Impact of a Summer Research Program for High School Students on their Intent to Pursue a STEM career: Overview, Goals, and Outcomes

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Watt, K. & Yanez, D. (2001). AVID: A comprehensive school reform model for Texas, Paper presented at 2001 AERA Annual Conference, Seattle, Washington.

Yanez, D. & Wenrick, M. (2000) Improving Algebra I End-of-Course Exam Scores: Evidence from the field, [Website]. Austin: The University of Texas at Austin, The Charles A. Dana Center, Available: http://www.tenet.edu/teks/math/index.html.

Yanez, D. (1999). Advanced placement capacity assessment tool (APCAT). Austin: The University of Texas, The Charles A. Dana Center.

Yanez, D. (1999). A study of ten pilot districts using data-driven decision making. Texas Education Agency's Commissioner's Public Access Initiative.

(1997). Educators supporting educators. Contributing author. Association for Supervision and Curriculum Development: Alexandria, Va.

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Impact of a Summer Research Program for High School Students on their Intent to Pursue a STEM career: Overview, Goals, and Outcomes

Abstract

The Young Scholars (YS) program at the National Science Foundation Nanosystems Engineering Research Center (ERC) for Nanomanufacturing Systems for Mobile Computing and Mobile Energy Technologies (NASCENT) at UT Austin, was a seven week long summer research experience designed for high school students entering 10-12th grade. The main goal of the program was to provide young women and underrepresented minority high school students with a laboratory research experience and inspire them to enter college and pursue STEM degree s. Each summer, students from local high schools were selected to participate in laboratory research as scholars under the supervision of a mentoring graduate student and faculty member. Each team composed of two YSs and their graduate mentor tackled problems in nanomanufacturing and made significant contributions to ongoing research projects. At the end of the program, each high school student gave a final presentation of the results to family members, teachers, graduate students and faculty. Over seven years, the YS program has hosted a total of 53 students, among them 56% women and 60% underrepresented minorities (URM).

In preparation for their research project, the YSs spent their first week participating in a "boot camp" that included a welcome orientation, short courses in fundamentals of nanotechnologies, basic concepts in engineering, laboratory safety training, *Innovators' DNA* skills' seminar, and an introduction to research. Following their bootcamp, students were expected to work on their project, performing original research under the supervision of their graduate mentor, read reference material and maintain a laboratory notebook. To supplement students' research experience, YSs participated in technical and career development seminars, field trips to local nanotechnology companies, and social activities.

Quality assessment of the program was performed by analyzing responses from pre- and post-surveys of the 2016 to 2019 cohorts. The main focus of this analysis is investigating the satisfaction of the participants and the impact of the program in increasing interest in a STEM career. The data analysis shows increasing awareness among participants of the many career opportunities in STEM and confidence in their ability to pursue a STEM career. Other aspects assessed are participants' confidence in conducting research and presenting findings, using lab tools, understanding scientific articles and guest lecturers' seminars.

Among the 39 YSs who graduated high school to date, 24 YSs are pursuing engineering degrees, 14 are majoring in non-engineering STEM disciplines, and 1 has attended trade school and is now interning at Samsung Semiconductor. These results confirm that the YS program has been extremely successful in achieving its above stated goals.

Getting published; I was not expecting it and during the last week of the program it was a surprise; I really didn't think I would get it but it was a process and now I realize how important it was…my college counselor said it would take me a long way with college acceptance (YS, Post-Survey 2016)

… the program gave me an opportunity to experience college through my work and my Mentor. (YS, Post-Survey 2018)

1. Introduction

On March 6, 2019, the House Science Committee held a hearing week to discuss ways the United States can maintain leadership in science and technology in the face of growing global competition [1]. The panel emphasized the importance for the U.S. to better develop domestic talent and continue to welcome students and researchers from abroad to ensure the future sufficiency of its STEM workforce [2]. Moreover, as of 2010, African Americans, Hispanics, Native Americans, and Native Hawaiian and Pacific Islanders together comprised 31.1 percent of the total U.S. population [3]. However, they are underrepresented in the fields of science, technology, engineering, and mathematics (STEM), with only 12.5 percent of engineering bachelor degrees earned by underrepresented minorities (URM) [4]. Equally alarming is the underrepresentation of women in STEM-related fields, in particular in disciplines such as physics, engineering, and computer science, with women earning only 20 percent of bachelor's degrees and representation declining further at the graduate level and in the transition to the workplace [5]. Engaging more students in science and technology careers, especially women and URMs, would not only contribute to the pool of talent needed to fill the job market's demand but it may also lead to a more equitable society, with a broader understanding of the many diverse communities that make up our nation [6].

