Girls' Interest in STEM

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***Abstract*—This is a work-in-progress. The dramatic decline in youth interest in science, technology, engineering and mathematics (STEM) during adolescence has been a phenomenon of societal concern for several decades. Researchers have documented the decline in youth math and science interest during and after middle school, noting an even greater decline amongst females and minorities. Results of structural equation modeling (SEM) from a previous study indicate girls' interest in life sciences, a non-analytical area, differs from boys' interest and that out-of-school STEM experiences may have a positive impact on student interest in STEM. Both of these findings have implications for how to predict STEM interest and design instruction for more students, especially since the study of physics, an analytical course, is less attended by girls and considered the gateway to engineering. This research utilizes surveys, observations, interviews and focus groups in an all-girls after-school STEM program, and expands upon the constructs of science, math, and STEM interest to consider additional affective components such as empathy and belonging that may play a key role in improving girls' interest in STEM, especially engineering.**

Keywords*—*STEM, interest, girls, after-school, empathy.

I. Introduction and Background

According to the National Research Council, 2006, interest is identified as a critical factor in predicting future engagement in STEM activities and careers [1]. Fewer and fewer students choose to major in scientific fields at high school and university levels [2,3]. In some areas of engineering, such as computer science, the number of women has declined [4]. Because of the importance to learning and future outcomes, educators are increasingly focused on identifying ways to capture and maintain student interest in STEM. However, research indicates STEM interest declines with progression in school, especially by the end of middle school. A recent national report by the President's Council of Advisors on Science and Technology recommends experiences be created inside and outside the classroom to inspire youth (age 10-14) interest in STEM [5].

Some researchers report a greater decline for girls and minorities [6], while others report girls and minorities interest begins and remains lower than boys [7]. Other studies focused on girls in STEM indicate there is no "achievement gap" between girls and boys, but a lack of interest from girls [8,9].

STEM has become part of our lives-in constant media messages, public policy, political platforms, national reports and in our children's school work. As a means to apply science content knowledge, engineering is included in the 2010 K-12 Next Generation Science Standards [10], further intensifying the STEM onslaught. Engineering practices are now required in teacher professional development in Washington.

The term "STEM" is thought of as one construct and also as individual constructs of science, technology, engineering and mathematics, making it a complex study. Previous research by Falk and colleagues [11] advances the field by evaluating student interest as a multi-faceted construct in all four STEM areas, in- and out-of-school, with social support and longitudinally. The research question is "What is the nature of the STEM-related interests of 10-/11-year-old youth living in a single urban community and what factors seem to influence whether these various dimensions of interest increase, stay the same or diminish over time?" This ongoing study includes both qualitative interviews and quantitative surveys. Contrary to previous studies [12], results from the first two years indicate students become more interested in some STEM areas (e.g., earth/space science, life science and technology/engineering) between the ages of 10/11 and 11/12. These findings support Hidi and Renninger's theory that interest development requires knowledge [13]. Additionally, the study indicates students who are more interested in STEM are more engaged in STEM out-of-school activities; and lastly, girls are significantly more interested in life sciences than boys ($p=.003$) with a moderate effect size ($d=0.48$) [11].

In a related study, Staus, Lamb and Lesseig [14] administered the STEM interest survey to over 800 students at two different schools (a STEM school and a traditional middle school whose teachers had been involved in STEM-related professional development). This study validated the survey through structured equation modeling and Rasch analysis. Until this model was developed few instruments captured all of "STEM" or measured outcomes in the affects domain in more than one STEM domain concurrently. One of the results indicates mathematic interest moderates science interest.

The Falk et al. survey and the Staus et al. measurement model will be used for a Rasch analysis of the data in this work-in- progress study using exploratory and confirmatory factor analysis and structural equation modeling. The resultant difference in girls' and boys' interest and the factors that contribute to girls' interest are the basis for the research.

II. Theoretical Framework and Literature Review

A. Theoretical Framework

The researchers are female. H. Burns, the primary researcher, is a female, immigrant, person of color, first generation college student, engineer and math/science education Ph.D. candidate. The other two researchers are white. One is a math professor and the other a science research associate. Although most of the time the researcher will only observe, at times the researcher will be a participant. The epistemological perspective is transformational and feminist. Unlike previous studies, this work will study STEM interest as a multi-level construct, evaluating the connection amongst interest, self-efficacy, belonging, identity and empathy. The fundamental purpose for the research is to unveil and define girls' interest and if STEM lessons with an empathy focus will increase girls' interest in STEM, especially their interest in pursuing analytical courses in high school and engineering in college and their sense of belonging. The theoretical framework stems from an interest lens as developed through the work of Hidi and Renninger [13], indicating interest develops over time and through knowledge, activities, engagement and social support. The work also depends upon identity theory and the link between social, role and person identities to belonging and self-efficacy [15].

