AC 2008-1820: KEY FACTORS RELATED TO HIGH SCHOOL GIRLS' INTEREST AND ASPIRATIONS IN ENGINEERING, SCIENCE, AND MATH

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Abstract

We present initial findings from an ongoing study taking place in 5 schools in a large urban district in the Northeast. For this investigation, we limited our analytic sample to the 549 female participants from whom we collected survey data in order to examine correlates of girls' interest in pursuing college coursework in engineering, science, and mathematics. Using a social-ecological framework, we found differing patterns of associations using engagement, capacity, and continuity variables (as suggested by Jolly et al.'s trilogy model) for the three domains. Engineering interests and aspirations were related to school characteristics, science and math self-efficacy, and experience with extracurricular activities. Interest and aspirations for science were correlated with science salience and support from science teachers, while interest and aspirations for mathematics study was associated with math self-efficacy, math salience, and support from math teachers. Gender ideology also played a role, but in the opposite direction expected.

To shed additional light on these findings, we analyzed data from Key Informant interviews conducted with several local and national STEM leaders. Themes from the Key Informant interviews included attention to extracurricular activities (infrastructural issues, socioeconomic support, the need to support adults in their work with urban youth, specific challenges associated with after-school STEM opportunities) and messages to girls regarding STEM involvement (gender-specific messages that can discourage or encourage girls, presentation of STEM opportunities that appeal to girls and speak to their interests). Implications for teaching and practice are discussed.

Background

Even as girls' and women's participation in some areas of science has risen considerably in the past few years, the field of engineering has changed very little with rates of female engineering majors estimated at between 18 and 20% [1]. Research on the patterns of girls' progression in the science, technology, engineering, and math (STEM) pipeline is well established [2], documenting attrition which begins in middle school and continues through graduate school. On the other hand, women who do enter into college science and engineering programs tend to be successful [3]. Thus it is critical to investigate factors that foster girls' interest and lead to increased participation and retention in STEM generally, and engineering in particular.

Significance and contribution of the current study

This paper describes an analysis of data collected as part of the Success in Science, Technology, Engineering, and Mathematics (SISTEM) research study. The SISTEM study seeks to build upon Jolly et al.'s [4] trilogy model, which delineates engagement (e.g., interest in STEM), capacity (e.g., knowledge and skills), and continuity (e.g., resources and opportunities) as inter-related and critical factors in students' STEM success and retention. While the STEM trilogy model attends both to individual (e.g., student interest) and structural (e.g., resources) factors, the SISTEM Study expands that focus by employing a more comprehensive social-ecological paradigm [5, 6]. The social-ecological framework allows us to examine multiple levels of influence in girls' and boys' lives ranging from proximal (e.g., family, peers, school, work) to more distal (e.g., local labor market for science-based student employment/internships, availability of community opportunities around science, and more macro-level cultural-level beliefs about gender roles, women/minorities in science, and achievement).

Theoretical framework of the socio-ecological model

In our study's social-ecological model, individuals' STEM engagement and capacity (Jolly et al.[4]) are nested within interconnected systems of influence ranging from proximal to more distal. The ***micro-system*** is characterized by face-to-face connections among individuals, i.e., students' interactions with family, peers, school, work (if applicable), and other potentially important entities such as neighborhood or church. The micro-system exists within the larger context of the ***exo-system***, those systems in which the individual does not directly participate, per se, but that influence the micro-systems of which the individual is a member. Examples relevant to students' STEM experiences include the larger school system, the local STEM employment landscape, cultural institutions, and local higher education. These systems operate within the more distal ***macro-system*** of societal cultural beliefs and practices; in this case, cultural beliefs about females in science, beliefs about minorities in science, and beliefs about achievement, success, and economic mobility.

Research questions and hypotheses

This paper presents initial findings from an ongoing longitudinal project taking place in five high schools within a large urban school district in the Northeast. A total of 1093 boys and girls participated in the first year of data collection; for this investigation we limit our analytic sample to the survey data collected from female participants (n = 549), in order to examine correlates of girls' interest in pursuing college coursework in engineering, science, and mathematics. Because of the relatively stagnant rates for girls' participation in engineering compared to other STEM domains [1], we hypothesize that capacity, engagement, and continuity will have differential associations with engineering, science, and math. Secondly, we hypothesize that girls who report interest and aspirations in engineering will also report stronger connections, participation, and supports for STEM in the micro-, exo-, and macro-systems. To provide further context for this investigation, we analyzed data from Key Informant interviews conducted with several local and national leaders in STEM education and promotion.