The strong impact of K-12 education on fueling interests or disenfranchising students towards mathematics and science related subjects has been widely studied in the literature [7, 8, 9]. To provide students with the best possible learning experience during the crucial K-12 years, the role of summer science and engineering enrichment programs has proved effective in improving self-efficacy and influence a positive attitude towards science [10, 11]. Science and engineering research programs engaging K-12 students in partnerships with universities are becoming increasingly popular, as vehicles for improving students' understanding of scientific inquiry, critical thinking and overall attitude towards STEM field disciplines. [12, 10, 13]. These hands-on programs are based on situated learning and apprenticeship theories where apprentices learn the tools and skills related to their discipline through direct participation [14, 15, 16]. They provide a deeply engaging learning experience where students work with an expert mentor performing authentic scientific research. The YS program described in this paper falls within this category.

The uniqueness of this YS program lies in the fact that, after the initial training, high schoolers had the opportunity to conduct daily laboratory research. The majority of the participants contributed to the ongoing research of their graduate mentors and, in one case, YSs were co-

authors of a published article. The other unique aspect of this program is the focus on engineering and the specific skills' set required in this field. This program "formalizes" the definition of engineering, emphasizing the multi-disciplinary and overall foundational validity of the required skills.

This paper provides an overview of the program, highlighting the combination of characteristics that represent the key ingredients of its success. The quality assessment of the program is performed by analyzing responses from pre- and post-surveys of the 2016 to 2019 cohorts. The main focus of this analysis is investigating the satisfaction of the participants and the impact of the program in inspiring them toward pursuing a STEM career. The evaluation questions are:

Question 1: To what extent did the YS summer program improve students' confidence in research skills?

Question 2: In what ways did the summer program influence students' decisions about their future careers?

Question 3: To what extent were students' expectations about the program met?

2. Methods

2.1 Program Overview

The YS program at the National Science Foundation Nanosystems Engineering Research Center (ERC) for Nanomanufacturing Systems for Mobile Computing and Mobile Energy Technologies (NASCENT) at UT Austin, was a seven week long summer research experience designed for high school students entering 10-12th grade. The main goals of the program were to develop a pipeline of students who are well prepared for careers in the STEM field, to provide high school students with laboratory research experience and to inspire them to enter college and STEM degree programs. Secondary aims of the program were increasing awareness among students and their families of engineering careers and opportunities, fostering students' development of the Innovator's DNA, and improving self-confidence in the ability to perform research and obtain a graduate level college education.

Each summer, students from local high schools were selected to participate in laboratory research as scholars mentored by a highly trained graduate student with whom they worked closely during the summer under the supervision of a faculty member. Each team composed of two YSs and their graduate mentor tackled problems in nanomanufacturing and makes significant contributions to ongoing projects (See Table 1 for list of summer 2019 projects).

Table 1: 2019 YSs projects

Area of research	Project
Nuclear Robotics	Development and Testing of a Remote Camerabot
Electrical Engineering	Effect of Carrier Gases on the Synthesis of MoS_2 and WS_2
Electrical Engineering	Effects of Strain on Thin GaSb Films
Design Engineering	Design and Fabrication of a Graphene Gas Sensor Housing for applications in Medical Diagnosis
Physics	Light and Matter interaction on a Nano scale

In preparation for their research project, during their first week, YSs attended a weeklong 'boot camp' that included:

- Welcome orientation, when YSs met mentors and faculty in an informal setting.
- Short courses in fundamentals of nanotechnologies (lithography, transistors, etc.), statistics and basic concepts in engineering.
- Laboratory safety training.
- Innovators' DNA skills seminar to improve questioning, observing, experimenting, networking and associating [17].
- Introduction to research that included three lab experiments including silver nanoparticle lab and the PDMS stamping lab, and experience in the clean room.

Throughout the years, the bootcamp went through a series of changes and refinements following feedback from staff, mentors and scholars. From the initial three-day program, the boot camp was extended to a weeklong training to accommodate for various activities, including lab experiments, technical and supporting coursework, and safety training. The curriculum of the boot camp was developed by graduate students, under the supervision of the Education & Outreach Staff Director (Mrs. Risa Hartman) and included statistics, fundamentals of nanotechnology and ethics classes to offer a wide range of useful preliminary information. The safety training (combination of online and onsite) for a total of four hours, under the guidance and supervision of trained laboratory graduate students, allowed YSs to learn about laboratory procedures. During the final day of bootcamp, mentors held a formal meeting with their scholars to discuss details, plans and expectations about the specific project.

