
AC 2012-3792: SYSTEMIC INTERVENTION: CONNECTING FORMAL AND INFORMAL EDUCATION EXPERIENCES FOR ENGAGING FEMALE STUDENTS IN ELEMENTARY SCHOOL IN ENGINEERING

Dr. Merredith D. Portsmore, Tufts University

Merredith Portsmore is a Research Assistant Professor in education at Tufts University, as well as the Director of Outreach Programs for Tufts Center for Engineering Education and Outreach. Portsmore has the unique honor of being a "Quadruple Jumbo," having received all her four of her degrees from Tufts (B.A. English, B.S. mechanical engineering, M.A. education, and Ph.D. in engineering education). Her research interests focus on how children engage in constructing solutions to engineering design problems. Her outreach work focuses on creating resources for K-12 educators to support engineering education in the classroom. She is also the founder of STOMP (<http://www.stompnetwork.org/>), and <http://www.LEGOengineering.com/>.

Ms. Jessica E. S. Swenson, Tufts University

Systemic intervention: Connecting formal and informal education experiences for engaging female students in elementary school in engineering

Abstract

This paper describes a project that is a *work in progress* on engaging female elementary school students in engineering. W-STOMP (Women and Student Teacher Outreach Mentorship Program) was designed as a systemic intervention for engaging 4th and 5th grade girls in engineering. The program works in the formal classroom through classroom teachers and undergraduate engineering mentors as well as through the summer camp opportunities. Eight 4th and 5th grade teachers from urban and urban-rim communities were recruited to participate in the program. Teachers participated in professional development during Summer 2011 that included topics in engineering, engineering design and gender issues in engineering instruction and activities. The teachers selected a set of activities for their classroom, ranging from LEGO Robotics to Service Learning projects, which they felt would engage all of their students in engineering learning to implement during the 2011/2012 school year. Each teacher is supported by two engineering students to aid with implementation of engineering. At least one undergraduate student in each classroom is a female to serve as a mentor and role model for the 4th and 5th grade female students. Capitalizing on the 4th and 5th grade girls formal classroom experience and the connection made with the undergraduate engineering students, the 4th and 5th grade female students will be invited to participate in a free summer program during Summer 2012.

The program hopes to demonstrate the value of looking at the engagement of females in engineering more systematically. Evaluation data will be collected on students' pre and post attitudes, interest, and conceptions of engineering through surveys and the Draw an Engineer Test. Qualitative data will also be collected in the form of classroom video observations. The results of this project will help to demonstrate its efficacy as well as new ways to think about how we address the issue of female participation in STEM (focusing on engineering).

Introduction

The comparatively low enrollment of female students in college engineering programs has focused attention on the experience K-12 female students have in STEM (science, technology, engineering and mathematics) [1]. There is evidence from research in science education that female attitudes toward STEM form as early as elementary school grades [2, 3], suggesting that interventions at the elementary level may be a productive component of changing female students attitudes and interests. W-STOMP has been designed as an intervention for elementary students to address multiple potential areas of impact that have been identified within the research on STEM interests and girls. The program is based on another program at Tufts University, STOMP (Student Teacher Outreach Mentorship Program), which places undergraduate engineering students into local K-12 classrooms to support teachers engaged in engineering activities. W-STOMP is a variant on that program that focuses on female engagement and expands the interaction between the program and the students. W-STOMP places the female elementary school student at the center of a network that looks to address

issues of engagement in engineering across multiple sources. Figure 1 shows Sally, our sample female elementary student, within a network of formal and informal activity opportunities as well as types of mentorship and encouragement.

