



## **Impact of a 5-Week Collegiate Level Residential STEM Summer Program on Secondary School Students (research to practice)**

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## **(Research to Practice, K-12 Engineering Resources: Best Practices in Curriculum Design)**

### **Abstract**

The foundation of modern engineering curriculums is a strong background in science, mathematics, and technology. Engineering education begins with math and science education at the grade school level. Without properly cultivating interest and excitement to study these fields, it is difficult for many students to endure the prerequisites to become engineers. In this paper, The Pennsylvania Governor's School for the Sciences (PGSS), a five-week residential summer science program at Carnegie Mellon University, is described and then assessed using feedback from students. Surveys were administered pre-program and post-program asking about attitudes toward STEM (Science, Technology, Engineering, and Mathematics), critical thinking skills, and their living/learning environment (home and at the program). Appropriate statistical analysis methods were applied to the results to show significant gains over the course of the program for the overall group as well as key demographics of interest, such as females and minorities. Comments from students are also shared to express their impression of the program.

### **Introduction**

A necessity of encouraging students to pursue engineering is to build their interest in science, math, and technology. A properly trained engineer will have a fully integrated STEM educational experience. The Accrediting Board of Engineering and Technology (ABET) requires that engineering student educational outcomes include the ability to apply knowledge of math and science as well as use modern engineering tools (technology).<sup>1</sup> Engineering cannot be isolated from science, math and technology; therefore education in these disciplines is linked closely with engineering education.

STEM education in America has also been actively trying to recruit more women and minorities into STEM careers, especially in fields where they are greatly underrepresented such as mathematics and computer science.<sup>2</sup> Programs designed to promote STEM to these demographic segments need to be aware of their specific educational needs to be able to retain them in degree programs and careers.<sup>3</sup> Scutt, et al, presents two sets of strategies for improving STEM education to better suit the needs of female students. The "Skills to Emphasize" set instructs teachers to "instill the importance of calculus, spatial reasoning, communication abilities, and resilience" in STEM classrooms. The "Scaffolding to Implement" set reinforces the importance of "active expert roles, clear feedback in grading, and re-evaluation of group work in the classroom." Their research has shown that addressing these seven issues properly tend to help females succeed in STEM educational settings.<sup>4</sup>

On the state level for education, Governor's School programs were initiated throughout the U.S. to introduce secondary school students to new ideas and opportunities within STEM and other specialized subject areas. The number of states which have these programs fluctuates, but is typically between 15 and 20, with many states offering multiple programs.<sup>5</sup> Subject specific

summer camps are effective ways of better targeting student interests and gathering the most motivated students for accelerated learning experiences.<sup>6,7,8</sup> Gifted students have many options for career paths, and without adequate exposure to rigorous STEM opportunities, our brightest minds may never realize their potential in these areas and gain the confidence to pursue engineering. Since many high schools do not have access to the technology and experienced researchers to teach STEM at a high level, Governor's Schools are an efficient way to offer these opportunities state-wide for top performing students. Statewide summer Governor's Schools have alternatives, one being full year public schools that selectively admit high performing motivated students, called "exam schools." These schools serve a limited population base of the students in their immediate vicinity; only 165 exam schools exist out of 20,000 public high schools and are not available to students in 19 states.<sup>9</sup> Governor's School's serve a much larger population base since students statewide can apply, and the residential aspect allows for total immersion into the program. Unfortunately, funding cuts in the past few years have forced the cessation of many of the summer programs. Governor's Schools are especially needed in Pennsylvania, where in recent years, state funding to support gifted education is not specifically earmarked in the special education budget. Additionally, the Pennsylvania General Assembly acknowledges that the services available to gifted students greatly vary by district.<sup>10</sup> A recent study of gifted programs in Pennsylvania revealed that 85% of gifted students are expected to receive differentiated curriculum to accommodate their needs, but "tangible supports are virtually non-existent for differentiating curriculum or instruction for gifted students."<sup>11</sup> By using the resources of the state to provide Governor's School programs at universities in the summer, Students can have access to research labs, technology and faculty to provide an accelerated and focused education which would be beyond the budget of individual high schools.

From 1982 to 2008 the Pennsylvania Governor's School for the Sciences followed this model and brought nearly 2,400 students from across Pennsylvania to Carnegie Mellon University for an intensive 5-week summer science program, until budget cuts in 2009 ended the program. This program was very successful at recruiting and retaining students in STEM careers. The alumni of PGSS have been well-documented and studied to gain insight into the long-term impact of the program. The data reveals 93% of alumni work in STEM fields and 25% of alumni are in Engineering; also 87% of the alumni hold graduate degrees with 60% of those being terminal degrees in their field.<sup>12</sup> A group of PGSS alumni and program supporters successfully restarted the PGSS program in the summer of 2013. To promote sustaining the program with continued funding from the state and various donors, it is important to analyze its educational efficacy to demonstrate the impact of the program.