During weeks 2-6, students worked on their project daily, performing original research under the supervision of their graduate mentor, reading reference material and maintaining a laboratory notebook. To supplement students' research experience, YSs participated in weekly meetings, in workshops geared to teach students technical writing, poster creation and presentation skills, and in technical and career development seminars where faculty members and guest speakers gave special interest talks around nanotechnology and manufacturing (See Table 2 for a sample of daily schedule).

Table 2: Sample of daily schedule week 2 to 6

9am	Arrive at Research Center, check in with mentors and begin research
12pm	Lunch at the cafeteria
1pm	Workshop on technical writing skills
3pm	Begin scientific poster creation using skills learned in workshop
5pm	Depart for the day

Field trips to local nanotechnology companies, university campus visits to other labs and facilities, and social events were organized throughout the summer to offer YSs additional learning and networking opportunities.

During week 7, YSs wrapped up their research, created scientific poster highlighting their research and prepared a short video and a presentation of their experience. The mentors prepared the YSs for the poster protocol, helped in the development of their results and supported them in developing their mini-presentations. During the last day of the program, each high school student presented his/her poster and gave a final oral presentation of the results in front of family, friends and faculty members.

2.2 Recruitment and Demographics

YSs were recruited from local schools, in close proximity to campus with particular attention placed on accepting students from schools with a high percentage of URMs. Emphasis was also placed on equal gender, to improve women and minorities access and awareness of STEM careers.

The recruitment process significantly changed throughout the years. Between October 2012 and February 2013, formal and informal meetings were held between the Education & Outreach Staff Director (Hartman) and school district/campus officials, with the intention to create a genuine relationship resulting in effective recruitment. Other outreach activities were conducted during the school year as well, including Nano Club and opportunities to tour the facility labs and meet faculty and graduate students. This involvement on campus during the school year 2012-2013 prior to the initial summer experience incited interest and curiosity about nanotechnology among teachers and students.

After the first year of working with one local district, a protocol was created to approach other districts. Interest was easily generated from other districts, and by year two, the program had more applicants than openings, imposing the need for a more structured application and review process.

Once the program became well-known in the area, partnerships were established with additional local schools and recruitment on campus became increasingly effective and straightforward. High school students were recruited in two ways, through an online application (started in 2018) open to the public and through peer recruitment, when former YSs were invited to talk about their summer experience during school recruitment sessions usually held in October. Once the application was received, students attended an in-person interview with the pre-college program

director to verify their ability to commit to the entire summer. A teacher's feedback was required to select students capable to maintain the commitment and to benefit particularly from this experience. In the selection process, grades were not important, but priority was given to women and students coming from schools with higher URM population. High school students were allowed to apply to the summer experience for a second year.

Over seven years, 245 students applied in total. The YS program has welcomed a total of 53 students, among them 56% women and 60% Underrepresented Minorities (URM), as illustrated in Table 3.

Table 3: Demographics of the Young Scholars program from 2013 to 2019

Race/ethnicity		Gender	
African American	11%	Female	56%
Asian	19%	Male	43%
Caucasian	21%		
Hispanic	49%		

2.3 Data collection

To answer the evaluation questions, responses from pre- and post-surveys of the 2016 to 2019 cohorts were analyzed. Interviews and focus groups were also conducted. Surveys, interviews and focus groups were planned and administered by the NASCENT Center Program Evaluator (Dr. Darlene Yanez).

Surveys were sent and collected through Qualtrics to the 2016 to 2019 cohorts. Students completed pre-surveys during the first day of bootcamp; post-surveys were administered during the last week of the program. Although participation was completely voluntary, the response rate was very high with only four students across the three cohorts who didn't complete the post-survey (Refer to Table 4).

The surveys contained between 13 and 29 questions, organized in various formats:

- 5-point agreement and satisfaction Likert-type scales.
- 4-point agreement and satisfaction Likert-type scales.
- Side by side and multiple choice questions.
- Open-ended text entry.

In addition, the YSs' mentors were surveyed and interviewed during the program to determine YSs' progress. An IRB protocol allows for data analysis/publication, and all YSs signed an informed consent and media release.

Table 4: Participants, surveys 2016 to 2018

	2016	2017	2018	2019
Total participants	9	10	9	9
Returning YSs	4	5	5	1
New YSs	2	5	4	8
Female	3	6	4	5
Male	3	4	5	4

2.4 Data analysis

The analysis of the surveys included both quantitative and qualitative methods.