Method

Survey design and procedure

Student Participants. The total number of students who participated in the survey administration was 1093, with a higher percentage of girls participating (52%) compared to boys (48%). For this analysis, we limited our investigation to girls in the sample. Female students (n=549) were recruited from five high schools in a large urban school district in the Northeast. These specific high schools were targeted within the district because they had an explicit focus on one of the STEM areas and/or a strong reputation for instruction in the STEM subjects. The schools represent a cross-section of the district in that they include a large school with a focus on humanities that require passage of an entrance exam for enrollment (n = 356 girls), a second exam school with an explicit math and science focus (n = 112 girls), and three smaller schools: one focusing on health sciences and technology (n = 35 girls), one with an explicit business focus (n = 26 girls), and one with an explicit focus on engineering (n = 20 girls). These three non-exam schools were created during a recent reorganization of district high schools which divided larger comprehensive neighborhood schools into smaller theme-based learning communities. Student racial/ethnic diversity included 17% Black, 29% White, 10% Latina, 25% Asian, 4% some other race/ethnicity, and 16% bi-racial or multi-racial. Students reported a range of maternal education levels: 10% did not complete high school, 20% had a high school diploma, 13% took some college courses, 23% completed a bachelor's degree, and 19% went to graduate school. School and district descriptions are described below and in Table 1.

District/School Site Characteristics. The school district in which this research took place is by all accounts a high need district that serves a diverse group of low-income, racial and ethnic minority students (see Table 1). The schools, as described above, varied in their exam/non-exam status as well as in STEM/non-STEM focus and also by student demographic and overall performance characteristics. Based on existing research [7] and on our theoretical framework using the social-ecological model we expected that the school and neighborhood environment would have a considerable influence on types of general academic and STEM-specific opportunities and supports available for students, and thus on STEM outcomes. Based on summary data derived from state Department of Education (DOE) records, students in the exam schools outperform students in the theme schools on state proficiency tests, have a higher percentage of students with plans to attend a 4-year college, and have much lower dropout rates, as would be expected given the schools' rigorous entrance requirements. In addition, the non-STEM focus exam school is distinct from the other schools and the district in general in its student racial/ethnic composition and percent of low-income students. These state-reported differences in school sites are taken into account in our inferential analyses through the selection of the non-STEM focused exam school as the referent by which to compare the other four schools.

Survey measures: control variables

School Site. Although each high school was selected because of its particular emphasis on STEM or STEM-related programming, the sites vary by neighborhood characteristics, student composition, and educational ranking (as described above and in Table 1). A series of dummy variables was created to test for differences by site. The non-STEM exam school is the reference in our logistic regression models.

Student Demographic Characteristics. The under representation of Black and Latino college engineering students relative to Asian and White students is well-established [8], thus demographic measures include the following racial/ethnic categories: Asian, Black, Latino, White, Other, and bi-racial/multi-racial. African Americans and Afro-Caribbeans are combined into a single group designating students of African descent to parallel school identification categories (although the singular “African American” is listed in DOE descriptors and we use “Black” here). Because of the very low numbers of Native Americans and Native Hawaiian/Pacific Islanders in our sample, those are combined in the Other race/ethnicity category which also groups students who self-identified as not belonging in the first four categories. The White category is used as the reference group for the logistic regression analyses.

Maternal Education Level. Because of intergeneration patterns of educational attainment [9], we include student report of mother’s highest level of formal education. Maternal educational level is also an important measure of students’ socioeconomic status (SES), although student reporting of this variable is often challenging [10]; for the logistic regression, data was imputed for 15% of students who were unable to provide this information (primarily because they did not know it).

Individual factors

Favorite Subject. Students were asked to name their “favorite subject or class.” The open-ended item was recoded to a dichotomous variable indicating a STEM subject as their favorite (1) or a non-STEM subject as their favorite (0). This recoded variable was included in the regression models as a measure of engagement.

Best Subject. Students were asked “In what subject or class do you get the best grades?” The open-ended item was recoded to a dichotomous variable indicating a STEM subject as their best (1) or a non-STEM subject as their best (0). This variable was used for descriptive analysis.

Self Concept of Ability in Math [11]. Students reported on how well they thought they performed in math. The 5-item scale has a seven-point Likert response of 1 (not at all good) to 7 (very good); alpha = .89. Sample items include “How good in math are you?” and “In general, how hard is math for you” (reversed).

Self Concept of Ability in Science. Students reported on how on how well they thought they performed in science. This set of questions was adapted from Self Concept of Ability in Math [11]; items have identical sentence stem but substitute “science” for “math.” The 5-item scale has a seven-point Likert response of 1 (not at all good) to 7 (very good); alpha = .88.

Grades. Students were asked to rank themselves compared to peers on grades received. The 5-point Likert response ranged from 1 (near the bottom) to 5 (one of the best).

Science Salience. Students were asked how much they agreed or disagreed (on a 4-point scale) with the following item: My interest in science is an important part of how I see myself.

Math Salience. Students were asked how much they agreed or disagreed (on a 4-point scale) with the following item: My interest in math is an important part of how I see myself.

Individual aspirations

Educational Plans. Students were asked “How far do you think you will go in school?” Responses on a 6-point scale ranged from “won’t finish high school” (1) to “will attend a higher level of school after graduating from college" (6). Students who planned to go on to college were also asked "what do you think you might choose as your major?" These open-ended responses were recoded to a dichotomous variable indicating either STEM subjects or other subjects for summary description.