Additionally, the framework draws upon the Stanford 4D Model for project design which begins with empathy (Figure. 1). The needs of the customer are core to the design definition. Empathizing is defined as "work to fully understand the experience of the user for whom you are designing...through observation, interaction and immersing yourself in their experiences" [16].

Figure 1. Stanford Design Model

The research questions for this work-in-progress are the following:

- Do the after-school program lessons with an empathy component increase girls' interest in STEM, especially in engineering or analytical courses (physics and computer science) and their sense of belonging?
- How are interest, self-efficacy, belongingness, identity, and empathy connected?

B. Literature Review

1) Interest: Some say the first affect, interest, has a larger influence than academic achievement on choice of STEM as a career [17, 18] and is connected to persistence [19, 20]. Interest is defined as a combination of cognate and affect (a state and a disposition), and is a relationship between a person, their environment and a topic [21, 22]. An example of research of interest of girls in STEM leading to success in engineering with various constructs is a study by Hoffmann and Haussler [23] which combines both interest perspectives; the relationship between a girl and an object (in this case, physics), and a girl and her environment (in this case, an all-girls class). An all-girls class was chosen to create a sense of belonging and physics was chosen because it is typically not taken by girls in high school [24]. In contrast, Robnett and Leaper indicate all-girls classes can be a negative influence when others girls are negative about STEM [25]. Leaper, Farkas, and Brown [26] propose the reason might be the importance of peer support to adolescent girls.

2) Self-efficacy: Self-efficacy is a student's self-perceived ability to do a task and a judgment of the value of the task [27]. A foundational study by Lent, Brown and Larkin [28] indicates students with high self-efficacy correlated positively with higher achievement and longer persistence in STEM majors than those with low self-efficacy. Self-efficacy and interest are mutually influencing [29].

Some studies indicate the concern on interest and self-efficacy is over-blown and girls are taking more science courses just different, empathy-focused ones, and matching or surpassing boys on academic achievement measures [30, 31].

3) Empathy: In her award-winning 2015 National Association for Research in Science Teaching (NARST) dissertation, A. Godkin's concludes girls are drawn to work with global social value [32]. Empathy and caring are also identified as important characteristics for acquiring 21st century skills [33] through project-based learning, as illustrated in the Stanford Design Model [34, 35]. However, just requiring empathy is insufficient. Research indicates those who excel in more analytical areas are less capable in emotional aspect of empathy [36]. Additionally, engineering educators and practitioners lack explicit attention to empathy and caring [37].

4) Belonging: Belonging and recognition, components of identity [32], are two affects women in engineering identify as success factors [38]. To have an identity as a member of a community requires not only the ability to perform the skills required of a member of the community, but also recognition by the community as a skilled member [39]. Women have to do engineering and also be accepted as engineers by their engineering community, a difficult task in the highly gendered culture of engineering [40]. Additionally, Voyer and Voyer [41] say women want to maintain their identities, preferring to study and work in areas of care and social change [8,9,42].

III. Methodology

We are studying approximately 900 middle school students, comparing demographics and gender to set a baseline to help teachers develop ideal instruction. Additionally, approximately 20 girls participating in an after-school STEM program are surveyed, observed and interviewed, over time. These girls are observed and interviewed for engagement in and expression of interest, belonging, self-efficacy and identity to empathetic lessons during an after-school STEM program. This sub-group of girls' interest are compared to the interest level of the girls in the general school population.

This study is conducted at a Pacific Northwest middle school of approximately 900 students grade six, seven and eight and approximately 20 girls grade seven and eight in an after-school program. The demographics of students at this school are in Table 1.

913	White	Hispanic	Pacific Islander	Low Income
All Students	39.7%	45.7%	6.2%	81.3%

Table 1. Middle School Demographics, WA. OSPI, 10/2015.