To answer evaluation question 1, the mean of pre- and post-survey responses have been compared using a nonparametric unpaired t-test, the Mann-Whitney test, on Stata.

To answer evaluation questions 2 and 3, a qualitative analysis has been conducted. For question 3, two subthemes have been identified: sense of pride and favorite part of the summer experience. Among the "favorite part of the summer" responses, satisfaction towards mentors, use of cleanroom and lab tools, and social activities have been isolated and analyzed.

3. Results

3.1 Evaluation Question 1: To what extent did the YS summer program improve students' scientific skills and confidence?

YSs were asked to rate their confidence in the research skills listed in Table 5 in the pre- and post- surveys on a scale of 1 to 5, with 1=Extremely Not Confident to 5= Extremely Confident. The arithmetic mean of the responses for each cohort was calculated and the Mann-Whitney test was run to determine statistical significance between pre- and post- survey data.

The data analysis shows an overall increase in confidence for almost all the statements throughout the years, with a few statistically significant improvements. For the 2016 cohort, "Using tools in the lab", "Collecting data" and "Analyzing data" significantly increased ($p \leq 0.05$) from pre- to post- survey. This result reflects the focus of the program on providing students with the opportunity to perform daily laboratory research, contributing to an ongoing research project.

Table 5: Research skills

Please rate the following scientific skills:	2016		2017		2018	
	Pre (n=6)	Post (n=9)	Pre (n=10)	Post (n=10)	Pre (n=9)	Post (n=9)
Understanding lectures	4.33	4.67	4.10	4.30	3.22	3.44
Working as a team member	5.00	4.83	4.60	4.90	4.00	4.12
Designing my own research	4.22	4.67	3.80	4.00	2.86	3.56
Using tools in the lab	4.44	5.00*	4.40	4.70	3.00	4.00
Collecting data	4.33	5.00*	4.50	4.80	3.56	4.00
Analyzing data	4.33	5.00*	4.10	4.30	3.33	4.11
Understanding scientific articles	3.78	4.00	3.60	4.10	3.33	3.89
Meeting with professors	4.56	4.67	4.20	4.40	3.86	4.44
Formally presenting my work	4.56	4.67	4.40	4.70	4.25	4.13

** $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$*

When asked to describe what two skills YSs have acquired as a result of their summer experience, many provided answers through the open-ended item included in the post-surveys, confirming the results of the analysis:

> *I acquired Cleanroom experience (Ellipsometer, AFM, RF Sputter, E-beam evaporator, 4-point tool) as a result of my summer experience. I've also acquired the skill of being able to create a Design of Experiments as a result of my summer experience. (YS, 2017)*

> *I have learned to analyze research articles and get information from different resources to form a new research question. I learned to gain knowledge through just reading of previous experiments and research to find a solution for an issue that I was working on. (YS, 2016)*

> *My communication skills gave improved in this program, in regards for asking for more help/clarification when needed. In addition learning to be resourceful to problem solve (FIB poor viewing, etc). (YS, 2016)*

Figure 1: YSs performing laboratory research

Some answers showcased the many skills YSs acquired that transcend the scientific knowledge, such as confidence in asking questions and communicating, patience and resilience during the research process and leadership skills, as expressed in the following quotes from post-surveys:

> *Skills that I have improved as a result of participating…are: not being afraid to ask questions, communicating and interacting with people you have never met before... (YS, 2016)*
>
> *Patience in constant failure of research and presentation skills for showing research. (YS, 2017)*
>
> *Leadership was another skill I practiced throughout the summer. At school, I'm on the volleyball team and since I am a senior, my coach has high expectations for myself (and other seniors) to practice leadership by leading and being good role models for the younger members of the team. I noticed this summer that I got to transfer what I have learned from volleyball to a real-world setting. This was interesting for me to see how skills can be used in different places. (YS, 2017)*

Throughout the summer, *Innovator's DNA* skills [17] (Questioning, Observing, Experimenting, Networking and Associating) were targeted during the daily laboratory practice and with specific activities organized during workshops. Table 6 reports the analysis of the responses of the 2016 and 2017 pre- and post- surveys where YSs were asked how often they use their *Innovator's DNA* skills on a scale of 1 to 5, with 1=A great deal to 5=Not at all. The arithmetic mean of the responses for each cohort was calculated and the Mann-Whitney test was run to determine statistical significance between pre- and post- survey data. The analysis shows an overall increase in the use of the listed skills in most cases; however, none of the comparisons were statistically significant.