Job or Career Aspirations. Students were asked "What would you like to do for a job or a career once you are finished with school?" These open-ended responses were recoded to STEM jobs/careers or other jobs/careers for summary description.

Interactions with micro-system

Teacher Support. The Teacher Attitudes subscale from the Modified Fennema-Sherman Attitudes Scale [12] was used to assess perceived relational support from teachers in two different domains: *science* and *math*. Sample science items include "I would talk to my science teacher about a career that uses science" and "It's hard to get math teachers to respect me" (reversed; alpha = .86). Math items have identical sentence stem to teacher attitudes regarding science but substitute "math" for "science" (alpha = .84).

Interactions with exo-system

Extra-Curricular STEM Activities. Students were asked to report on whether they had ever participated in the following activities: (1) visited a science museum, (2) participated in a science fair, (3) participated in a STEM competition (e.g., Robotics), (4) joined a STEM-focused school or after-school club, (5) attended a STEM-focused summer camp, (6) participated in a STEM-focused program at local college or university, and (7) had a job or internship related to STEM. A single score with a range from 0 to 7 was created by adding up affirmative responses.

Interactions with macro-system

Societal Support for Girls' Higher Education. Students were asked to respond on a 4-point scale (1 = very unsupportive to 4 = very supportive) "How supportive do you think U.S. society is of girls and women getting a college education and then a really good job?"

Societal Support for Girls' Science Careers. Students were asked to respond on a 4-point scale (1 = very unsupportive to 4 = very supportive) "How supportive do you think U.S. society is of girls and women who want to study or work in science?"

Femininity Ideology. The Adolescent Femininity Ideology Scale [13] assesses the degree to which girls have internalized beliefs about how they are supposed to act, feel, and be feminine. The two subscales were administered: Objectified Relationship to Body (AFIS-ORB; alpha = .78) and Inauthentic Self-in-Relationship (AFIS-ISR; alpha = .73). Higher scores on these two subscales reflect an internalized repressive hegemonic femininity ideology.

Dependent variables

Engineering Aspirations. Students were asked to report "How much do you want to go to college to study engineering?" (1 = not at all, 5 = a lot). Responses from the 5-point scale were used to create a dichotomous variable representing plans to study engineering ("a little" or "a lot") versus lack of interest in studying engineering ("not at all" "not much" or "neutral").

Mathematics Aspirations. Students were asked to report "How much do you want to go to college to study math?" (1 = not at all, 5 = a lot). Responses from the 5-point scale were used to create a dichotomous variable representing plans to study math ("a little" or "a lot") versus lack of interest in studying engineering ("not at all" "not much" or "neutral").

Science Aspirations. Students were asked to report "How much do you want to go to college to study science?" (1 = not at all, 5 = a lot). Responses from the 5-point scale were used to create a dichotomous variable representing plans to study science ("a little" or "a lot") versus lack of interest in studying engineering ("not at all" "not much" or "neutral").

Qualitative design and procedure

Key Informant procedure and *participants.* Seven female leaders in the local STEM field participated in a Key Informant Interview component of the study. The purpose of this component was to provide an understanding of the wider "social ecology" of STEM for our study participants and the larger context of STEM-related opportunities in the district and metropolitan area. Specific items asked about the availability of extracurricular STEM activities (including after-school, vacation, and summer opportunities), local employment opportunities, and local higher education opportunities. Participants included the director of science education for the focal school district, an administrator at a local museum of science, a nationally recognized researcher of STEM education, a university engineering professor who collaborates with middle and high schools, and three administrators of different programs bridging student education and employment. Each interview lasted approximately one hour and was conducted by one or more of the three lead researchers on the project. Six of the interviews were audio-taped and transcribed and one was conducted over the phone with written notes to document the interview.

Analysis plan

Statistical analyses. Descriptive and inferential analyses were conducted using SAS 9.1 (SAS Institute, Inc., Cary, North Carolina). First, we estimated the rates of girls' interest in high school STEM coursework, and aspirations for STEM college and career paths. Secondly, we examined correlates of engineering, science, and math college aspirations using three sets of logistic regression models. Demographic variables such as school site, race/ethnicity, and maternal education level were included in the models along with individual factors and micro-system and exo-system measures. Missing values were multiply imputed using the PROC MI procedure in SAS [14]. We report odds ratios and 95% confidence intervals.

Survey Results

Descriptive statistics

Slightly less than half of the girls (48%) named a STEM subject as their favorite subject and 37% reported a STEM subject as the subject they earned their best grades in. All of the girls expected to complete high school and only 2% reported they had no plans to attend college. Six percent (6%) reported plans to attend some college, 32% planned to complete college, and 60% planned to attend graduate school.