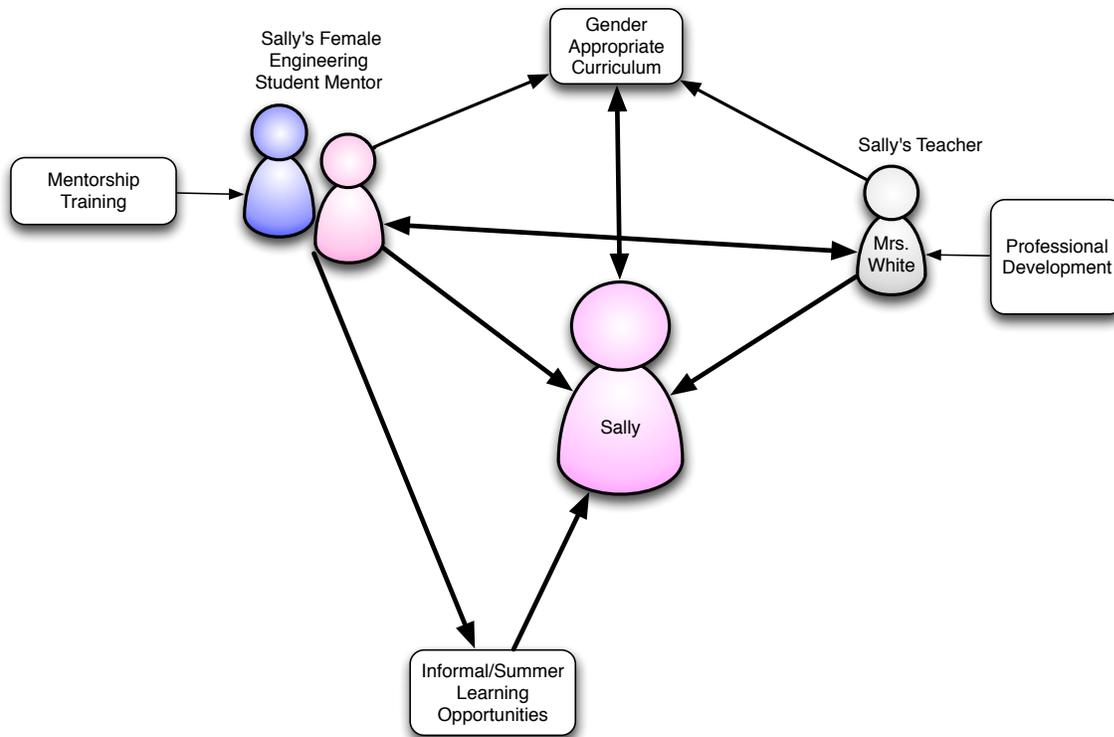


Figure 1: W-STOMP model of interaction

Typically, science or engineering- based interventions for female K-12 students focus on one particular kind of interaction or intervention. There are numerous examples in the literature of one day events [4], classroom-based interventions [5], mentorship, and informal education experience[5, 6]. However, the nature of female engagement with science has also been shown to be different from males with females looking for more social experiences within science and basing their choice to pursue science personal connections [7]. Moreover, research in female engagements suggests that the multiple factors that impact female students pursuit of science interact or work in combination. Hence, W-STOMP has been designed to address multiple factors (activities and interpersonal relationships with a teacher and mentor) in two different settings (the formal classroom and a summer camp experience) to increase the duration and the variation in the type of intervention that female students are exposed to.

Program Implementation

W-STOMP was implemented during the 2011/2012 academic years with multiple intervention components. The four main areas of design for the program included:

1. Teacher Preparation
2. Selection of Activities
3. Mentorship

4. Informal Education Opportunities – Summer Camp

Teacher Preparation

Fourth and fifth grade teachers were selected from the core communities of Tufts University by an application process. They participated in a one-week (35 hour) teacher professional development session at Tufts Center for Engineering Education and Outreach. The professional development exposed teachers to engineering and engaged them in engineering design activities. Table 1 shows the activities the teachers engaged in over the course of the week.

Table 1: Engineering Activities for W-STOMP Teacher Professional Development

Wind Tunnel Design Challenge	Challenge: Design a device that will float in a vertical wind tunnel for as long as possible Materials: Cups, Tape, Plastic Bags, String, Paper Clips
<i>The Mouse and the Motorcycle</i> Design Challenge	Challenge: Ralph the Mouse, a literary character, has driven his motorcycle into a wastebasket. Design a way for him to get out using materials typically found in a wastebasket. Materials: Toilet Paper Roll, Paper, String, Remains of an apple, Paper Clip
Animal Structure Model Design (LEGO)	Challenge: Design and model a new (imaginary) animal that would live in the Amazon Rainforest. It should have movement, defense and eating structures. Materials: LEGO materials (bricks, beams, connector pegs)
Animal Behavior Model (LEGO)	Challenge: Design and model the behavior for your new animal that will live in the Amazon Rainforest. Materials: LEGO Materials (NXT, Sensors, Motors, other pieces)
Service Learning	Challenge: Identify an engineering design problem in your school that you could prototype a solution for. Materials: Anything
Squishy Circuits	Challenge: Design a circuit that can light 2 LED lights Materials: Batteries, LEDs, Play dough