The after-school program meets on Tuesdays and Thursdays from 3:30 pm until 5:30 pm. A Mathematics, Engineering, and Science Achievement (MESA) program meets at the same time. The program is funded by a state non-profit and the coordinator is employed by a local education service district who sponsors the program. The program is the only one in the school district. This coordinator has run the program for at least two previous years. The program began in September but observations began in January. The girls have a positive relationship with the coordinator, Ms. F. When she decided to take a different job in February some of the girls stopped coming. In April fewer girls came on average (20 to 12). The temporary coordinator is a female of color currently working in a daycare center in early childhood development with no STEM experience. The program is also supported by a female of color college student, a female of color math teacher and a male of color English intervention specialist. The girls attend voluntarily and most take a bus home.

The program begins with snacks followed by a fireside format "STEM Connections" chat when girls share any STEM experiences from the previous days. The typical lesson (Figure 2) is a brief explanation by the coordinator, sometimes with artifacts or iPads (provided by the school to all students) in whole classrooms, of the handout and what the girls are to do followed by breakouts into assigned groups. The girls usually have to write or draw and then obtain approval before they can build. At the end of the class they share their builds.

A. Data Collection Methods

Data collected for this study includes: (1) quantitative survey administered to the entire school population which will be analyzed through SEM (Table 2); (2) observations, field notes and artifacts from the all-girls after-school STEM program; and (3) student focus groups and interviews with the teachers and program coordinator of the after-school program. This is the same short survey administrated and validated by Falk et al. [11], and will be distributed by the school.

1) Survey: The Table 2 student self-reported survey is a 5-point Likert scale containing three pages of 15-20 questions in the four categories of STEM.

	Like a lot	Like a little	Neither like nor dislike	Dislike a little	Dislike a lot
How stars and planets form					
Mixing materials to see what happens					

Table 2. Sample Survey Questions From Falk et al. [11].

2) Interviews and focus groups: The researcher uses interview and focus group protocols. Field notes are taken and audio/video tools used depending on number of permission slips received. Focus groups are audio/video taped and headed by this researcher and program teachers.

3) Lessons: Researcher observes students' level of engagement, content of drawings, notes girls' language utilization (related to constructs studied, i.e., interest, liking, belonging, empathy, and their feelings about the impact of the lesson on themselves or on society) in student conversations and written work with an observational protocol. Words tracked are those typically utilized in the literature and as defined by Webster's Online Dictionary. Field notes are taken and the girls lesson notes are studied.

PROJECT NAME: Live Like an Animal
SOURCE: eGFI-For Teachers
BIG IDEA OR CONCEPT: STEM Saves the World!
DAY ONE:
Background: When engineers use examples from the natural world to influence their design they call it "biomimicry."
Real World Connection: The 2008 Beijing Olympics main stadium is an example of this type of design. Architects and structural engineers who built it designed it to look like an enormous bird's nest.
Intro to project: When you were younger, did you ever build a fort out of pillows, a blanket, cardboard, or tree branches? Can you think of an example from nature that resembles your fort? What kind of animal structure was it similar to? (Bats or bear cave, bird's nest?) What are some advantages of the examples given? (I.E. lightweight, strong, sheds, protection).
Activity: In self-selected groups of three to four the girls are going to design a human structure based on an example from the animal kingdom they pick. The animal will be researched for ways that animal finds/builds their own shelter. Using that information, the girls brainstorm ideas and design a human structure that incorporates some of the useful features of the animal shelter and sketch and model to the sketch their structure with dimensions and identify needed material.
DAY TWO:
Intro to Project: Ask the girls, "Why do you think an architect or engineer would model a building, automotive, or other human device on the animal and natural world? How do you think you might feel about biomimicry if you were the animal?"
Activity: The girls will recap this week's STEM challenge, present their design, discuss what was improved and identify any inspirations.

Figure 2. Typical STEM Lesson.

B. Data Analysis

1) Survey: Compare STEM interest of girls in after school program with larger school population using descriptive statistics. Compare constructs using SEM and Rasch analysis.

2) Lessons: Assess language utilized when drawing, writing or speaking about and/or during lessons. Determine level of engagement as low, medium or high for each lesson. Code data a priori based on commonly used vocabulary to assess interests and empathy from literature search. Identify, organize and establish patterns in a code book and compare lesson to lesson.