We inquired about aspirations using two different sets of items. First we reported outcomes of the scaled items used in our logistic regression analyses, then to provide greater context we summarized the open-ended responses (missing data for open-ended responses limited our ability to use this information in inferential analyses). Table 2 shows correlation results of the three variables measuring aspirations for college coursework using the original 5-point scale. Plans to study engineering were moderately related to plans to study science (r (549) = .37, $p < .0001$) and mathematics (r (549) = .43, $p < .0001$). In contrast, plans to study science were weakly correlated with plans to study mathematics (r (549) = .22, $p < .0001$). Reviewing results from our dichotomous recoding of this set of dependent variables, we found that 18% of the girls in the study reported some plans ("a little" or "a lot") to study engineering in college, 42% reported plans to study science, and 33% reported plans to study mathematics.

In reviewing our open-ended set of questions regarding aspirations, 42% of girls reported plans to study a STEM subject in college. This open-ended format allowed for inclusion of reported interest in technology components of STEM. Examples of the variety of STEM majors named included: chemistry, computer technology, aerospace engineering, electrical engineering, environmental engineering, mechanical engineering, mathematics, medical science, physics, and so on. However, many fewer girls reported aspirations for a career in a STEM field (13%). Examples of STEM career aspirations named by girls included: chemist, computer programmer, aerospace engineer, mechanical engineer, forensics, marine biologist, medical research, radiologist, video game designer, to name a few. Of the specific STEM components, girls expressed the least interest in engineering with only 6% reporting explicit plans to study a particular engineering major in college and only 4% explicitly naming a future engineering job or career.

Comparisons of logistic regression models

In Table 3, we present the results of our logistic regression models examining correlates of engineering, science, and math college aspiration outcomes in side-by-side comparisons. Students at the theme school with the engineering focus were 5 times more likely (odds ratio (OR) = 5.40) to report plans for studying engineering in college but had decreased odds (OR = 0.23) of reporting plans to study science compared to students in the exam school with the humanities focus. Students at the science and math focused exam school and the theme school with the business focus had significantly lower odds of reporting plans to study science compared to the humanities focused exam school (OR = 0.51 and OR = 0.30, respectively). There was no relationship between school site and plans for studying math in college.

Racial/ethnic background only had one significant association with outcomes, as students who were grouped together in the "other" category were more likely to report plans for studying math in college (however, this included a wide variety of monoracial/ethnic identities and most of these students were enrolled in the exam schools so this might simply be confounded with school site). Maternal education level was not associated with STEM college aspirations.

For every one point higher rating on grades compared to peers, students were 30% less likely to report plans to study math (OR = 0.70). For every one point increase in science self-efficacy score, there was a 14% increase in odds of reporting college engineering plans. For every one point increase in math self-efficacy there was a 26% higher odds of reporting plans to study engineering (OR = 1.26) and over twice the odds of plans to study math (OR = 2.22). Every one point increase in science salience was associated with over three and one half times the odds of plans to study science (OR = 3.63), while every one point difference in math salience was associated with almost three times odds for plans to study math (OR = 2.92), but lower odds for studying science (OR = 0.76).

Students who perceived higher relational support from teachers in the domain of science were twice as likely to report plans for studying science in college for every one point difference in the Fennema-Sherman (OR = 2.20) while perceived relational support from teachers in the math domain was positively associated with college plans to study math (OR = 1.76 for every one point difference). Every additional reported extracurricular STEM activity was associated with higher odds of planning to study engineering in college (OR = 1.42). Finally, girls who had internalized more conventional femininity ideology in their ideas about their body and appearance (for every one point higher score on Objectified Relationship to Body) were more likely to report plans to study engineering (OR = 1.29) or math in college (OR = 1.34).

Qualitative Results

Key Informant analysis

As a complement to the quantitative analysis just described, we conducted qualitative analysis of data collected from our seven Key Informants in order to shed additional light on the correlates we identified of girls' aspirations to study engineering in college. Specifically, given that girls' engineering aspirations were related to their participation in extracurricular STEM activities and the extent to which interest in math and science was a salient aspect of their identities, we were interested in our Key Informants' insights into the actual delivery of *extracurricular programming*, some of which may explicitly focus on girls' STEM identities, as well as the *messages transmitted to girls about STEM* that may encourage or discourage their engagement with STEM areas. Thus, we began by identifying the following types of occurrences in the transcripts: (1) any mention of extracurricular activities in the local area, (2) any mention of opportunities in the local STEM landscape that might seek to promote girls' seeing themselves as engineers, scientists, or mathematicians, and (3) any STEM-related messages which may encourage or discourage girls' active STEM participation.

These data were then analyzed following three steps characteristic of inductive qualitative research [15]. In a first step, our goal was to organize our "chunks" of data in these two topic areas [16] by identifying units of meaning within them, known as *first-level codes* [17]. In a second analytical step, our goal was to reduce the number of units of meaning by combining concepts with similar concepts and placing them into higher-order *conceptual categories* (Harry et al.[17]). In a third and final round, our goal was to synthesize further the conceptual categories to allow us to tell the "underlying message or stories of these categories," (Harry et al, p. 5[17]) which we call *thematic categories*.