Each activity was followed up with discussions about the engineering design practices it developed and the issues with engaging all students, particularly female students, in these types of activities. The role of the teacher in modeling positive attitudes and interest was emphasized and the dynamics of partners was also discussed. Where possible, teachers also watched video of students engaging in the same or similar tasks and discussed what they saw in the way different genders interacted with the challenge and how they could support productive engagement with the task as a teacher.

Selection of Activities

W-STOMP does not prescribe a set of activities that teachers must use in their implementation of engineering but instead provides teachers with multiple options. The professional development gave teachers a sampling of each of the kind of activities they could use and they selected the ones that best fit their classroom. The selection provided

was based on identified best practices in engaging female students. Key principles included engagement with other topics, opportunities for socialization and communication, and creative input [7].

Table 2: Activities available to W-STOMP teachers

Integrating Engineering and Literacy	Classrooms engaging in designing solutions to problems faced by characters in a fiction novel or short story
Science Through LEGO Engineering	A set of units that use engineering as a context for the development of science topics[8]
Service-based Engineering Projects	Identification of problems that face communities or schools and the design and prototyping of a viable solution that can be presented to the client or community

Teacher also had the option of using the LEGO Materials to teach more traditional robotics topics of design, programming and problem solving. Teachers selected activities to use for one hour each week (during the 12 weeks of the Tufts University academic semester] during Fall 2011 and Spring 2012.

Mentorship

W-STOMP selects students from Tufts University’s population of undergraduate and graduate engineering students to act as classroom assistants to teachers and mentors to students. Each classroom participating in this program had two engineering students in the classroom for one hour per week during the fall and spring academic semesters to help with implementation. While the students have significant science, mathematics, and engineering knowledge, they are not trained educators. Training for the W-STOMP program involves preparing engineering students for how to interact with teachers and students. Their preparation includes attention to productive interactions and questioning techniques for working with students on engineering activities, ways to make personal connections with students, and how to interact with teachers.

Informal Education Opportunities – Summer Camp

A significant portion of the W-STOMP program model is devoted to the formal classrooms with resources dedicated to developing teacher’s facility with engineering and gender equity, activities that are appropriate and engaging, and providing mentors to all students. However, planned for Summer 2012 is a summer camp opportunity for the female students in the participating classrooms. Informal education opportunities, like summer camps, offer freedoms of time and content that are not possible in formal classrooms. The planned summer camp will be only open to female students and structured to follow their interest by engaging them in larger scale service learning design experience that will make use of LEGO and other robotic/electronic technologies and be presented to a public audience. A selection of female engineering students will serve as camp counselors continuing the mentorship.

Overview of Classroom Activity

W-STOMP was implemented during Fall 2011 and will also be implemented during Spring 2012. As previous stated, each teacher choose different activities two implement. Three of the teachers used the Science through LEGO Engineering units on Properties of Material and Sound[8]. Three teachers chose to pursue robotics and sturdy building for part or the whole semester, having their students build a chair for Mr. Bear, a robot, or a Mars rover. One teacher chose to integrate engineering and literacy by having students use the engineering design process to solve problems from the book *Hatchet* by Gary Paulsen. One teacher focused on service learning and two of the aforementioned teachers included a smaller service learning engineering activity in their classroom.

During Spring 2012, these classrooms will continue to explore the engineering design process through multiple activities and methods. Three of the classrooms will continue with Science through LEGO Engineering units on Simple Machines and Animal Adaptations. Three additional classrooms will tackle engineering problems from the book *Hatchet*. Finally, three classrooms will learn basic programming by complete a number of LEGO robotics challenges that have different themes that appeal to both genders. For example, one classroom is exploring the issue of safety and how vehicles can be designed to protect their passengers will be using the LEGO materials to prototype designs.

