



## STEM Summer Institute Increases Student and Parent Understanding of Engineering

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Dr. Stacy Klein-Gardner began as the Director of the Center for STEM Education in April 2011 just as the Center began. An engineer by training and in her ways of thinking, she received a BSE in biomedical and electrical engineering from Duke University in 1991. She then earned her M.S. from Drexel University in 1993 and her Ph.D. in biomedical engineering from Vanderbilt University in 1996. Dr. Klein-Gardner's career focuses on K-12 science, technology, engineering and mathematics (STEM) education, particularly as it relates to increasing interest in and participation by females. Dr. Klein-Gardner serves as the Director of the Center for STEM Education for Girls at the Harpeth Hall School in Nashville, TN. Here she leads professional development opportunities in STEM for K-12 teachers and works to identify and disseminate best practices from successful K12, university and corporate STEM programs for females. This Center also leads a program for rising high school girls that integrates community service and engineering design in a global context. She continues to serve as an Adjoint Professor of the Practice of Biomedical Engineering, Teaching & Learning, and Radiological Sciences at Vanderbilt University. She served as the Associate Dean for Outreach in the Vanderbilt School of Engineering from 2007-2010. Dr. Klein-Gardner currently serves as the chair of the American Society for Engineering Education's K12 division.

## **STEM Summer Institute Increases Student and Parent Understanding of Engineering – Work in Progress**

### **Abstract**

The STEM Summer Institute (SSI) is a non-residential, ten-day summer camp for rising high school girls held by the Center for STEM Education for Girls at the Harpeth Hall School in Nashville, TN. In 2013, twenty-eight girls participated in the program. Two-thirds of the girls were from local public, comprehensive high schools, while the other third attended independent schools in the area. The curriculum was based in both service learning and engineering design within a global context. The Lwala Community Alliance of Kenya "hired" the participants to work on two projects. The rising 9th and 10th graders designed a fish pond to enable the Lwala residents raise fish to use as a commodity. The rising 11th and 12th graders designed an oven for the women of Lwala to bake mandazi in large quantities to use as a commodity for trade. Participants used the engineering design process to manage the designs along with appropriate scientific inquiry, statistical analyses, CAD drawings, and hands-on prototype building to accomplish this task. Each group also prepared an oral presentation and a video of their fish pond or oven in action. These videos ran while the girls stood in front of the posters, giving their oral presentations, to judges, parents, and teachers from their home schools on the final engineering design competition day. We also did things to make this feel a bit more like a traditional camp - and not just academics – such as making ice cream, making shrink-dinks, going to the playground, etc. We also included topics like college planning and building up the girls' social capital. Parents were specifically engaged at two points during the program: a homework assignment designed to have parents and daughters brainstorm about the Lwala design challenges and an invitation to parents to participate in the engineering design project presentations on the last day.

The Parents' Engineering Awareness Survey (PEAS)<sup>1</sup> was administered to all consented parents (one per participant) prior to and following the SSI. The PEAS survey includes knowledge, attitude, and behavior aspects; only the knowledge and attitude aspects were hoped to be impacted by this program due to the short intervention time between implementations of this survey. The Draw an Engineer Test (DAET) (Knight and Cunningham, 2004) was administered to all consented student participants prior to and on the last day of the SSI. The PEAS survey indicated a significant increase in parental knowledge of engineering. The parental attitude aspect increased as well, but did not reach statistical significance. Using qualitative analysis, the DAET test indicated an increase in the accuracy of student understanding of what engineering is and what engineers do. The STEM Summer Institute program is an effective model for helping both girls and their parents increase their knowledge of what engineering is and should be replicated and emulated in other programs, both academic year and summer, for girls.

## **Background**

The need for more females in the STEM disciplines has been well documented over the years. To accomplish this goal, it is imperative that programs designed for females take into account what the literature has to offer about what females both need and desire in a STEM classroom or program. For example, studies have shown that women are attracted to STEM programs that include civic engagement<sup>2</sup>. Similarly, the use of problems that contextualize a topic to girls' interests is important<sup>3</sup> and that may include instances where altruism and science overlap<sup>4</sup>.