Thematic categories: extracurricular activities

With regard to extracurricular activities, the first thematic category to emerge involved *infrastructural issues*. One of our key informants with national expertise in STEM programming made note of the "luck of the draw" involved in access to opportunities, many of which are small-scale efforts, offered for a limited time until the soft-money funding runs out. In her opinion, we need to be asking the question: "What kinds of structural things are within your environment on a regular basis that provide you with … access?" Another key informant, with expertise in local workforce development, pointed out that gender disparities in participation in engineering-related after-school or summer jobs may be the result of earlier gender sorting into themed high schools. For example, if more boys choose to attend an engineering-themed school, then more boys will be placed in jobs in engineering companies because job placement intermediaries frequently do school-based placements. This Key Informant also remarked that if we are serious about diversifying the engineering workforce, in terms of gender and race/ethnicity, industry needs to have a "culture that's built up around it," and to "be willing to let them [urban students] into your shop, have a job that meets their needs … they need to make money."

A similar thematic category of *socioeconomic support* emerged from a Key Informant who pointed out that many urban students, girls and boys, have a particularly strong need to make money during the summer months. Another Key Informant pointed to the career coaching model as a program that offers support around socioeconomic pressures that students face outside of their high school experiences.

A third thematic category to emerge involved *the need to support adult*s *in their work with* urban students. With regard to school personnel, one Key Informant suggested that personnel such as guidance counselors might not know enough about engineering as a possible area of study and career. She also commented on cultural differences in parents' ideas about what's appropriate for girls to do in terms of camps and other programs: "There is a level of … cultural processing that goes on about what's acceptable or not acceptable." She also made the point that families differ in the extent to which they are comfortable visiting a science museum and some families may need more in the way of orientation.

A final thematic category to emerge related to extra-curricular activities involved the *specific challenges associated with after-school STEM opportunities*. One Key Informant commented that "we have not been thoughtful about science programs in after-school" and many after-school staff serving elementary school students are "afraid" to bring in science, and may not be qualified to do so. She pointed to a study she conducted in which hands-on engineering experiences actually made the kids more gender-stereotyped. With regard to high school after-school initiatives, another Key Informant suggested that the students who participate in after-school STEM activities (e.g., Robotics) are those who are already in the pipeline, so these programs may not be helpful in bringing in more girls.

Thematic categories: Messages to girls regarding STEM involvement

We identified four inter-related thematic categories related to messages to girls about STEM involvement. Two of these themes focused on messages connected to gender stereotypes regarding girls' abilities and potential to balance work and family life in the future. The last two themes focused on how STEM is marketed and how much marketing fits with girls' interest and values. These themes address both negative societal messages and stereotypes. Key Informants provided recommendations as to how to counter these negative messages and to encourage girls' engagement within STEM areas.

The first theme involved *gender-specific messages that discouraged girls* from STEM involvement, such as questioning girls' STEM abilities and their capacities to balance work and family life. For example, our informant with national expertise in STEM identified common stereotypes, such as engineering being "too hard" or "too dirty" for girls. Several Key Informants discussed messages that engineers work constantly, and that engineering is therefore incompatible with having a family. For example, our national expert stated, "I think there are a lot of stories about, 'I'm there twenty-four hours a day.' You know? You are not…that image is a tough image." Another Key Informant addressed negative social perceptions of girls in science: "They [girls] go into these science classes in high school when it's not cool to be female and smart in science, so they just shut up."

A second theme addressed new ways to pitch STEM to girls that *encourage STEM involvement and counter traditional gendered messages* passed on to girls. One Informant talked about the importance of changing the image of engineering and confronting false stereotypes about this field: "So you know at one level change the metaphor, but the other part is change the image. I do not believe that men work harder- I'm sorry. I think it's an image." The museum administrator noted that girls' exposure to real-life lab settings can help them to see that stereotypes of STEM are often inaccurate. For example, "…the whole idea that they can have lives outside the lab is just stunning to them – they have families and they have boyfriends, and that's just, for them, it helps them to realize that it's not sort of the stereotype that they've been brought up in."

The third theme that emerged involved *ways that STEM is presented*, which may exclude girls or fail to engage their interests or values. A common pattern in advertising STEM was identified as "a bunch of geeky white boys on all the brochures," which may suggest that STEM is for boys only. Key Informants also talked about the presentation of engineering as "reductionistic" and focused mainly on technical aspects of this field that may not appeal to girls. For example, "If you put it like, this was one of my big issues, robotics, if you advertise it as a robotics camp you may find one girl who's like, 'Yes!'- I mean there might be one."

In the final theme, Key Informants highlighted specific ways of engaging girls in STEM that *speak to their interests* better than do traditional ways of "pitching" STEM areas. They commented on girls' interests in real-world problem solving that has the potential to benefit society, and the mis-match of this emphasis with traditional messages about engineering. The need to change the language related to gender and engineering was discussed: "…we started talking about 'women are perfect for engineering.' It's like, because there's all this teamwork and you're really building things that are better for families in the world." Similar recommendations were shared by another informant about how to adapt the way that STEM is presented to girls: "It's about girls want to do something they see as functional, they want to know what problem it's going to solve, how it's going to help people."