IV. Results

Because the survey was conducted the last three days of school only 217 students took the survey online: grade six boys (49), girls (64); grade seven boys (24), girls (36); grade eight boys (28), and girls (16). Approximately 40 students submitted hand-written surveys. Of the twelve who remained in the STEM program, eight girls participated in the focus groups held in June. Four sixth-grade girls participated in both the after-school STEM program and the online survey. Teacher interviews will be conducted over the summer. Observation and field notes, and artifacts (photos and reflection journals) collected for three months, and the transcribed focus groups will be fully evaluated.

Preliminary analysis of online survey responses from the sixth-grade, for the kinds of projects that interest girls, reveals three areas of significant difference (t-test 2-tailed, unequal variances, $p<0.05$) between sixth grade boys and girls interest. Those three interest items are designing games ($p=0.002$), learning about engines ($p=0.011$), and making shapes and patterns ($p=0.006$). Results indicate girls are less interested instead of more interested in these areas than boys. However, when comparing STEM girls to other all sixth-grade girls, the percentage (number interested/total group size) of STEM girls interested in STEM is higher than the general sixth-grade girls in all 24 STEM areas in the survey. The exception is the human body; 25% of STEM girls are interested, 31% of the 64 girls and 45% for the 49 boys.

Focus group responses were analyzed for the kind of projects mentioned, the words and expressions used to describe their experience relating to the research questions and career aspirations, i.e., comments related to empathy, self-efficacy, identity, belonging and the future. When asked in the focus groups which projects are most memorable girls mentioned biomimicry and the food packaging projects. What they like about the STEM program is "building things" and learning "why thing work, unlike regular school." A common response when asked what they like about an all-girls program, was camaraderie and teamwork. When asked if girls belong in engineering one girl's response was "girls are better than boys at engineering because we have more of. What is that? Intuition? No, common sense."

V. Discussion

Based on observations girls are becoming more interested in the program, especially in empathy-based lessons, e.g. bicycle helmet design, architectural mimicry and robotic arms. After building a model to mimic an animal's natural habitat, the girls asked to have their photos taken with their artifacts for the first time. During the mimicry research they constantly talked about animal cruelty and how they would not like to be taken away from their homes.

Baseline observations and field notes indicate girls are interested in empathy based careers. "I want to be a doctor and help people." Whereas, some responded to engineering as a career as "a lot of work and thinking." However, during the focus groups the girls indicated the experience was fun and they enjoyed making things that work. The primary response to what they like about the program was not the nature of the projects but the bonding and sense of belonging they felt. The survey reflects an overall increase in interest in STEM compared to their peers. The comparison of all sixth-grade boys to girls does not indicate girls preferred empathy based areas more than boys but, instead indicates girls are less interested in engines, games design and patterns.

Hands-on activities are preferred to writing and even drawing but this may be due to ESL status of many of the girls. The girls do not like documenting their ideas. "I hate writing, it is my worst subject, my favorite part is the building." Nevertheless, when asked what they dislike about the program they added the sketching and redesign required of the design process. They struggled to recall the design process.

The girls are eager to help this researcher and often ask questions about why I chose engineering and why I am not "doing" engineering now. In addition to being "doctors" some want to be "teachers". Contrary to common perception of girls as more cooperative, these girls are very competitive, often checking others' work to compare and eager to present their results at the end of class. During the focus groups girls noted a feeling of safety when sharing with all girls, but some said it was less boring with boys. One girl said, "I like to build, but not what I am told to do. I like to build what I want to build." Girls walk around to help, but are not always welcomed. Teamwork is still a challenge. Girls prefer to sit with friends.

Before each lesson girls meet to share STEM Connections, experiences with STEM they had since the last lesson. The number of and type of examples the girls bring to class are increasingly more about empathy based social and/or family issues. For example, girls often mention designing a device to help a pet, a friend, or relative with a disability or injury.

Work to be completed includes analysis of all materials; surveys, focus groups, observation and field notes, artifacts and teacher interviews. The survey may be repeated next year. Findings could inform future curriculum design, advance research and practice regarding increasing the number of women interested in and persisting in engineering fields. Additionally, this work seeks to transform the reputation of engineering and reveal its nature as an empathetic profession. Our hope is by highlighting empathy in k-12 curriculum, especially in analytical sciences, elevating the status of the caring sciences, and changing the perception of engineering as a more welcome culture where girls will feel they belong. Perhaps this drive to make engineering more welcoming will be the key to adding value to female occupations and to what is "feminine," as desired by women who persist in STEM [38]. A successful world for females in STEM is a world of a growth mindset where no one believes a brain is, or is not, hard-wired for math or science [43] is long overdue.

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