Table 6: DNA Innovator's skills 2016, 2017

How often do you use the following Innovator's DNA skills?	2016		2017	
	Pre (n=6)	Post (n=9)	Pre (n=10)	Post (n=10)
Questioning	4.33	4.17	4.30	4.50
Observing	4.56	4.67	4.50	4.70
Experimenting	4.11	4.67	3.80	4.50
Networking	3.89	4.17	3.50	4.00
Associating	3.89	3.50	3.60	4.40

** p≤0.05, **p≤0.01, ***p≤0.001*

For the 2018 surveys, YSs were asked to agree or disagree with the following statements on a scale of 1=Does not describe me to 5=Describes me extremely well.

- I feel like a scientist. Reported as Experimenting in Table 7.
- I feel like a networker. Reported as Networking in Table 7.
- I am able to make connections with things that are not always clearly connected. Reported as Associating in Table 7.

The arithmetic mean of the responses for each cohort was calculated and the Mann-Whitney test was run to determine statistical significance between pre- and post- surveys' data (Refer to Table 7). The table shows an overall improvement of *Innovator's DNA* skills for the 2018 Cohort; however, none of the comparisons were statistically significant.

Table 7:Innovator's DNA skills 2018

Innovator's DNA skills	2018	
	Pre (n=9)	Post (n=9)
Experimenting	3.44	4.11
Networking	2.68	3.67
Associating	3.45	4.22

** p≤0.05, **p≤0.01, ***p≤0.001; "Questioning" and "Observing" are not reported in 2018*

A very interesting comment came from a YS in the 2017 post-survey when asked about skills that she learned in the summer. She seemed particularly proud of her ability to "connect the dots" and put in practice knowledge acquired elsewhere:

> *One skill I learned was associating. During a Digital Electronics class I took last school year, we created circuits on breadboards using IC chips. I quickly realized that transistors were inside of IC chips and this connection helped me understand my project even more. (YS, 2017)*

The analysis of quantitative and qualitative data suggests that the program positively impacted YSs' scientific skills and their confidence. Data shows improvements in the students' laboratory skills, reflecting the focus of the program on daily lab research. YSs reported a better understanding of scholarly papers and their importance for their research project or to form future research questions. Moreover, it appears that the program fostered students' appreciation

for authentic research and the patience and resilience required to succeed. Some students reported increased confidence in their communication and leadership skills.

3.2 Evaluation question 2: In what ways did the summer program influence decisions about their future careers?

In the pre-surveys, 29 out of 34 respondents expressed the desire to attend college once graduating high school, with many interested in engineering majors. The remaining 5 didn't express a preference for college but some expressed desire to enter a research career. Twenty-one students wanted to pursue engineering, although many not settled on a major yet, 3 students were interested in other STEM fields, and one student was interested in education. Six YSs mentioned curiosity towards graduate school opportunities.

Upon completing the YS program, 24 students indicated that their college pathway was engineering with most of them already decided on a major. One student was interested in Physics. Nine students were already planning for graduate school (See Figure 2).

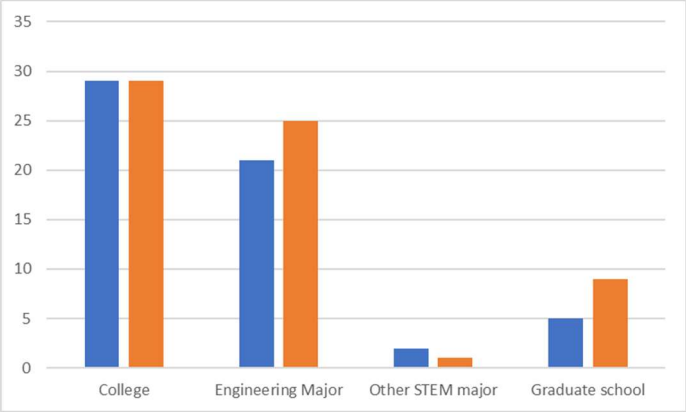

Figure 2: Career interests pre- and post- surveys

In the open-ended questions of the post-surveys, all of the YSs except one reported that the summer experience had a strong impact on their decision either helping them select a major or opening their eyes about opportunities in graduate school:

> *I did not have any plans before I started the program besides knowing that I would pursue an education and career in a STEM field. But now knowing more about the many different pathways one could take in engineering, I am basically convinced I will graduate with a degree in some form of engineering. (YS, 2019)*

> *My summer experience has only given me more reason to pursue engineering and electronics. Although undergrad school is just a stepping stone to a career, there are so many opportunities to grow and you just have to be aware and take them. This summer experience has also given reasons to why I should go to grad school, something I'm considering more, now. (YS, 2017)*

One student reported that although the program didn't influence his academic path already strongly oriented towards engineering, it increased his confidence in his ability to pursue an engineering degree:

> *No this program has not changed my plans in fact it only made me more confident in it because now I know that if I put my mind to it I can get it done. (YS, 2016)*

Among all the students, only one reported that the impact of the program was negative because it made her come to the realization that she didn't want to pursue an engineering career.

