knowledge and awareness of engineering concepts, it is unique and has the potential to generate new questions in engineering education research.

Introduction

A talent pool with workers competent in the science, technology, engineering and mathematics (STEM) disciplines are necessary to be able to compete in the global economy [1]. STEM workforces play an important role advancing technology and generating new approaches, ideas, and technologies [1]. While there is a high need for people who are proficient in STEM areas, there is a scarcity of interest for students who are dedicated to going into STEM fields, specifically engineering [2, 3]. Enrollment in many STEM fields is declining and similarly, the amount of students who pursue a graduate degree in science and engineering fields in the U.S. has been decreasing since 1993 [4].

Research shows that parents are important models in children's decision making regarding career and life aspirations [1, 5-8]. Many studies have shown that parental involvement and parental expectations help students to have greater ambition for school success and career development [4, 9, 10]**.** These results are echoed by many others [11-15]. Because parental influence plays a significant role in children's educational achievements and career choices, parents can represent the necessary solution for the lack of STEM professionals [4]. In this sense, it is critical that parents have the necessary knowledge and understanding of STEM areas; in the case of this work specifically, engineers and engineering. Parents who have accurate knowledge and understanding of engineers and engineering will be able to introduce their children to these areas early and guide their children to consider STEM fields in general, and engineering specifically, as good fields for their future careers [7].

Student Summer Workshops

Four one-week summer camps for junior high school students, which were one component of an NSF-funded project, took place at different locations in Texas with the support of Texas A&M University in 2017 and 2018. These summer camps were aimed at increasing students' knowledge and understanding of STEM, specifically engineering concepts. Another goal was to improve participants' attitudes toward the STEM fields. In addition, these summer camps tried to help students realize that engineering is a collaborative profession that requires many disciplines working together to achieve a common goal. Engineering faculty and learning scientists prepared the camp curriculum and modified it as needed. The camps were scheduled for seven hours per day for the entire week. Students worked on a problem-based project in the camps. They designed a "Smart Home" and developed a model that was energy efficient and environmentally friendly by using connected devices and additive manufacturing. During their work on the project, students learned scientific concepts and engaged in real-world engineering and technology challenges using 3D printers (for additive manufacturing), computer-aided design (CAD) tools, and the Internet of Things (IoT for connected devices). Table 1 lists the summer camp activities students completed.

At the beginning of the summer camp, parents gave their consent for their children to participate in the activities. Parents were involved in the summer camp activities at different instances. For example, parents brainstormed with their children and conducted research with them to complete the take-home assignments on engineering concepts and innovative technologies. Parents participated in the STEM Competition Night where the student groups presented their smart homes and their engineering designs. Most students had at least one parent attend these STEM Competition Night presentations to see the students' performances and to support their efforts. Various aspects of the camps are shown in Figures 1-4.

Table 1. Camp Overview

Camp Overview
DAY 1 – Introduction to smart home principles
- Introductions: instructors, team members and students - Introduction of the concept of smart home - Introduction of the engineering design process; explanation of how it will be applied during the competition - Experiment: test/evaluate thermal properties of building material pieces of equipment and analyze temperature data. - Discussion on design requirements: building codes, lot, furniture and budget - Students design their home, draw floor plan including material specs, measurements, pricing etc. - Homework: Students ask their parents about temperature profile at home and do research together
DAY 2 – Introduction to programming
- Discuss homework results - Calculate average temperature from the different families - Introduction to programming & sensors - Exercises: hello world, blinking led, pulse width modulation (PWM) signals, control blocks, loops, buttons etc. - Programming applied to smart homes - Output – LED/fan control (on/off) - Input - button to control LED/fan (light intensity/speed of fan) - Automation - sensor to control LED/fan based on ambient light/temperature - Network: report sensors to server, receive control messages from server
DAY 3 – IOT & 3D printing
- Illustration of IoT concept through the "city" (network) - Show students how the city is able to access data via dashboard - MQTT protocol and IOT vocabulary: publish/subscribe/brokers/topic - Show examples of IOT in action - Design individual dashboard for each home, students connect to a webpage & access their data - Guided programming: give students pre-built code; students run it and tweak it. - Introduction to 3D printing and 3D design - Guest lecture regarding CAD/3D printing - Show 3D printer to students