Additionally, a challenge exists at the collegiate level to attract and retain engineering students until graduation (especially with females and minorities). Therefore, through pre- and post-surveys, it would be beneficial to verify whether students attending advanced STEM programs during high school years increase their interest and retention in STEM fields by gaining broader knowledge, skills and confidence.<sup>13,14</sup>

## **Program Details**

The Pennsylvania Governor's School for the Sciences is a 5-week summer residential academic experience on a college campus. Students are eligible to attend only during the

summer after their junior year of high school and typically range in age from 15-17. Students must be residents of Pennsylvania to apply. PGSS was advertised by the Department of Education directly to the school districts in the state through a statewide network of 29 regional Pennsylvania educational centers, called Intermediate Units. In 2013, there were over 500 applications for 60 openings; 30 male and 30 female students were admitted (only 59 students completed the program due to one female student's illness). At least one qualified student is selected from each Intermediate Unit to ensure geographic diversity. In this instance 28 of 29 units were represented due to one unit not sending any applicants. Acceptance into PGSS includes a full scholarship to cover tuition, room and board. The program has faculty comprised from several local universities, with most representing the host university. College students are hired for the dual role of teaching assistants and counselors, with one or two designated as residence life directors to manage the dormitory, social events, and non-academic issues.

Classes are held Monday through Friday starting at 8am, with core classes for 4 hours. After lunch is a period reserved for electives and guest speakers followed by a three hour block for team project or lab. After dinner, two hours are available for electives to meet but all classes are done by 8:30 PM. There is a social activity in the dorm every night around 9 and the rest of the evening is spent doing homework. The breakdown of hours for each weekly schedule activities is shown in Table 1. Students are restricted to their dorm room level after midnight, with males and females on different levels of the building. There is no curfew to be in their room and many will stay up past midnight working on assignments in study lounges. Classes are seldom held on the weekend; Saturday and Sunday are reserved for social activities, homework, and catching up on sleep.

**Table 1 Weekly time allotment for courses and activities for weeks 1-4 (week 5 is dedicated to team project)**

	<b>PGSS Curriculum</b>	<b>Hours per week</b>
<b>Core Classes</b>	Biology, chemistry, computer science, math, physics (required)	4 each course
<b>Electives</b>	Various applied science and engineering topics, may take multiple electives.	2 each course
<b>Labs</b>	Choice of one between biology, chemistry, computer science, physics	6
<b>Team Project</b>	Choice of one between various biology, chemistry, computer science, math, physics projects	6
<b>Guest Speakers</b>	Various STEM topics	1-2
<b>Optional non-academic social activities</b>	Athletic competitions, group games, dances, student musical performances, field trips	10-15

Courses focus on advanced topics taught at a college level, so the material is new for most of the students. For example, the physics course concentrates on special relativity; chemistry focuses on aspects of organic chemistry and molecular synthesis. Each course gives a homework assignment every week, designed to be challenging enough to require collaborative effort to solve. No student is advanced enough in all areas of science to complete each assignment independently. This forces gifted students who rarely encounter true academic

challenges to be pushed from their comfort zone. To succeed they must ask for and accept assistance from their peers or teaching assistants. The difference between collaboration and plagiarism is clearly explained at the beginning of the program and students must write on their paper who they worked with to complete the assignment. This sharing of credit and citing sources for assistance reinforces the collaborative academic process and also allows teaching assistants to track and correct mistakes made by a group. The homework is not graded, but evaluated for comprehension. No grades are given at any point in the program; it is a pass/fail process. If a homework assignment is not completed or poorly done, a student is asked to redo it. Not completing assignments results in early curfew and restrictions from social events. Failure to complete assigned work jeopardizes graduation from the program and in some cases warrants early removal. Students are rewarded for their performance after the program with a personalized letter of recommendation that talks about their accomplishments. The letters are written with input from all faculty and teaching assistants who interacted with the student.

The team research project is another important aspect of the curriculum. Most projects are original research sponsored as a subset of a university professor’s work, condensed into a project that can be undertaken in 5 weeks. Potential projects are identified prior to the program, with anticipated material resources gathered or purchased. Depending on the project, students sometimes have the latitude to customize it. Students are expected to do a background literature search, set up and run experiments, and analyze the data. Each team produces a research paper and prepares a PowerPoint presentation. Each student participates in a public research symposium, presenting their research and taking questions from the audience.

**Table 2 PGSS Team research project examples**

Subject	Example of Student Research Project from 2013 PGSS Journal
Biology	The Effects of Chemical Exposure on Neurophysiological Functions of <i>Lumbricus terrestris</i>
Chemistry	Attempts at Optimizing Yttrium-Based Superconductors
Computer Science	Computational Adaptable Stochastic Simulator: A Practical Tool for Modeling Biochemical Networks
Mathematics	Fantasy on Euler’s Formula (various proofs and applications of Euler’s formula)
Physics	ThereMac: Theremin Team 2013 (built working Theremin in a classic Mac computer housing)

## Materials and Methods

Pre- and post-program surveys were conducted to assess the student’s dispositions towards STEM and STEM careers along with critical thinking and problem solving skills using Likert scale responses. The questions were assembled from several published methods of educational evaluation. The pre-survey was administered on the first day of the program. The post-survey was completed during the fifth (final) week of the program.