> *This summer experience has opened my eyes to the engineer field. It has helped me make the decision not to become an engineer. (YS, 2018)*

According to a follow-up email sent in January 2019, among the 39 YSs who graduated high school so far, 24 YSs are pursuing engineering degrees, 14 are majoring in non-engineering STEM disciplines, and one has attended trade school and is now interning at Samsung Semiconductor. These results confirm that the YS program has been extremely successful in achieving its goals related to influencing career decisions.

3.3 Evaluation Question 3: To what extent were expectations about the program met?

The majority of YSs was very pleased with the experience and suggested that, given the opportunity, they would come back for another summer and even recommend the program to their peers. Overall, the data analysis shows that expectations were met or exceeded, and the summer experience was successful for the vast majority of the students.

YSs reported a strong sense of pride for the work they have accomplished and the academic growth that they achieved. In the 2018 post-survey, when asked to provide a grade for themselves, two YSs, whose quotes are reported below, strongly felt that they had reached the goals set for themselves and for the project, being able to truly contribute to the research project.

> *I came into this program not knowing what was going to happen. I did not have prior experience in doing rigorous research and I was unsure of what to expect. However, looking back on I feel that I accomplished so much. I was able to get a lot done and I learned so many things. For that reason, I feel I deserve an A. (YS, 2018)*

> *I feel that I was able to effectively take lead of the project and engage with my mentors where they were able to help to the best of their ability. We accomplished the objectives we set for ourselves at the beginning and are leaving good documentation for others to pick up our work in the future. (YS, 2018)*

In the particular case of returning YSs, the overall experience during the second year was even more rewarding. Returning students came with the advantage of having already learned basic skills during the boot camp of the previous year and of already knowing the environment and the dynamics of the research and the lab. The confidence and the results achieved after a second year were clearly expressed by one returning YS:

During my first year … I was intimidated by everything and I didn't really know what I was doing. My second year, I was really able to have a deeper understanding of the material and this motivated me and helped me develop an interest in engineering. (Returning YS, 2018)

This YS suggested that, having overcome first year hesitations, she was able to achieve a deeper understanding of the research project.

When asked about their favorite part of the summer, students reported satisfaction with many aspects of the program, including working with their mentors, the amount of time spent in the cleanroom, use of tools, and opportunities for social interactions. Table 8 shows the experiences that students reported as their favorite and the number of preferences these received.

Table 8: Favorite part of the summer experience

Favorite part of the summer experience	Number of responses
Working with the mentor/ experience college with the mentor	9
Working in the clean room/ lab tools	8
Social activities and informal gatherings	6
Research project	6
Meeting engineers and faculty	4
Final presentation	4
Research success/failure	3
Seminars and guest speakers	3
Field trips	2

Other aspects of this experience mentioned by students not included in Table 8 are improving scientific knowledge and organizational skills, problem solving, constant opportunities to showcase their work, team spirit, training and certifications.

3.3.1 Working with the mentor/ experiencing college with the mentor

The overall satisfaction of participants towards mentors was very high. The analysis of the 2018 and 2019 post-surveys confirms that the majority of YSs met with their mentors daily, with few YSs meeting their mentor less than 4 times a week, for duration ranging from 15 to 60 minutes. The purpose of these meetings was to review progress and receive feedback, discuss findings, make plans and provide needed clarifications. Scholars also worked with mentors in the lab one to four times per week, depending on their project and its direct connection to their mentors' research. When asked to grade their mentors, the majority of participants gave a grade A with the lowest grade being B-. The graduate student mentoring training was refined and perfected throughout the years thanks to the analysis of interviews and surveys administered each year, at the beginning and at the end of the summer program, to both mentors and Scholars. For example, in 2018, the YSs reported that the mentors did not adequately connect the research to the real world. This feedback was important in the 2019 mentors' training with increased emphasis

placed on connecting the project with a real world application, in order to make it more relatable to YSs and allow them to see the "big picture".