- Provide students with CAD design of a “blank” enclosure for their home computer - Students customized their design for the 3D printer - Print their design
DAY 4 – Build out
- Review judging criteria with students - Go over best practices for team work (strategies) - Construction of the smart homes (cutting, gluing, etc.) and programming - Finishing smart homes for final competition
DAY 5 – Competition
- Students prepare their presentation - Finish constructing /programming - Parents arrive – students show their home and significance of their design - Demonstrate automation part, simulation of 24-hour period - Presentation: students show their understanding of smart home principles by presenting their design strategy - Demo: simulation of the different controls, using their app (10 minutes) - Question and answer session - Judges meet and evaluate groups. - Announce winner, distribute certificates

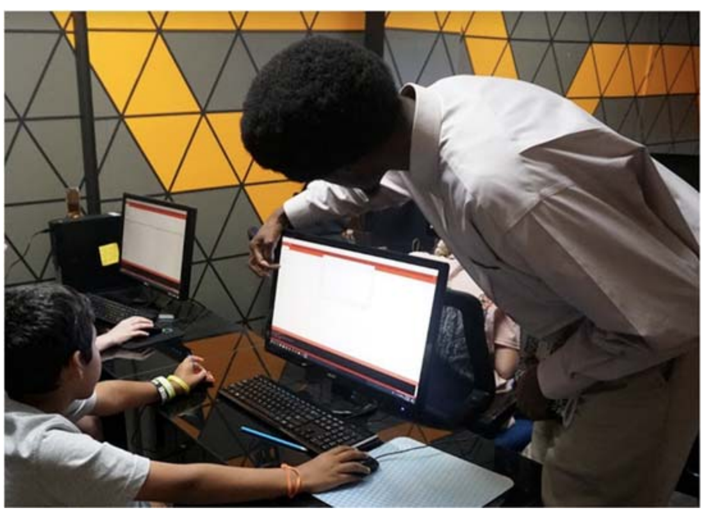

Figure 1. Instructor Working with Students

Figure 2. 3D Printer and Guest Speaker Day

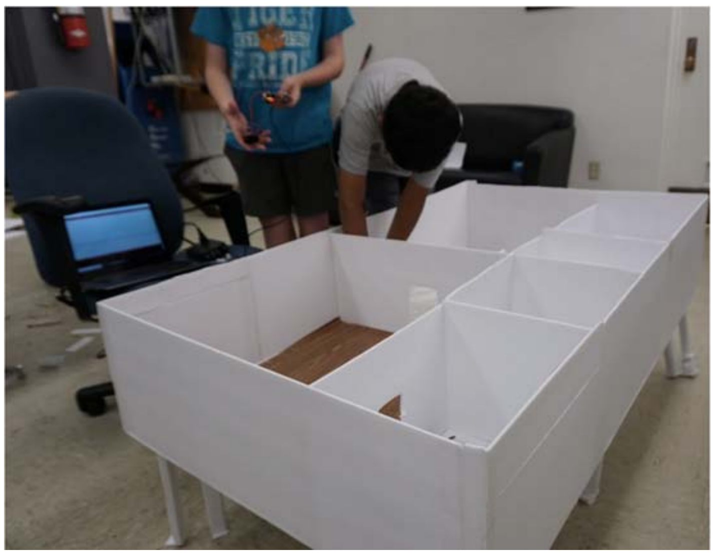

Figure 3. Students Working on Their Homes

Figure 4. STEM Competition Night Preparation

Methods

Participants

There were a total of four one-week summer camps in the present study. One camp in Bryan, TX was completed in the summer of 2017; two camps in Mission, TX and one in Bryan, TX were completed in the summer of 2018. The study participants were the upper elementary and middle school students and their parents attending the summer camps. Thirty-two parents and thirty-three students participated in the camps' activities. While there was a small fee for camp participation, there was also an available scholarship for the students who were in financial need and applied for the scholarship. The demographic characteristics of the parent participants are presented in Table 2.