A STEM semantics section measures student’s impression of terminology, asking about “science, technology, engineering, math and a career in a STEM field.” It used a 7 point Likert scale for opposing paired terms such as mundane/fascinating, unappealing/appealing, easy/challenging and was based on a similar survey used by researchers at the University of

North Texas.<sup>15</sup> It also asked the student's likelihood of going to college, earning a STEM degree, pursuing graduate work in STEM and working on a STEM field.

The next section of the survey contained a critical thinking analysis asking them questions about their problem solving approach and actions/reaction for situations to reveal their level of critical thinking and decision making ability. The pre-survey represents baseline critical thinking skills prior to coming to the program. The post-survey shows changes due to the educational experience and problem solving rigor of the STEM program. This portion of the survey is based on an approach developed by education researchers at Penn State University.<sup>16,17</sup>

#### Critical Thinking Questions (never, rarely, sometimes, often, always)

1. I think of possible results before I take action.
2. I get ideas from other people when having a task to do.
3. I develop my ideas by gathering information.
4. When facing a problem, I identify options.
5. I can easily express my thoughts on a problem.
6. I am able to give reasons for my opinions.
7. It is important for me to get information to support my opinions.
8. I usually have more than one source of information before making a decision.
9. I plan where to get information on a topic.
10. I plan how to get information on a topic.
11. I put my ideas in order of importance.
12. I back my decisions by the information I have on hand.
13. I listen to the ideas of others even if I disagree with them.
14. I compare ideas when thinking about a topic.
15. I keep my mind open to different ideas when planning to make a decision.
16. I am aware that sometimes there are no right or wrong answers to a question.
17. I develop a checklist to help me think about an issue.
18. I can easily tell what I did was right or wrong.
19. I am able to tell the best way of handling a problem.
20. I make sure the information I use is correct.

The survey also attempted to capture the benefit of the program's living/learning environment with questions about their high school in the pre-survey and the summer program in the post-survey. The questions ask about working on academic projects in teams, participation in social/athletics events, having peers that share interests, and feeling accepted. Responses ranged from strongly disagree to strongly agree on a five point scale.

#### Living/Learning Questions (Strongly disagree, disagree, neutral, agree, strongly agree)

1. You feel your opinion is valued in an academic working group.
2. You have a chance to express your opinion and contribute to a group.
3. You enjoy social events with your classmates.
4. You enjoy participating in athletic competitions with your classmates.
5. You enjoy participating in intellectual competitions with your classmates.
6. You feel comfortable in co-ed social settings.
7. You do more than your fair share on academic team projects.

8. You feel like a valued team member in school project groups.
9. You feel more comfortable on a single gender team for academic work.
- 10 You feel more comfortable on co-ed team for academic work.
11. You are comfortable accepting help when you don't understand a concept.
12. You feel confident in your ability to complete difficult academic assignments.
13. You prefer to spend your free time alone using an electronic device.
14. You have friends that share your academic passions.
15. The majority of our peers contribute positively to your learning experience.
16. You place a higher emphasis on your grades than learning the subject.

Each survey asks about interest level in each of the five core subjects of the program (Biology, Chemistry, Computer Science, Mathematics, and Physics) using a five point Likert Scale. The response to this section on both the pre-survey and post-survey shows overall trends of growth or loss of interest. This data is tracked as an aggregate and not on an individual basis. By design, students are exposed to all five subjects regardless of interest level. This exposure can help students decide which areas of science are most appealing to them and they may lose interest in other areas after learning more about them. Individual student gains of interest could cancel out loss of in interest by another student (and vice versa) when comparing pre- and post-data. For future studies it would be better to track changes individually to fully measure impact on an individual level.

The post-program survey also included free response questions, where students were prompted to give feedback on the program. To help with recruiting efforts, they were asked where they learned of the program. Additionally, there were questions about the experience with the team projects and the students were asked about the best features of the program and if there was anything they would change. It was also asked if the program had a noticeable influence on them, although it may be too soon for some students to see the long-term benefits of the program.

These surveys, along with observations of a faculty member (Campbell) and teaching assistant/counselor (Robb) are used to judge the program's impact on students. To analyze scores on the survey responses for significant changes between the pre-survey and post-surveys a 2-sample z test was applied to the data with a 95% confidence interval. The population was parsed up by demographic information to show impact on various populations. A z-test was used rather than t-test because the population mean is known when analyzing the whole population. It is also a good approximation for the demographic segments despite one student not responding to the demographic information.