The crucial role of the mentors is highlighted in the open-ended entries of the post-surveys. For some YSs, the mentor played the important role of guiding them through the research project and improving their confidence in the ability to perform the various tasks assigned, as expressed in the following quotes:

> *When I first started this summer I was so scared I was gonna do something wrong and mess up the research but my mentor worked with us in the lab and within a couple of weeks we (team) were in the lab using the tools like the other grad students. (YS, 2018)*

> *I really enjoyed working with my mentor and I appreciated how he always wanted to give us the best learning experience and expand our knowledge. Specifically, I enjoyed the times when we would sit in our mentors to discuss in detail some of the hard topics. (YS, 2017)*

One YS reported that working with a graduate student allowed him to experience college, clearly impacting his future career choices.

> *I really enjoyed working alongside graduate student mentor, which allowed me to get a bigger picture of what engineering research is like and helped me prepare for my college years. (YS, 2018)*

3.3.2 Cleanroom and Laboratory Tools

Working in the cleanroom and using laboratory tools was a favorite experience cited by several YSs. For example, the majority of students in the 2019 cohort reported to have worked in the lab daily or no less than 3-4 times per week with one exception who reported 1-2 times per week.

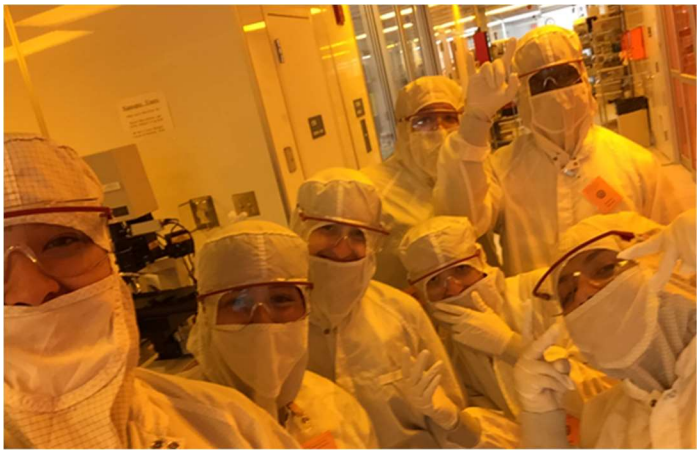

Figure 3: YSs working in the cleanroom

An interesting observation about the work in the lab came from a female young scholar in 2014 when asked, during an interview, how she felt being in a lab around mainly male graduate and post-doctoral students; she responded, "*The lab provides an even playing field – when we are in the clean room, no one can tell who we are - just the work we do is looked at.*" The student's

comment seems to indicate that the cleanroom, where researchers are fully covered, mitigated gender-related obstacles since no one was able to distinguish one student from another.

3.3.3 Social activities

YSs also appreciated the formal and informal social opportunities provided. Many social events were organized throughout the summer. The kickoff meeting on the first day gave students a chance to interact with the faculty, staff and mentors in an informal setting during a welcoming lunch offered by the institution. Throughout the summer, other popular events, such as the ice cream social, the two lunches with a professor, and the final celebration at the end of the program offered enrichment networking opportunities to the YSs. Even more notable are the informal social interactions students had during the summer. For example, gathering at lunch time, they usually played cards and other games, talking and sharing their experiences, and this became their fun and relaxing hour. For one YS, the social gathering became an important part of each day:

> *[My favorite thing about the experience was] talking with my mentor and teammates about our favorite things in life after we were done with the day. (YS, 2017)*

4. Conclusions

The strength of this program lies in its effectiveness in inspiring and promoting engineering among high school students. The apprenticeship hands-on model where students contribute to ongoing research projects and are able to connect research with real world applications has been demonstrated to be successful. Moreover, the supporting activities, such as bootcamp, lectures, reading and understanding of scientific journals, focus on Innovator's DNA skills, poster development and presentation delivery have clearly contributed in making this an enriching experience, where YSs learned scientific and other foundational skills applicable to their future careers. Even more important, YSs have been exposed to the success and failure of authentic research. The feedback received was very positive and the program met or exceeded participants' expectations.

By prioritizing URM and female students, this YS program has had a substantial impact on broadening participation, in inspiring and spreading awareness of engineering opportunities among students who are traditionally marginalized in STEM. Students' confidence in their ability to pursue a college degree, especially among the returning YSs, as evaluated in the results section, increased during this summer experience. Furthermore, the relationship between the YSs and the graduate mentors expanded high school students' ideas about the opportunities that graduate school has to offer. As a result of the program, many participants weren't just planning to go to college, they were already considering applying to graduate school.

All the activities fostered a strong social aspect that united students, faculty and staff from various backgrounds and interests to achieve the common goal of increasing exposure and excitement toward STEM education. The program established a strong and long-lasting relationship among the NASCENT ERC, UT Austin and local school districts. Schools have access to resources, through their connection with the institution, that they might not have gained

otherwise, in terms of expertise and guidance from graduate students and faculty members, science clubs and science fair support, for example.