Table 2. Parents' Demographic Information.

Criteria	Categories	Total
Gender	Male	9
	Female	24
Ethnicity	White	12
	Black	1
	Hispanic or Latino	19
	Two or more	1
Age	No answer	4
	20-35	3
	36-49	20
	50+	4
Education	High School Degree	7
	Associate Degree	4
	Bachelor's Degree	8
	Professional Degree	1
	Master's Degree	9
	Doctorate Degree	4
Camp Location	Bryan, TX	18
	Mission, TX	15
Student Grade	Elementary	8
	Secondary	25

Study Design and Instruments

Quantitative data were collected from the students and their parents. While the students were surveyed before and after the one-week summer camp, parents were only surveyed at the end of the summer camp. The quantitative data were analyzed using descriptive and inferential statistics as well as correlation analysis.

The Parents' Engineering Awareness Survey (PEAS), which was developed by Yun, et al. [16], was administered to all consenting parents (one for each parent) after the summer camp was completed. The PEAS focused on capturing parents' knowledge of engineering; attitudes towards engineering; and their behaviors about engineering. The original version of the PEAS is a five-point Likert-scale [17] survey with many items. In the present study, a subset of the PEAS (in other words, some of the selected items of the PEAS) was used. This subset comprised 25 items. For each construct of the subset of the PEAS (i.e., knowledge, attitude, and behaviors), the parents' responses to the items were summed up to assign each parent an overall survey score. All items were positive.

A demographic questionnaire and an evaluation questionnaire were also administrated to the parents after the summer camp was completed. In the evaluation questionnaire parents responded to the items that were designed to capture the participants' knowledge and understanding of building automation, IoT, the engineering design process, and engineering careers.

The S-STEM survey consists of 37 items. It is a five-point Likert-scale instrument that was developed to capture students' attitudes toward science, math, engineering/technology, and 21st century skills [18]. In the present study, the survey questions that measure students' attitudes toward science, math, and engineering/ technology concepts were utilized. Students' responses to those questions were analyzed.

Results

At the completion of the summer camp, evaluative feedback was collected from the parents regarding their knowledge and understanding related to building automation, Internet of Things, the engineering design process, and engineering careers. The evaluative feedback form asked the parents to indicate their knowledge and understanding before and after the summer camp.

Self-reported answers from the parents are summarized in Table 3. The non-parametric Wilcoxon signed-rank test showed that the mean difference between the parents' responses to the evaluative feedback items before and after the camp were statistically significant at the $p<0.001$ level.

Table 3. Statistical Comparison of Pre- and Post-Parent Responses

		Pre-data		**Post-data**		Wilcoxon Test	
Evaluation Questions	***N***	***M***	***St. Dev.***	***M***	***St. Dev.***	***Z***	***p***
Your knowledge of building automation to maximize energy use	32	2.75	1.24	3.69	1.03	-4.02	0.000**
Your understanding of engineering design process	32	2.87	1.34	3.75	1.02	-3.695	0.000**
Your awareness of engineering careers	32	3.41	1.27	4.13	0.87	-3.246	0.001**
Your understanding of Internet of Things (IoT)	32	3.31	1.26	3.97	1.09	-3.140	0.002**

** Correlation is significant at the 0.01 level (2-tailed).

Similarly, data were gathered from parents regarding their children's knowledge and understanding related to building automation, Internet of Things, the engineering design process and engineering careers. Parents were asked to score their children's' knowledge and understanding before and after the summer camp in one form. Parents' pre- and post-summer camp feedback responses were compared in Table 4. The non-parametric Wilcoxon signed-rank test indicated that the mean difference between the parents' responses before and after the camp were statistically significant at $p<0.001$ level.