## **Survey Results and Analysis**

### **Demographics**

The PGSS program attempts to give opportunities to students who are traditionally under served in their home district, with an emphasis on recruiting females, minorities, rural students, and economically disadvantaged students. All but one student (58) responded to the demographics section. Respondents were all high school students who had just completed their

junior year and live in Pennsylvania. The state is divided into 29 geographic units by the department of education and 28 of those regions are represented by the population attending the program, ensuring geographic diversity. The main demographic breakdown of the class can be seen in Table 3. The comparison of the race/ethnicity of the program with the state's actual breakdown is shown in Table 4. Gender diversity is evenly split for the program. For minority representation, compared to the state's racial/ethnic makeup, the program was lacking in representation from Black/African American and the Hispanics/Latin students, but had a percentage of Asian students 9 times higher than the state's overall percentage. The number of rural students in the program closely matched the state's percentage of students in rural districts. The program has a cost of nearly \$5000 per students, which is assumed to be out of reach for low income families and a challenge for middle income families. The students who could probably not afford the tuition for the program represent 57% of the population; the full scholarship for all attendees ensures that these students are getting equal access based on the merits of their application.

**Table 3 Summer Program Participant Data**

Demo-graphics	Category	Number of Students	Percentage of sample size
Gender (n=59)	Male	30	50.8%
	Female	29	49.2%
Race / Ethnicity (n=58)	Asian or Pacific Islander	16	27.6%
	Black or African American	1	1.7%
	Hispanic or Latino	1	1.7%
	White	39	67.2%
	Other	1	1.7%
Geographical Area (n=58)	Rural (26% of students in the state are in a rural district) <sup>18</sup>	13	22.4%
	Suburban	37	63.8%
	Urban	8	13.8%
Economic Status <sup>19</sup> - self identified (n=58)	Low Income (4) and Lower Middle Class (6)	10	17.2%
	Middle Class	23	39.7%
	Upper Middle Class (23) and Wealthy (2)	25	43.1%



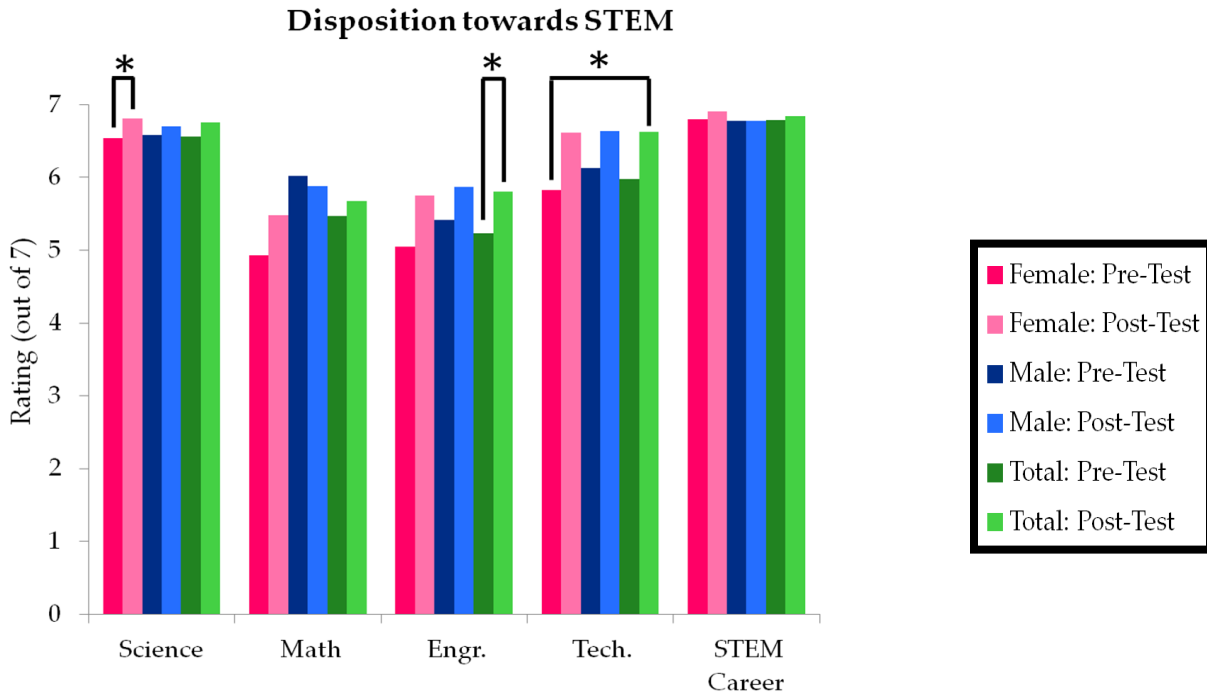
**Table 4 Race/ethnicity of program participants in comparison to state composition**

Race/Ethnicity	% of program (58 respondents)	% of state population <sup>20</sup>
Asian or Pacific Islander	27.6%	3.1%
Black or African American	1.7%	11.4%
Hispanic or Latino	1.7%	6.1%
White (non-minority)	67.2%	83.5%