Last, great satisfaction came by appointing as counselors two former YSs who completed the program in an earlier cohort and completed their first year of college as engineering majors. This represents a complete cycle – YS to undergrad to YS counselor – and a successful story for the program.

As evidenced by the overwhelmingly positive student feedback and by the career path that the vast majority has chosen, this program is a strong and successful model for broadening participation in engineering and other STEM majors.

ACKNOWLEDGEMENTS

The program described was supported by the National Science Foundation, through Cooperative Agreement No. EEC-1160494. The opinions expressed are those of the authors and do not represent views of the National Science Foundation.

References

[1] "Maintaining U.S. leadership in science and technology," 6th March 2019. [Online]. Available: https://science.house.gov/hearings/maintaining-us-leadership-in-science-and-technology.

[2] M. Ambrose, "Panel Warns US Faces STEM Workforce Supply Challenges," 14 March 2019. [Online]. Available: https://www.aip.org/fyi/2019/panel-warns-us-faces-stem-workforce-supply-challenges.

[3] 2010. [Online]. Available: https://data.census.gov/cedsci/profile?q=United%20States&g=0100000US&table=DP05&tid=ACSDP1Y2018.DP05.

[4] 2013. [Online]. Available: https://www.nacme.org/underrepresented-minorities.

[5] Catherine Hill Christianne Corbett Andresse St Rose, "Why So Few? Women in Science, Technology, Engineering, and Mathematics," 2010. [Online]. Available: https://www.aauw.org/aauw_check/pdf_download/show_pdf.php?file=why-so-few-research.

[6] Pamela R. Aschbacher, Erika Li, Ellen J. Roth, "Is Science Me? High School Students' Identities, Participation and Aspirations in Science, Engineering, and Medicine," *Journal of Research in Scientific Teaching,* pp. VOL. 47, NO. 5, PP. 564–582, 2010.

[7] S. Catsambis, "Gender, race, ethnicity, and science education in the middle grades," *Journal of Research in Science Teaching,* pp. Vol. 32, 243–257, 1995.

[8] Jones, M. G., Howe, A., & Rua, M. J., "Gender differences in students' experiences, interests, and attitudes toward science and scientists," *Science Education,* pp. Vol. 84, 180–192, 2000.

[9] R. George, "A cross-domain analysis of change in students' attitudes toward science and attitudes about the utility of science," *Journal of Science Education,* pp. Vol. 28, 571–589, 2006.

[10] Barab SA, Hay KE, "Doing science at the elbows of experts: issues related to the science apprenticeship camp," *Journal of Science Teaching,* p. 38(1):70–102, 2001.

[11] D. A. Fields, "What do students gain from a week at science camp? Youth perceptions and the design of an immersive, research-oriented astronomy camp," *International Journal of Science Education,* pp. 31(2), 151–171, 2009.

[12] "Engineering Research Center," n.d.. [Online]. Available: http://erc-assoc.org/content/research-experience-high-school-students.

[13] Knox KL, Moynihan JA, Markowitz DG, "Evaluation of shortterm shortterm impact of a high school summer science program on students' perceived knowledge and skil," *Journal of Science Education,* p. 12:471–478, 2003.

[14] J. G. Greeno, "Learning in Activity," in *The Cambridge Handbook of the learning Sciences*, Cambridge, UK, Cambridge University Press, 2014, pp. 79-96.

[15] W. J. Clancey, "A Tutorial on Situated Learning," in *Proceedings of the International Conference on Computers and Education*, Taiwan, 1995.

[16] Lave, J., & Wenger, E., Situated learning: Legitimate peripheral participation, Cambridge: Cambridge University Press, 1991.

[17] J. Dyer, H. Gregersen, C.M. Christensen, The Innovator's DNA: Mastering the Five Skills of Disruptive Innovators, Boston, MA: Harvard Business Press Review, 2011.

[18] "STEM 101: Intro to tomorrow's jobs," 2014. [Online]. Available: https://www.bls.gov/careeroutlook/2014/spring/art01.pdf.

[19] "Next Generation Science Standards," n.d.. [Online]. Available: https://www.nextgenscience.org/.

[20] Business Round Table, "The Skills Gap, Explained," 2018. [Online]. Available: https://www.businessroundtable.org/policy-perspectives/building-americas-tomorrow-ready-workforce/closing-the-skills-gap/the-skills-gap-explained.