Table 4. Statistical Comparison of Pre- and Post-Parent Responses

		Pre-data		**Post-data**		Wilcoxon Test	
Evaluation Questions	***N***	***M***	***St. Dev.***	***M***	***St. Dev.***	***Z***	***p***
Your child's knowledge of building automation to maximize energy use	32	1.94	1.16	3.81	1.11	-4.602	0.000**
Your child's understanding of engineering design process	32	2.06	1.11	3.90	1.08	-4.690	0.000**
Your child's awareness of engineering careers	32	2.28	1.20	3.84	1.16	-4.347	0.000**
Your child's knowledge of the Internet of Things	32	2.62	1.31	3.90	1.19	-4.082	0.000**

At the completion of the STEM Competition Night, parents were also asked "How would you rate this STEM Competition Night?" There were four alternatives ranging from "Not a good use of my time" to "Definitely worth attending." Analyses revealed that most parents found the STEM Competition Night interesting and worth attending.. "It was definitely worth attending" was chosen 20 times, "found it interesting" was chosen 17 times, and "learned a few things" was chosen three times by the participating parents. None of the parents provided a negative response to the question. The summary of the parents' responses is illustrated in Figure 5.

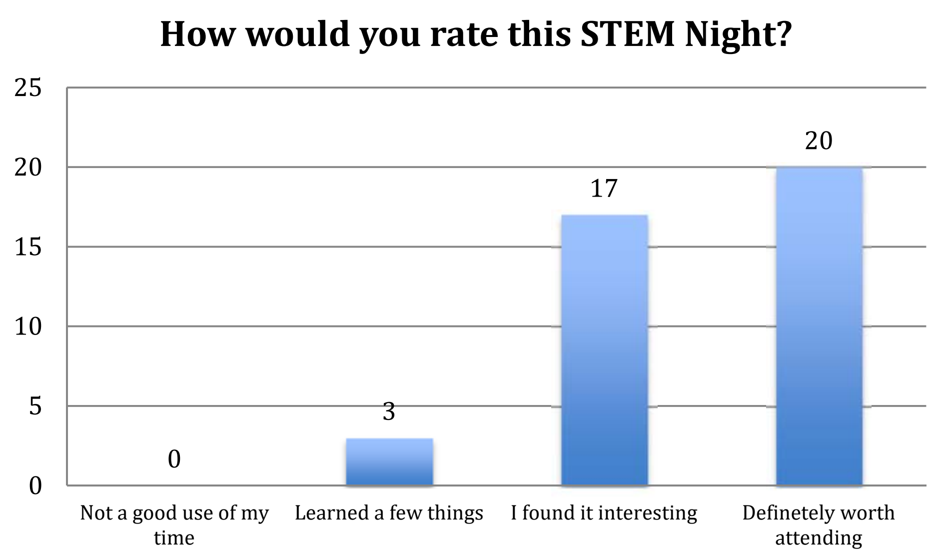

Figure 5. This bar graph that represents the responses to the question, "How would you rate this STEM Night?"

Parents' engineering knowledge, behavior, and attitude were computed separately. For each construct, a sub-scale score was generated for a parent by summing each of these constructs, separately. In all survey items, a five-point Likert-scale was used with alternatives ranging from 1 to 5 (i.e., 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree). The mean score of the parents' engineering knowledge construct was 3.99 with a standard deviation of 0.66. While the mean score for the parents' engineering behavior construct was 4.16 with a standard deviation of 0.55, the average score was 4.29 with a standard deviation of 0.30 for the parents' engineering attitude construct. These numbers show that while parents have positive behaviors and attitudes toward engineering, their engineering knowledge was comparatively low. These results were consistent with the previous research published in the literature [16].