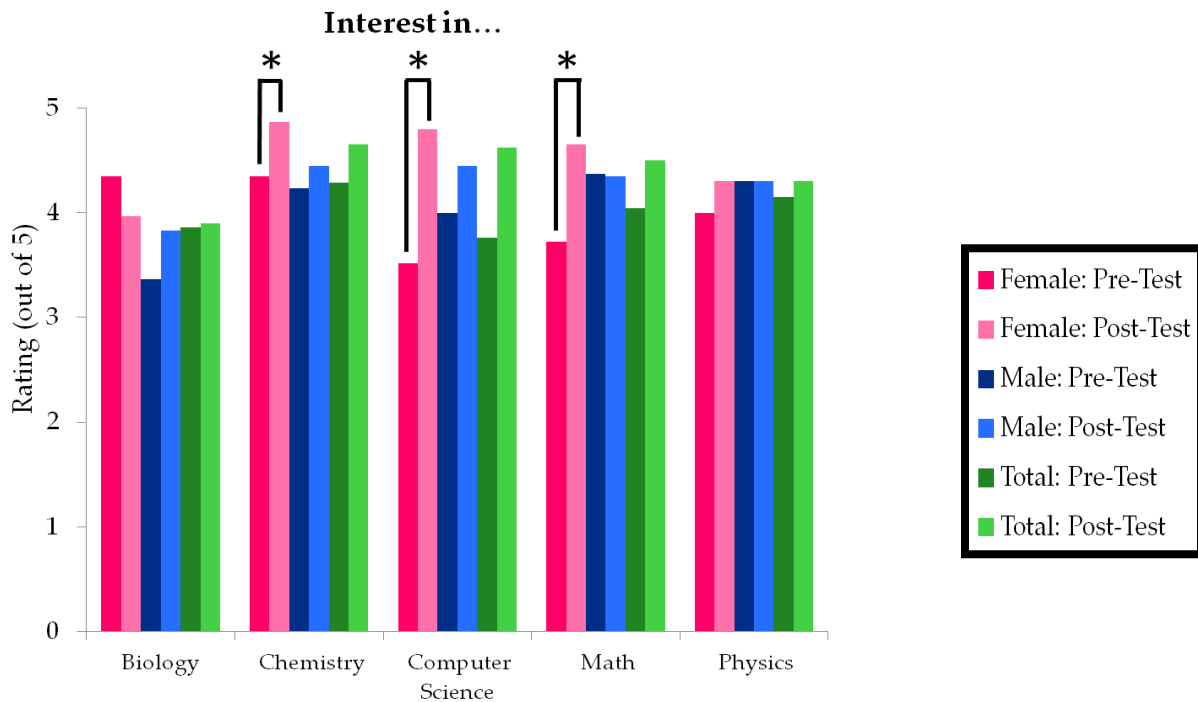
### STEM Semantics and Subject Interest Results

The student's impressions of the terms that comprise STEM (Science Technology, Engineering and Mathematics) showed several statistically significant improvements between the pre- and post- survey results as seen in Figure 1. Female students showed an increase favorability of science, and both genders had an increased interest in engineering and technology. Most of the remaining categorizes had slight increases that did not meet the z-test requirements for statistical significance. On the PGSS subject interest questions shown in, the program helped to significantly increase female interest in chemistry, computer science, and mathematics. A decrease for interest in biology for females is not statistically significant, and even if it was, the majority of females entering the program were inclined most toward biology (as evidenced by the team project and lab preferences). The increased interest in other areas may have been related to a loss of interest in biology after learning more about the other subjects. Some students report that the program is as helpful in showing them which fields they do not want to pursue as it is giving them direction for STEM areas they hope to explore. It is not the goal of the program to make all students love every subject, but rather to provide a high level exposure so that the student can make better informed choices about their college and career plans.

In other analysis, when dividing the group among minority and non-minority status, both groups saw a statistically significant increased disposition toward science and technology and an interest in computer science. Minorities however showed an increase interest in physics and the non-minorities has stronger gains for interest in chemistry and mathematics and disposition toward a STEM career.



**Figure 1** STEM semantics and career interest results with average scores of pre/post female, pre/post male and pre/post total, respectively for each subject. \* indicated statistically significant improvements.



**Figure 2** Subject interest results for most significant changes in responses, average scores of pre/post female, pre/post male and pre/post total, respectively for each subject. \* indicated statistically significant improvements.