Parents play an extremely important role in their daughters' choice of whether or not STEM is "for them." Many studies have shown that adults' math-gender stereotypes influence both their expectations and attributions of girls' math achievements, which then influences girls' own math attitudes and achievements. Specifically, a parent's own math anxieties may be passed on to their children. Related to this is a parent's belief that whether or not one's math ability is stable or not – the growth mindset – and how this is transmitted to a child. Children are then at risk of gender-based stereotype threat which leads to underperformance in STEM-based fields<sup>5,6,7,8,9</sup>.

For females, especially females of color, parents play an important role in determining whether or not she will pursue a STEM field in college. Goodman and Cunningham<sup>10</sup> found that mothers and fathers were highly influential in students' decisions about her major, with over 70% of study participants citing a parent as the most or second-most influential factor in their decision to pursue engineering. Because parents play such a critical role in determining their daughter's future major choices, it is also critical that parents understand what engineering is so that can encourage their daughters to pursue when it is a good fit. Parents must also deem engineering to be an "appropriate" choice for their daughters.

## **The Program**

The STEM Summer Institute (SSI) is a non-residential, ten-day summer camp for rising high school girls held by the national Center for STEM Education for Girls. The program has completed two successful years and is described in great depth in another publication<sup>11</sup>, though a brief summary of results is provided here. The program has been shown to be successful in increasing girls' self-efficacy in STEM related areas. The students also had a greater feeling of inclusion both inside and outside the classroom after attending the SSI. As a result of the SSI, there were greater expectations in the outcomes of taking math courses and doing well in math. Improvement in engineering self-efficacy was evident post the SSI, where the students were confident in completing an engineering program. After the SSI, the girls understood that engineering design is not always creating something but it is more often improving what already exists. The students had an increased understanding of engineering that is beyond such superficial ideas that suggest that engineers fix cars or build houses and bridges. The girls also realized engineering comprises multiple disciplines and subject areas (such as math and science).

The curriculum was based in both service learning and engineering design within a global context. The Lwala Community Alliance of Kenya<sup>12</sup> "hired" the participants to work on two projects in the summer of 2013. The rising 9th and 10th graders designed a fish pond to enable the Lwala residents raise fish to use as a commodity. The rising 11th and 12th graders designed an oven for the women of Lwala to bake mandazi in large quantities to use as a commodity for trade. Participants used the engineering design process to manage the designs along with appropriate scientific inquiry, statistical analyses, CAD drawings, and hands-on prototype building to accomplish this task. Each group also prepared an oral presentation and a video of their fish pond or oven in action. These videos ran while the girls stood in front of the posters, giving their oral presentations, to judges, parents, and teachers from their home schools on the final engineering design competition day.

We also did things to make this feel a bit more like a traditional camp – and not just academics – such as making ice cream, making shrink-dinks, going to the playground, etc. We included topics like college planning and building up the girls' social capital. At lunch on eight of the ten days a female STEM professional joined us for lunch and the girls could choose whether or not to sit at her lunch table. The visiting STEM professionals were encouraged to discuss their career, their path to their career, and their work-life balance with the girls and to participate in casual conversation with them.

Prior to the start of the SSI program, parents had to give consent for their daughter to participate in the program. No inventory was made of the parents' roles in teaching their daughters about STEM. During the course of the program, parents were specifically engaged at two points: a homework assignment designed to have parents and daughters brainstorm about the Lwala design challenges and an invitation to parents to participate in the engineering design project presentations on the last day. To our knowledge, all of the girls completed the parent brainstorming homework and more than half of the girls' parents attended the engineering design day presentations.

### **SSI Participants**

The STEM Summer Institute exclusively served rising high school girls in Davidson County (TN). In 2013, twenty-eight girls participated in the program. Two-thirds of the girls were from local public, comprehensive high schools, while the other third attended independent schools in the area. Every public high school and approximately half of the middle schools in the Metropolitan Nashville Public School (MNPS) system was contacted about this program. The majority of recruiting took place through classroom teachers, many of whom had a preexisting relationship with an SSI staff member. These teachers played a critical role in encouraging their students to apply. Whenever invited, a SSI staff member went to meet with girls who were interested in the SSI at their schools. An effort was made to encourage underrepresented female students to participate in the program and to assure all applicants that financial aid was available and that money should not hinder their application. Potential applicants were assured that they

did not have to be expert students in their science or mathematics classes in order to be considered for the Institute. They were told that the Institute was looking for girls who wanted to participate and problem solve, using the engineering design process. The candidates were asked to submit an application form, one teacher recommendation, and an essay explaining why they should be chosen for the program.