Case Study of Service Learning

One class in particular, Mr. Welsh's 5th grade classroom, spent the majority of the Fall 2011 on their service-learning project. On the first day of the service learning unit the students, two undergraduate engineering student mentors, and the teacher walked around the school and surrounding neighborhood to find problems. At the end of class time, students were asked to write the problem they found most compelling on a post-it note to share with the whole class. At the beginning of the next lesson, students were broken into groups of four and asked to pick which problem they wanted to pursue based on their initial ideas about how to solve it and the feasibility of creating a prototype and testing it. Initially, the term feasibility seemed to be limiting the thinking and risk taking of the groups, but the further the students got into their projects, the more confidence they gained to explore their problems in depth and make them more complex. The five projects that emerged from this day were The Toilet Flushing Problem, The Trash Problem, The Backpack Straps Problem, The Gum on the Bottom of Desks Problem, and The Stairs Problem.

Students then created a stop motion action movie (using SAM Animation Software [9]) to communicate their problem and a possible solution to the class. Figures 2-4 below are screenshots from the students' movies depicting their problems and proposed solutions.

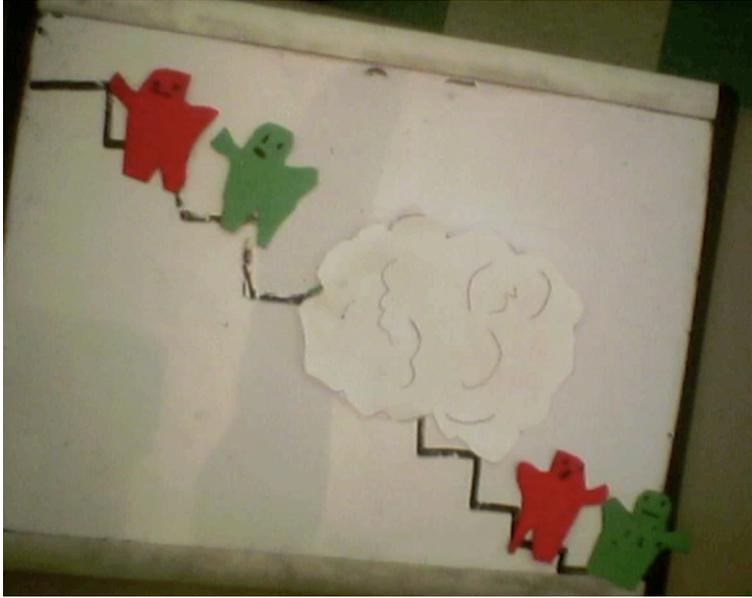


Figure 2: The Stair Problem's illustration of what happens when two classes are going opposite directions on one staircase



Figure 3: A possible solution proposed by the Trash Problem



Figure 4: A possible solution proposed by The Toilet Flushing Problem.

The purpose of the stop action animation was for the students to clearly define and explain the problem they were proposing to engineer a solution for. Students were evaluated by their classmates on how well they communicated the problem and proposed solution.

The following three weeks were dedicated to prototyping. Each group produced multiple iterations of prototypes, some consistently adding to the same device, such as The Guminator, while others created many prototypes for different locations in the school. A number of the prototypes can be seen in Figures 5-7 below.



Figure 6: Prototype from The Trash Problem



Figure 5: The Guminator was designed to remove gum from the bottom of desks.



Figure 7: The Stair Problem group and their prototype of colored tape arrows

Initial qualitative observation of the classroom showed gender dynamics within the groups, with groups with a higher number of girls sharing the project work and leadership more equally. The Gum on the Bottom of Desks group, The Backpack Straps group, and The Stairs group were all comprised of three boys and one girl. These groups were lead by one dominant boy, or in the case of The Backpack Straps group, two boys. In these groups the girl typically was the most active participant after the leader, rarely voiced their opinion, and was very active in the construction of the prototype. The Trash group was comprised of two girls and two boys and equally made decisions and constructed their prototypes together. The Toilet Flushing group consisted of three girls and one boy. This group also shared responsibility in decision-making and prototype construction.