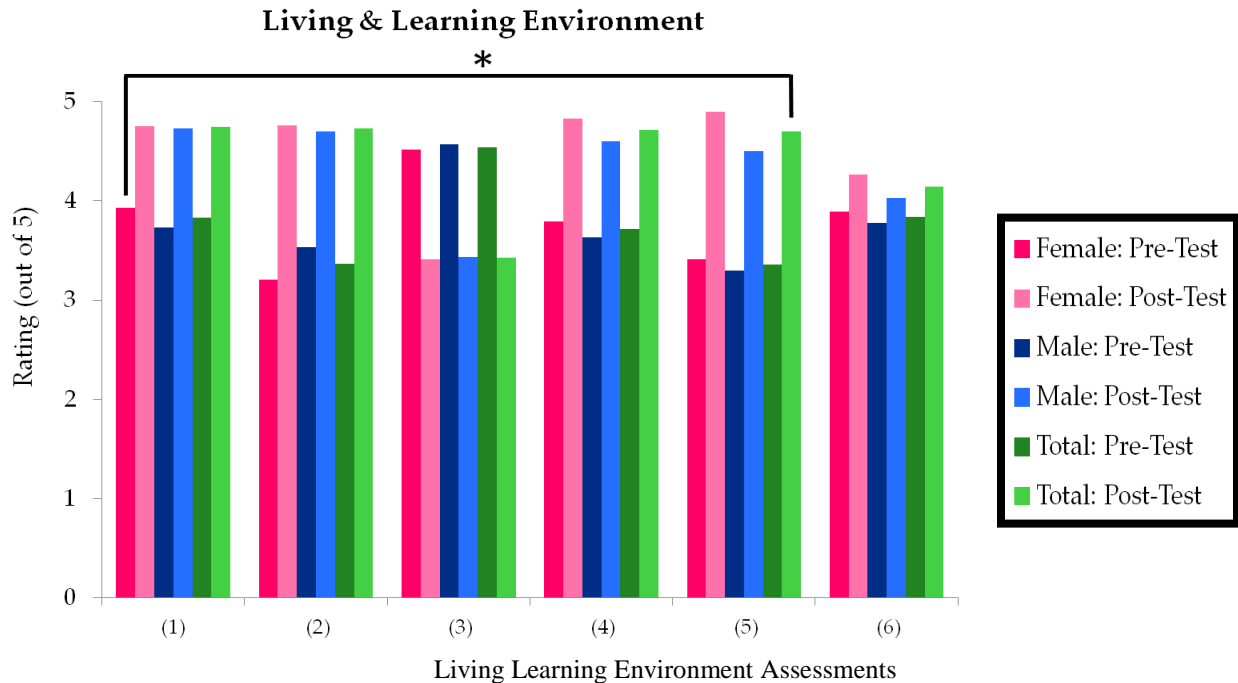
## Living/Learning Environment and Critical Thinking Results

Of the sixteen assessment statements pertaining to the living and learning environment, the five with the largest changes in score--which also have statistical significance--have been reported here as seen in data sets 1-5 in Figure 3. This data shows the ability of the program to create an educational environment different from the one the students experience in their high schools. Two improvements are non-academic, with students enjoying social events and athletic events more in this summer setting. Two others relate to the peer group with students finding that they have more in common with their peers in the program and those friends are a positive contribution to their learning environment. One trend that showed lower scores in the post survey (as expected) pertained to doing more than a fair share of a team project. Results showed that these students tend to take on extra work in group projects in high school but during the summer program there was a more even distribution of work and effort. In an analysis of impact on minorities, both minority and non-minority students saw the same significant increases for the five areas of the living/learning environment responses.

Living and Learning Responses with largest significance:

- (1) You enjoy social events with your classmates
- (2) You enjoy athletic competitions with your classmates
- (3) You do more than your fair share on team projects
- (4) You have friends that share your academic passions
- (5) The majority of your peers contribute positively to your learning experience
- (6) Critical thinking skills (average over 20 questions)

The critical thinking section of the survey failed to show any statistically significant results, although there were gains in the post-test for nearly every category. Averaging across all of the critical thinking questions shows a net increase in critical thinking skills, but as with the individual responses, not a statically significant increase, as seen in the sixth set of data in Figure 3. One possible explanation is that the gifted students enrolled in the program already possessed high critical thinking skills and there was not much room for drastic improvement in such a short time frame. To assess this, scores from a control peer group would be needed to see if the baseline of the group in this summer program was similar or elevated. This additional comparison was beyond the scope of this study and no directly comparable peer group was found in the literature.



**Figure 3 Living Learning results for most significant changes in responses (1-5) and the average of the critical thinking responses (6); scores are averaged over all respondents in that sub group: pre/post female, pre/post male and pre/post total, respectively for each subject. \* indicated statistically significant improvements.**

Sample of free response answers from students on post-survey

Please describe briefly your experience with the team projects (likes, dislikes, etc.)

- My team project was an amazing experience. The collaboration was really fulfilling. The fact that the project required all different fields showed me how multidisciplinary science is.
- Everyone was highly motivated ... instructor was hands off allowing for creativity but still there to help, which was perfect.
- The Theremin project has been enjoyable, in that it is very technical and hands on. Also, the problem solving is unrivaled (circuits troubleshooting)
- The team project helped me to learn what research is like. We run into many problems along the way, but we were able to cope with them and complete our project, and still have fun along the way

What, to you, were the most important features of PGSS? Please explain.