## **Study Participants**

All twenty-eight participants and their parents were recruited to take part in this research study. Once parents gave informed consent for their daughters, the participants were request to give their assent to take part in the study. Fourteen participants chose to take part in the student study, while eight of their parents participated in the full parental study.

## **Methods**

The participants who gave assent and whose parents gave consent were given the assessment Draw an Engineer Test at the start and completion of the STEM Summer Institute. The Draw an Engineer Test (DAET)<sup>13</sup> was developed to help assess students' ideas about engineering before intervention. Through the survey, students described their knowledge about engineering through written and drawn responses. The survey included the following questions or prompts: "In your own words, what is engineering?", "What does an engineer do?", and "Draw a picture of an engineer at work."

The Parents' Engineering Awareness Survey (PEAS)<sup>1</sup> was administered to all consented parents (one per participant) prior to and following the SSI. The PEAS survey includes knowledge, attitude, and behavior aspects; only the knowledge and attitude aspects were hoped to be impacted by this program due to the short intervention time between implementations of this survey. The knowledge aspect is comprised of sixteen survey questions that are summed to create a score for this aspect. These survey items range from "I know what engineers do" to "I know how to explain engineering related concepts to my child" to "I know how to help my child with his/her engineering skills and ideas". The survey did not ask the parent to name specific instances or examples of these items. Similarly, the attitude aspect is comprised of twenty-questions that are summed to create a score for this aspect. Here, the survey items range from "I think engineering improves our society" to "I want my child to understand what engineers do". Yun, et. al,<sup>1</sup> have shown the instrument to be statistically reliable through the use of Cronbach's alpha.

## **Data and Data Analysis**

*Draw an Engineer Test – Student Study*

Students were asked on the Draw an Engineering Test to give a written response to the question “Q1. What is engineering?”. To gain a better sense of the students’ overall understanding of engineering, thematic groupings were created based on the students’ written responses on the survey: Building, Brainstorming, Designing and Creating, Fixing, Improving, Operating, Solving, STEM Subjects, Teamwork, Technology, and Testing as illustrated in Figure 1. In our earlier manuscript on this program<sup>11</sup>, this author and her co-author worked to develop these categories and iterated until agreement had been reached in all instances in the earlier set of data. These same categories and the way that student responses were placed into these categories was repeated for this second set of data. A new category of “Teamwork” was added this year based upon student responses.