While working in their groups, all eight girls in the class always remained active participants throughout the entire hour. The boys were divided with four as very active leaders, four who were active contributors, and four that remained distracted by other groups or friends and contributed very little to the design process. These observations suggest that the gender composition of the groups may be an important consideration in engagement of genders.

Other Observations

Spring 2012 observations are ongoing in two additional classrooms – Mr. Lawrence and Mrs. Parker’s paired 6th grade classrooms. These classes are using NXT Lego kits to

build Mars Rover-like robots and program them. In a meeting with the teachers before the spring semester started, the teachers informed us they would be separating the students by gender (1 classroom for all the girls and 1 for all of the boys). Videotaping and observations are currently ongoing in both groups. Initial observations have indicated that there may be qualitative differences between the genders in the building iteration process. Boy groups iterate by adding onto the existing structure, while girl groups deconstruct and then re-build. Further observations and analysis will occur as the spring semester continues.

Data & Evaluation

Evaluation of the W-STOMP program involves multiple measures of students. Using a pre/post/post design, students complete a Pre and Post Engineering Conceptions Instrument (which includes Draw an Engineer) as well as a Pre and Post Engineering and Science Attitudes[10] to measure the change in their understand of engineering and the change in attitudes. Students have completed the pre assessments and will take the post assessments at the end of Spring 2012. Students who participate in the summer program will take an additional posttest at the end of their camp experience. Classroom observations (a small sample is included in the Classroom In Action section) are also being conducted to look for the classroom dynamics that may be playing a role in the development of female students understanding and attitudes of engineering.

Conclusions

W-STOMP combines many successful approaches to engaging female students in engineering in a new, blended, systemic program. Current research of female in STEM education indicates that there are multiple social as well as academic aspects that influence female students attitudes and choices. It is crucial that we think about addressing those systemically so that we not only reach more females but also reach them more effectively. The outcomes of this project, will not only likely (data pending) have indicate a direct impact on female students but also help to inform how we need to think about programs to engage girls across multiple modalities. Future directions may include looking at multi-year interventions – working with female students from elementary school through middle and high school – in formal and informal settings to continue to build relationships and develop knowledge and interest.

References

1. National Science Foundation *Science & Engineering Indicators*. 2000.
2. Sullins, E.S., et al., *Predicting who will major in a science discipline: Expectancy–value theory as part of an ecological model for studying academic communities*. *Journal of Research in Science Teaching*, 1995. **32**(1): p. 99-119.
3. Kotte, D., *Gender Differences in Science Achievement in 10 Countries*. Vol. 9. 1992, New York: Peter Lang. 305.
4. Kennedy, K. *Engineering Career Day For Girls: Briding the Gap Between High School & The "Real" World*. in *American Society for Engineering Education*. 2006. Portland, Oregon.
5. Christie, B. *Girls, Solidworks, Robots and Mouse Trap Cars....Oh My*. in *American Society of Engineering Education Annual Conference*. 2010. Louisville, KY.
6. Noble, J., et al. *Empowering Girls: Measuring The Impact Of Science Technology And Engineering Preview Summer Camps (Steps)*. in *American Society for Engineering Education Annual Conference*. 2008. Pittsburgh, PA.
7. Baker, D. and R. Leary, *Letting Girls Speak Out about Science*. *Journal of Research in Science Teaching*, 1995. **32**(1): p. 3-27.
8. Wendell, K.B., et al. *Engineering-Design-Based Science, Science Content Learning, and Science Attitudes in the Elementary Grades*. in *National Association of Research in Science Teaching*. 2011. Orlando, FL.
9. *SAM Animation*. 2012 [cited 2012 January 1]; Available from: <http://www.samanimation.com>.
10. Lachapelle, C.P. and C. Cunningham. *Engineering is Elementary: Children's Changing Understandings of Science and Engineering*. in *2007 American Society for Engineering Education Annual Conference & Exposition*. 2007. Honolulu, Hawaii.