Discussion

Capacity, engagement, and continuity

Our regression results supported our first hypothesis that capacity, engagement, and continuity would have differential associations with engineering, science, and math. In summary, although the three outcome variables were related to each other, they represented distinct domains of interest with differing patterns of correlates. School site, science and math self-efficacy, hands-on extracurricular experience, and femininity ideology appeared to be influential for girls' interests and aspirations for engineering. Comparatively, science salience and supportive relationships with science teachers were associated with college aspirations for science. Girls who were interested in pursuing mathematics reported higher math self-efficacy and math salience and were more likely to report supportive relationships with math teachers. Engineering aspirations were related to both science and math factors, while science and math appeared to be domain-specific in our models. Students with aspirations in math tended to report lower grades, but that may reflect more difficult coursework with more rigorous grading standards rather than lower ability levels.

Systems of influence

Our second hypothesis, that girls who report interest and aspirations in engineering would also report stronger connections, participation, and supports for STEM in the micro-, exo-, and macro-systems, was supported to a lesser degree. Our measure of teacher support was not a significant correlate representing the micro-system, however, extracurricular activities, reflecting the exo-system, and femininity ideology, representing the macro-system, were significantly correlated with engineering interest and aspirations. It may be that other measures of relational support do a better job of capturing important interactions in the micro-system. Or it may be that engagement in extracurricular activities includes important relationships with teachers in the micro-system who also broker interactions with institutions outside of the local school system in the larger exo-system [18]. Finally, the relationship between femininity ideology and STEM outcomes was counter to the expected direction. Girls who had internalized more conventional femininity ideology in regards to appearance had greater odds of reporting engineering and science aspirations.

This sort of unexpected finding related to gender may reflect the complex interaction of personality and context in a dynamic environment. In other research exploring gender in male dominated STEM fields, Brown et al. [19] found that feminine sex role orientation was positively related to career decision-making self-efficacy for female computer science majors. It may also be that girls interested in male-dominated domains such as engineering also internalize objectified expectations about appearance expressed by male peers in the classroom environment (echoing messages in the larger culture and media about femininity ideology). It would be important to explore this further to discern the robustness of this finding and whether it is developmentally influenced and thus may change or diminish as girls move from adolescence into adulthood.

Implications for educators and engineers

The initial findings presented in this paper can be used to inform the development of new interventions, or the refining and implementation of existing interventions, designed to promote girls' and women's entry into engineering and other STEM fields. Specifically, there are extracurricular and supportive ways to increase a high school girl's aspiration to enroll into a college engineering program. These approaches, based on findings from our study in an urban setting, include internships, guidance counselor information, after school programs, and family support for participation in various activities related to STEM. Key Informants stressed that systemic approaches for long-term growth are needed to develop a culture in which girls have opportunities and access to these outreach programs and internships. Continual support through financial incentives and mentorship are important as well as delivering positive messages that transcend gender stereotypes and emphasize engineering's ability to help people and to be compatible with family life. Frome et al.[20] found that "leaks" in the STEM pipeline were related to young women's perceptions of a lack of occupational flexibility in STEM that would interfere with being able to balance family and career. Pitching engineering to girls must be done in a thoughtful and consistent manner within the systems of influence surrounding the student.

Educators at the high school and college level and practicing engineers can work together locally to support the development of a community and culture in which there are consistent messages about engineering and STEM linkages. This needs to happen in the classroom, after-school activities, guidance support, internships, college activities, and industry practices. The messages need to address the real-world, problem-solving nature of engineering that helps people and the environment; that personal and family life options would not be diminished if a girl pursues engineering or other STEM fields; and that the stereotypes that boys and men are better suited for hard work related to STEM is erroneous[21]. These messages must be delivered in a pitch that engages high school girls' interests. Research has shown that outreach programs that allow role models from college and industry to connect with high school girls have a positive affect on increasing girls' interest in engineering[22]. Opportunities such as this provide a forum to answer questions about career and lifestyle as well as school plans, while also demonstrating hands-on problem solving engineering activities designed to pique students' interest.

Developing the community and culture of engineering opportunities for girls can be done purposefully and should be made sustainable with broad and deep support. Broadly, the neighborhood businesses, school connections, and home support need to work together to understand the issues, values, and details about promoting engineering for girls and women. A common ground for the community can be established in which buy-in and support can be thought out, prototyped, tested, and continually redesigned. This process can be initially supported by local, state, and federal support; but the overall health of a more inclusive engineering culture depends on the identification of sustainable resources, people, and funding that can adapt with changing times.