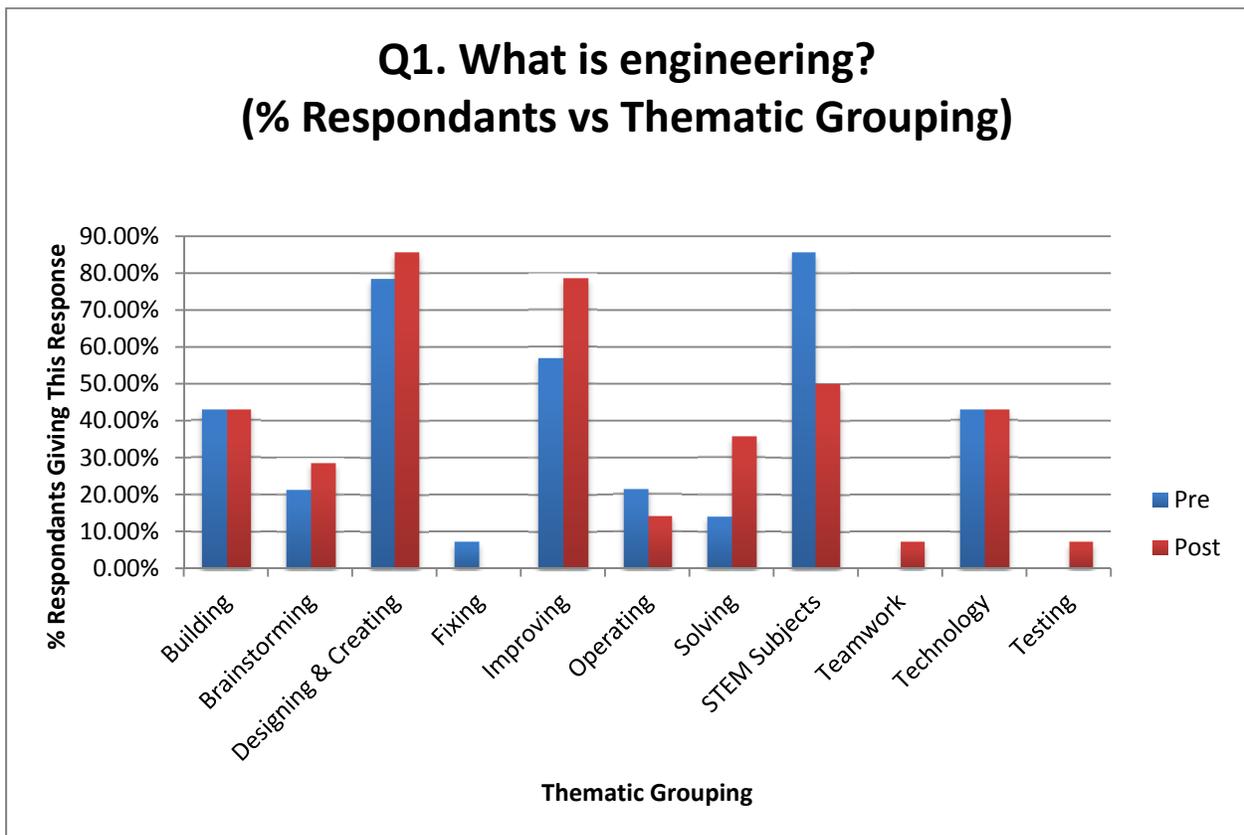


Figure 1. Bar graph representing responses to Q1. What is engineering?, split into thematic groups. The % Responding is the occurrence of image in grouping/ total # of occurrence of images (N=14).

Students were asked to respond to the question “Q2. What does an engineer do?” To gain a better sense of the students’ overall understanding of engineering, thematic groupings were created based on the students’ written responses on the survey: Brainstorms, Builds, Designs & Creates, Fixes, Improves, Operates, Plans, Tests, Solves, STEM Subjects, Teamwork, and Technology as illustrated in Figure 2. Once again, the categories were reused from the earlier research

manuscript. A new category of “Teamwork” was added in this study based upon student responses.