- Being in a setting with other driven, intelligent students who also wanted to be here allowed me to preform my best.
- The laboratory experience and team project. It showed me what scientific research is really like. It allowed me to use equipment and technology not available at my high school.
- The most important part was getting to work with equally brilliant people. I never realized before what it was like to exchange ideas with someone as motivated and passionate about learning as me.

- The lack of academic pressure (grades, tests) was important in that it gave me more liberty to talk, really learn the material ... The planned social events also gave me good opportunities to interact with all my friends here.
- I think the whole college experience was the single most important feature. This program really gave me a sneak peak of college at a very high level university, and that has influenced where I want to go to college. I want to go to one of the best universities and be really challenged to succeed.
- The opportunity to work with other students in an environment that stimulates cooperation, social bonding, and academics, without competition for rankings, as it is by far the best way to learn and grow.
- The unique opportunities to learn areas of subjects not commonly taught in schools. Meeting amazingly smart people who are downright brilliant. I can't wait to see what they will accomplish in the future. The free time was also a much needed decompression time.

Please describe how PGSS has influenced your life,

- I have hope for college, because I think I'll be able to meet people to love science and who are passionate about STEM. I also learned to work harder, and that I must collaborate in order to finish my work.
- My problem solving is better, I've learned to make new friends; I have just loved this whole experience.
- PGSS has influenced my friendships, my passion for science and my networking as well as giving me advanced scientific experience that will be beneficial in my later life.
- I've learned how to survive in high-stress situations and how to trust people (other people not just me) to do group work
- I'm interested in fields outside what I already knew I liked. I value collaboration so much more now.
- I feel that it has made me more independent and mature and has also increased my interest, understanding and appreciation for science.
- PGSS has helped me learn how to be accountable for myself, given me lifelong friends, helped me learn to accept failure and imperfection, and has given me a lot more interest in a STEM career.
- PGSS has taught me how important it is to surround yourself with really smart people. They are the ones who bring out the best in me and make me perform at a higher level. I am way more likely to work in a team setting after this experience because that was the only way to succeed here, by working as a team

In response to suggesting changes for the program, many of the students had no criticism. There were naturally some non-academic suggestions, like allowing more time to sleep, host more social activities and have air-conditioned dorms. A common complaint was the occasional need to redo a homework assignment multiple times, with several students suggesting a redo be limited to one submission. A couple students suggested less homework (event calling out one of the authors of this paper by name for this suggestion). Another complaint was with some of the guest lectures. Due to the funding sources for the program, some guest lectures were mandatory and on scientific topics some may consider controversial. The students suggested having more

interesting and less political guest speakers. The students also commonly asked for more time to work on their research projects, which was unique since it was one of the few common suggestions that was asking for more time to spend on an academic aspect, as opposed to reducing the load of the academic portion of the program.

Overall, pre- and post-program data found a general increase in attitudes toward and interest in STEM. Additional analysis of post-program free response questions found the many students realized the importance of collaboration and teamwork, felt more prepared to attend college, and felt program participation reaffirmed their goal to pursue a STEM career. The responses also show that all students plan on attending undergraduate and graduate school for a STEM degree. A long term (>5 years) follow-up survey is needed to confirm this. The study of this program would also be strengthened by a comparison to a group of peers who did not attend the program (control group). This type of control group is not easily assembled and tracked, but efforts are being made to find a comparable method of a control comparison for future studies.

## **Conclusions**

The current program structure is effective in increasing both male and female student's disposition towards and interest in certain STEM areas, being especially noticeable on women's interest in math, computer science, and chemistry. The program had a statistically significant increase on the student interest in engineering and technology. Additionally, free response answers indicated the program had a positive impact on student social skills and ability to work on teams. To promote better diversity, efforts should be made to solicit applications from more African American and Hispanic students to better align with state demographics. The percentage of students from rural areas in the program is comparable to the state's overall composition.

Despite many free response questions indicating an increase of confidence in critical thinking and problem solving skills, the Likert-scale question analysis do not show a significant increase in student confidence in these skill sets. This may be due to students already having high confidence in these areas. Future studies to better evaluate the curriculum, survey sections focusing on critical thinking and problem solving will be improved for increased resolution. But the free response section shows overwhelming support for the structure of the program and the impact that students feel it had upon them. When compared to the previously mentioned seven strategies shown to help females succeed in STEM education, this program utilizes six of them: spatial reasoning (organic chemistry, math and physics coursework), communication abilities (homework help groups, labs and team projects), resilience (surviving intense academic experience), active expert roles (highly involved faculty and counselors), clear feedback in grading (no grades but assignments are checked for comprehension), and re-evaluation of group work in the classroom (high level research group with evenly distributed workloads). The emphasis of these areas helps all students in the program and set it apart from their typical high school experience.