References

1. Noeth RJ, Cruce T, Harmston MT. *Maintaining a strong engineering workforce. ACT Policy Report* 2003.
2. Blickenstaff JC. Women and science careers: Leaky pipeline or gender filter? *Gender and Education.* Oct 2005;17(4):369-386.
3. U.S. Department of Education. National Center for Education Statistics. *Entry and persistence of women and minorities in college science and engineering education.* NCES 2000-601, by Gary Huang, Nebiyu Taddese, and Elizabeth Walter. Project Officer, Samuel S. Peng. Washington, DC 2000.
4. Jolly EJ, Campbell PB, Perlman L. *Engagement, capacity, and continuity: A trilogy for student success*: GE Foundation; 2004.
5. Bronfenbrenner U. *The ecology of human development: Experiments by nature and design*. Cambridge, MA: Harvard University Press; 1979.
6. Bronfenbrenner U. *Making human beings human: Bioecological perspectives on human development*. Thousand Oaks, CA: Sage; 2005.
7. Catsambis S, Beveridge AA. *Neighborhood and school influences on the family life and mathematics performance of eighth-grade students.* Maryland: Office of Educational Research and Improvement (ED), Washington, DC.; Oct 2001. CRESPARR54.
8. National Science Foundation. *Women, minorities, and persons with disabilities in science and engineering, 2004. (NSF 04-317).* Arlington, VA: Author; 2004.
9. Hardy JB, Astone NM, Brooks-Gunn J, Shapiro S, Miller TL. Like mother, like child: Intergenerational patterns of age at first birth and associations with childhood and adolescent characteristics and adult outcomes in the second generation. *Developmental Psychology.* 11 1998;34(6):1220-1232.
10. Entwisle DR, Astone NM. Some practical guidelines for measuring youth's race/ethnicity and socioeconomic status. *Child Development.* 1994;65(6):1521-1540.
11. Eccles J, et al. Age and gender differences in children's self- and task perceptions during elementary school. *Child Development.* 1993;64(3):830.
12. Doepken D, Lawsky E, Padwa L. Modified Fennema-Sherman Attitude Scales. http://www.woodrow.org/teachers/math/gender/08scale.html. Accessed January 2, 2006.
13. Tolman DL, Porche MV. The adolescent femininity ideology scale: Development and validation of a new measure for girls. *Psychology of Women Quarterly.* 2000;24(4):365-376.
14. Allison PD. *Missing data*. Thousand Oaks: Sage Publications, Inc; 2001.
15. Strauss A, Corbin JM. *Basics of qualitative research: Techniques and procedures for developing grounded theory*. Thousand Oaks: Sage Publications; 1990.
16. Miles MB, Huberman AM. *Qualitative data analysis : An expanded sourcebook*. 2nd ed. Thousand Oaks, CA: Sage Publications; 1994.
17. Harry B, Sturgis KM, Klinger JK. Mapping the process: An exemplar of process and challenge in grounded theory analysis. *Educational Researcher.* 2005;34(2):3.
18. Holloway JH. Extracurricular activities and student motivation. *Educational Leadership.* 2002;60(1):80.
19. Brown C, Garavalia LS, Fritts MLH, Olson EA. Computer science majors: Sex role orientation, academic achievement, and social cognitive factors. *Career Development Quarterly.* 2006;54(4):331.
20. Frome PM, Alfeld CJ, Eccles JS, Barber BL. Why don't they want a male-dominated job? An investigation of young women who changed their cccupational aspirations. *Educational Research and Evaluation.* 2006;12(4):359.
21. Spelke ES. Sex differences in intrinsic aptitude for mathematics and science: A critical review. *American Psychologist.* 2005;60(9):950-958.
22. Anderson L, Gilbride K. The future of engineering: A study of the gender bias. *McGill Journal of Education.* 2007;42(1):103.

Table 1 Individual School and Overall District Characteristics as Reported by the State Department of Education

	Exam School/ Humanities Focus %	Exam School/ Math & Science Focus %	Theme School/ Health & Technology Focus %	Theme School/ Non-STEM Focus %	Theme School/ Engineering Focus %	District %
Race/Ethnicity						
African American	10.7	43.4	52.8	71.9	53.2	40.9
Asian	27.6	22.2	1.2	1.5	0.9	8.5
Hispanic	7.3	22.3	35	24.6	38.4	.35.2
Native American	0.2	0.2	0.6	0.4	0.3	.05
White	52.6	11	9.8	0.8	6.6	13.5
Native Hawaiian, Pacific Islander	0.0	0.0	0.0	0.0	0.3	0.1
Multi-Race, Non-Hispanic	1.6	0.8	0.6	0.8	0.3	1.3
Language						
First Language Not English	28.1	42.7	34.7	22.3	37.6	38.9
Limited English Proficient	1.2	2.0	5.5	3.5	8.1	18.3
Low Income	27.9	61.6	66.9	64.6	59.2	72.7
Special Education	0.7	1.2	19.3	29.6	28.3	19.7
Percent Female Enrollment	55.6	59.7	59.5	45.8	24.6	48.6
Grade 9-12 Dropout Rate	0.0	0.5	8.0	15.5	7.7	10.0
Attendance Rate	96.1	94.8	89.3	83.5	81.4	91.5
Retention Rate	1.1	5.5	15.3	15.1	15.7	7.4
Plans of High School Graduates						
4-Year College	95.0	76.0	data unavailable	30.0	25.0	42.0
2-Year College	1.0	9.0	data unavailable	26.0	32.0	13.0

*10th Grade State Proficiency Test**						
Test Results for 2006-2007: % Proficient or Better						
Mathematics	100.0	98.0	49.0	22.0	34.0	55.0
English Language Arts	99.0	92.0	34.0	22.0	38.0	50.0

* All public school students are tested on state assessments, which are designed to measure performance on curriculum and learning standards. All students must meet proficiency on 10th grade Mathematics and English Language Arts in order to receive a high school diploma.