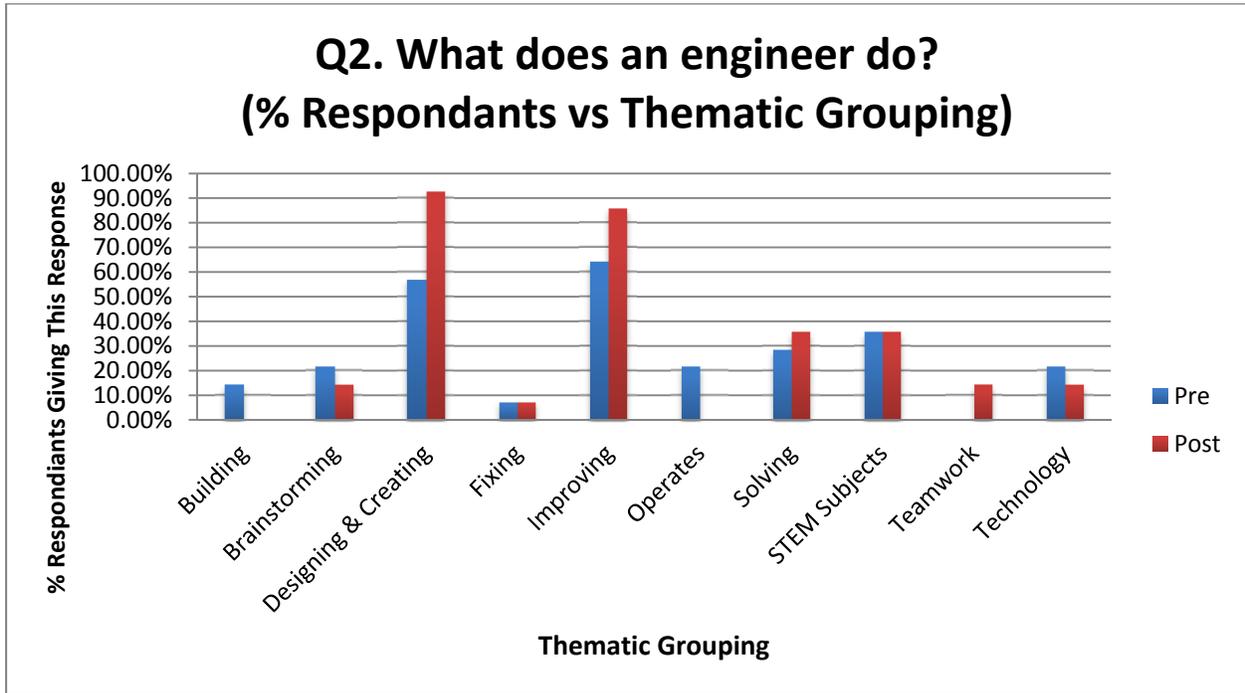


Figure 2. Bar graph representing responses to Q2. What does an engineer do?, split into thematic groups. The % Responding is the occurrence of image in grouping/ total # of occurrence of images (N=14).

### *Parents’ Engineering Awareness Survey (PEAS)*

For each parent participant, their responses to the sixteen Likert-scale questions in the knowledge section of PEAS were summed for both pre- and post-SSI. The summed scores were then compared statistically using a paired t-test. The scores could thus range from a 16 to an 80. Prior to their daughters’ participation in the SSI, the parents scored an average of  $56 \pm 6$  on the knowledge portion. After participation, the parents scored a significantly higher average ( $p < 0.04$ ) of  $64 \pm 10$ .

Similarly, the twenty-two Likert-scale questions in the attitude section of PEAS were summed for both pre- and post-SSI. The summed scores were also compared using a paired t-test. The scores could thus range from a 22 to an 110. Prior to their daughters’ participation in the SSI, the parents scored an average of  $88 \pm 6$  on the knowledge portion. After participation, the parents scored a non-significantly higher average ( $p = 0.21$ ) of  $90 \pm 6$ .

### **Discussion and Conclusion**

These girls entered our camp with at least some interest in STEM, as demonstrated in the essays they wrote in the application process. They were recommended by a teacher for the program as

well. We did not assess their incoming knowledge of all STEM fields, rather we focused on the engineering field alone.

Through the analysis of the DAET test results, the students have been shown to gain a better understanding of what engineering is. Not only does the frequency of misunderstandings, for instance the engineering is fixing or operating something, decrease, but their understanding of what engineering is increases. Student participants now better align the steps of the engineering design process with their understanding of engineering. They also include ideas such as teamwork in their conceptions of engineering as well. These results match the results of our first year of SSI well.

The results of this initial parent study of the STEM Summer Institute are encouraging. Already, the parents of these girls have increased their knowledge of what engineering is. As with any field, a parent cannot specifically encourage their daughter to consider participation in STEM, specifically engineering, if they do not know what the field is. While parental knowledge of what engineering is does not necessarily imply that they will encourage their daughters to participate, parents are very unlikely to encourage a child to a field or major if they have no knowledge of it. Because parents play such a role in helping their daughters choose their major, it is crucial that STEM programs educate not only the students themselves, but their parents as well.

Ideally, not only the parents' knowledge of engineering will increase, but also their attitude towards the field. Little change was seen in this initial study in this field. This could be because the parents already had high scores in their attitudes towards engineering. A larger participation rate or perhaps additional means of involving the parents in the SSI program could help in the future.

The parental results of this study can be drawn into question with only eight out of twenty-eight parents participants (a 29% response rate). The author does plan to continue this study in future summers and hopefully the response rate will increase, perhaps with additional incentives for participation.

The STEM Summer Institute program is an effective model for helping both girls and their parents increase their knowledge of what engineering is and should be replicated and emulated in other programs, both academic year and summer, for girls. The author will begin replication sites in the summer of 2014 that will include four independent all-girls' school summer camps, one public all girls' charter school summer camp, one public all girls' charter school middle school curriculum, and one public university in its STEM preparation courses for teaching candidates. The author hopes to move to additional sites, including international ones, in the future.

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