To be able to understand relations between parents' knowledge and awareness of engineering and their students' summer camp learning experiences and outcomes, a Pearson correlation test was run among eight variables (i.e., parents' engineering knowledge, parents' engineering attitude, parents' engineering behavior, parents' education, parents' age, students' post science attitude, students' post math attitude, students' post engineering/technology attitude) using the SPSS software. We interpreted the results based on Cohen's correlation criteria [19].

As shown in Table 5, parents' engineering knowledge and parents' education displayed a statistically significant and moderately positive correlation, $r = .386$, $p <0 .05$. Similarly, parents' education was positively correlated with students' post science attitudes, $r= .428$, $p <0 .05$. Likewise, students' post math attitudes showed a statistically significant and moderately positive correlation with the parents' education, $r= .361$, $p <0 .05$. In addition, one of the independent variables, parent age, showed a statistically significant and strongly positive correlation with the parents' engineering behavior, $r= .529$, $p <0.01$ and moderately positive correlation with the parents' engineering knowledge, $r= .473$, $p <0.01$. Furthermore, the parents' engineering behavior and the parents' engineering attitude displayed a statistically significant and moderately positive correlation $r= .395$, $p <0 .05$. Lastly, there was a statistically significant and moderate correlation between the students' post science attitude and the students' post engineering/technology attitude, $r=0.465$, $p <0.01$. There were not any other significant correlations among the other dependent and independent variables observed.

Table 5. Correlations among survey variables

Variables	Parent Education	Parent's Age	Parent Eng. Behavior	Parent Eng. Knowledge	Parent Eng. Attitudes	Student Post Science Attitude	Student Post Math Attitude	Student Post Eng. Tech Attitude
Parent Education	1	0.253	0.154	.386*	-0.241	.428*	.361*	0.101
Parent Age	0.253	1	.529**	.473**	0.215	-0.026	-0.044	-0.117
ParentEngBehaviour	0.154	.529**	1	0.345	.395*	-0.079	0.109	-0.003
ParentEngKnowledge	.386*	.473**	0.345	1	0.027	-0.085	0.105	-0.262
ParentEngAttitudes	-0.241	0.215	.395*	0.027	1	-0.097	-0.192	0.23
StudentPostScience_Attitude	.428*	-0.026	-0.079	-0.085	-0.097	1	0.272	.465**
StudentPostMath_Attitude	.361*	-0.044	0.109	0.105	-0.192	0.272	1	0.251
StudentPostEngTech_Attitude	0.101	-0.117	-0.003	-0.262	0.23	.465**	0.251	1

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Conclusions

This study's results suggest that parents found the summer camp interesting and worth attending. In addition, participating in STEM Competition Night helped them to understand some innovative technologies and engineering concepts better. When parents increase their engineering knowledge and generate more positive behaviors and attitudes towards the engineering topics and concepts, this will reflect on their children. Because parents have a powerful impact on their children's future career choices [1], helping the parents' improve their engineering knowledge, behavior, and attitude might be an effective solution to the STEM recruitment crisis. Increasing parental participation in the student STEM camps by creating an environment that they can interact with their children in can be a good starting point. As students observe their parents' interest and engagement in STEM camp activities, they will become more interested in the STEM fields and view the engineering activities as more contextual and meaningful in their lives [20-22].

The findings presented in this work should be interpreted within certain limitations. First, the sample participant size is relatively small. Non-parametric statistical analyses were used given the small sample size. Additionally, the population is self-selecting and may not be representative. Families that would sign up and pay for a STEM-related summer camp were biased towards an interest in STEM fields. Even those that received scholarships were being proactive in seeking out STEM activities for their children. Future work will attempt to overcome some of these limitations. A wider and larger population from a traditional school setting will allow for these data to be compared to that of parents and students who are less proactive in searching for STEM-related activities.

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