Table 2
Intercorrelations, Means, and Standard Deviations for Scores on Plans to Study Engineering, Science, and Mathematics in College; Percent with Higher Aspirations for Subject Coursework (n = 549)

Measure	Engineering	Science	Mathematics	M	SD
Engineering	1.0	.37***	.43***	2.26	1.23
Science		1.0	.22***	3.03	1.45
Mathematics			1.0	2.69	1.39
Percent with Higher Aspirations for Subject Coursework[1]	18.4%	42.4%	33.3%		

*** $p < .001$
[1]Higher aspiration outcome variable recoded from original 5-point scale to dichotomous outcome: 1 = “A Little” or “A Lot”

Table 3
Comparisons of Logistic Regressions Predicting Retention in College Engineering, Science, and Mathematics. Odds Ratios and Confidence Intervals Presented (n=549)

Independent Variables	Model 1 Plans for College Engineering	Model 2 Plans for College Science	Model 3 Plans for College Mathematics
School Site			
Exam School/Math & Science Focus	1.19 [0.57, 2.48]	0.51~ [0.26, 1.02]	0.90 [0.45, 1.81]
Theme School/Business Focus	0.75 [0.16, 3.41]	0.30* [0.09, 1.01]	0.47 [0.13, 1.77]
Theme School/Health and Technology Focus	0.46 [0.10, 2.13]	0.48 [0.15, 1.59]	0.91 [0.29, 2.92]
Theme School//Engineering Focus	5.40* [1.24, 23.41]	0.23* [0.06, 0.93]	3.15 [0.68, 14.61]
Exam School/Humanities Focus	1	1	1
Race/Ethnicity			
Black	0.70 [0.27, 1.86]	1.12 [0.52, 2.43]	1.33 [0.56, 3.15]
Asian	1.30 [0.62, 2.71]	0.63 [0.32, 1.22]	1.06 [0.53, 2.12]
Latino	1.21 [0.45, 3.24]	1.16 [0.49, 2.72]	1.00 [0.39, 2.55]
Other	1.00 [0.26, 3.93]	0.78 [0.23, 2.65]	3.51* [1.00, 12.36]
Bi-racial/Multi-racial	0.94 [0.39, 2.26]	0.68 [0.33, 1.41]	0.69 [0.31, 1.57]
White	1	1	1
Mother's Education Level	1.02 [0.83, 1.27]	1.07 [0.88, 1.29]	0.84 [0.69, 1.04]
Grades	0.82 [0.55, 1.23]	0.82 [0.57, 1.18]	0.70~ [0.48, 1.02]

Science Self-Efficacy	1.13 [0.83, 1.55]	1.26 [0.95, 1.66]	1.07 [0.79, 1.44]
Math Self-Efficacy	1.26 [0.94, 1.70]	1.06 [0.82, 1.36]	2.22*** [1.63, 3.01]
Science Salience	1.53** [1.11, 2.10]	3.63* [2.66, 4.97]	0.94 [0.69, 1.27]
Math Salience	1.50* [1.08, 2.08]	0.76~ [0.55, 1.04]	2.92*** [2.13, 4.01]
Favorite Subject is STEM	0.83 [0.53, 1.29]	0.94 [0.64, 1.38]	1.36 [0.90, 2.06]
Fennema-Sherman Math Teacher Support	1.21 [0.64, 2.30]	1.49 [0.87, 2.53]	1.76~ [0.95, 3.26]
Fennema-Sherman Science Teacher Support	1.03 [0.53, 1.99]	2.20** [1.25, 3.90]	0.85 [0.47, 1.53]
Societal Support for Girls' Higher Education	0.971 [0.64, 1.47]	0.90 [0.63, 1.28]	1.11 [0.76, 1.62]
Societal Support for Girls' Science Careers	1.14 [0.75, 1.73]	1.26 [0.88, 1.80]	0.74 [0.50, 1.10]
Experience with Extracurricular STEM Activities	1.42*** [1.17, 1.71]	1.14 [0.95, 1.36]	1.00 [0.83, 1.20]
Femininity Ideology Scale: Objectified Relationship to Body	1.49* [1.03, 2.16]	1.34~ [0.97, 1.85]	1.32 [0.93, 1.88]
Femininity Ideology Scale: Inauthentic Self-in-Relationship	0.84 [.59, 1.21]	1.13 [0.83, 1.56]	0.98 [0.70, 1.38]

~ $p > .10$, * $p < .05$, ** $p < .01$, *** $p < .001$