This program is a successful method for growing and solidifying interest in STEM degrees and careers. It provides resources that are not available at high schools to the students most motivated to fully utilize their academic opportunities. It should serve as a model for other states to create or improve their programs as summer camps or STEM tracks in high schools with

the goal of attracting bright students into STEM fields and preparing them for a successful career.

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## References

- <sup>1</sup> ABET. (n.d.). *Criteria for accrediting engineering programs, 2014 - 2015*. Retrieved from <http://www.abet.org/eac-criteria-2014-2015/>
- <sup>2</sup> Wright, D. (2013). *Weaving a Computer Science Tapestry: Results of a Workshop Promoting the Recruitment and Retention of Girls in High School Computer Science*. 2013 ASEE (American Society for Engineering Education) Annual Conference and Exposition - Computational/CS Initiatives , Atlanta, GA.
- <sup>3</sup> Yilmaz, M., Yilmazer, N., Torres, E. C., & Guillen, T. D. (2013, June). *A female-only camp for STEM disciplines*. 2013 ASEE Annual Conference and Exposition - Outreach to K-12 Females, Atlanta, GA.
- <sup>4</sup> Scutt, H. I., Gilmartin, S. K., Sheppard, S., & Brunhaver, S. (2013). *Research-informed practices for inclusive science, technology, engineering, and math (STEM) classrooms: Strategies for educators to close the gender gap*. 2013 ASEE Annual Conference and Exposition – Research Initiatives, Atlanta, GA.
- <sup>5</sup> *Governor's school FAQs*. (2012, October 5). Retrieved from <http://www.ncogs.org/index.php/faqs/governor-s-school-faqs>
- <sup>6</sup> Healy, N. Berenstein, A. (2012). *Using Summer Programs to Excite Secondary Students about Nanoscale Science and Engineering*. 2012 ASEE Annual Conference and Exposition - Secondary (6-12) Outreach, Atlanta, GA.
- <sup>7</sup> Sirinterlikci, A. Sirinterlikci, S. (2013). *Development of a Summer High School Research Program*. 2013 ASEE Annual Conference and Exposition - K-12 Robotics, Atlanta, GA.
- <sup>8</sup> Winn, G. Kweder, J. Reagan, C. (2012). *Re-Assessing the Effects of Summer Camp on the STEM Enrollments Using an Innovative Survey Strategy*. 2012 ASEE Conference and Exposition - Out-of-School and Informal Activities, San Antonio, TX.
- <sup>9</sup> Finn Jr. C.E. (2012, September 18). Young, Gifted, and Neglected. *New York Times Op-Ed*.
- <sup>10</sup> Legislative Budget and Finance Committee. (2013, December). *The status of special education for gifted students in the commonwealth*. Retrieved from <http://lbfc.legis.state.pa.us/reports/2013/86.PDF>.
- <sup>11</sup> Maguire, K. G. (2008). *Gifted education: In-class differentiation and acceleration in pennsylvania schools*. (Doctoral dissertation, Teachers College, Columbia University), Available from ProQuest. (UMI Dissertations Publishing).
- <sup>12</sup> Campbell, B. and Nickl R. (2012). *The Impact of STEM Enrichment Opportunities on Secondary School Students*. 2012 First Year Engineering Education Conference, Pittsburgh, PA.
- <sup>13</sup> Dillihunt, M. Smith, D. Farrington, P. (2012). *Impact of Innovative Student Project for the Increased Recruitment of Engineering and Science Students (InSPIRESS)*. 2012 ASEE Annual Conference and Exposition - Linking K-12 to Post-secondary, San Antonio, TX.

- <sup>14</sup> Weibe, E., Faber, M., Corn, J., Collins, T.L., Unfried, A., & Townsend, L.. *A Large-scale Survey of K-12 Students about STEM: Implications for Engineering Curriculum Development and Outreach Efforts*. 2013 ASEE Annual Conference and Exposition – Research Initiatives, Atlanta, GA.
- <sup>15</sup> Knezek, G., Christensen, R., & Tyler-Wood, T. (2011). Contrasting perceptions of STEM content and careers. *Contemporary Issues in Technology and Teacher Education*, 11(1), 92-117.
- <sup>16</sup> Mincemoyer, C., Perkins, D. (2005). Measuring the impact of youth development programs: A national on-line youth life skills evaluation system. *The Forum for Family and Consumer Issues*, 10(2).
- <sup>17</sup> Mincemoyer, C., and Perkins, D. (2003). Assessing decision-making skills of youth. *The Forum for Family and Consumer Issues*, 8(1).
- <sup>18</sup> *Rural/urban PA*. (n.d.). Retrieved from [http://www.rural.palegislature.us/rural\\_urban.html](http://www.rural.palegislature.us/rural_urban.html)
- <sup>19</sup> American Fact Finder. (n.d.). Retrieved from <http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmmk>
- <sup>20</sup> *State & county quickfacts: Pennsylvania*. (2014, January 20). Retrieved from <http://quickfacts.census.gov/qfd/states/42000.html>