High School to STEM - Dean's Early Research Initiative

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Dr. Filippas received her B.S. in Electrical Engineering from the University of Patras, Greece. After earning her M. S. and Ph. D. from the University of Texas at Austin, she completed post-doctoral research with the Institute of Accelerating Systems and Applications in Athens, Greece. Post-academically, she worked for Ansoft Corporation as a research scientist spearheading the development of the next generation code for Ansoft DesignerTM. Dr. Filippas joined Virginia Commonwealth University as an Assistant Professor in the School of Engineering in 2004. She went on to achieve the position of Associate Professor and Associate Chair of Electrical and Computer Engineering in 2008. In 2010, Dr. Filippas agreed to serve as interim associate dean of undergraduate studies in the School of Engineering. Dr. Filippas was appointed to the position of associate dean of Undergraduate Studies in 2015, and was promoted to Professor in August, 2016. In this role, she is responsible for all aspects of the undergraduate program. She provides vision and leadership in achieving the School's objectives for substantial growth in the size and quality of its undergraduate enrollment while maintaining its commitment to excellence in undergraduate engineering education. Focus areas include contemporary teaching and learning technologies, capstone, VIP, special degree programs with partnering academic institutions, and K-12 outreach. Dr. Filippas is especially proud of her collaboration with NSBE at VCU, an organization that embodies excellence in academics as well as community service, leadership and diversity. In addition, Dr. Filippas was instrumental in establishing oSTEM on the campus as well as reaching out to other underrepresented minority groups to further the university's commitment to student success and inclusive excellence.

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Dean's Early Research Initiative (DERI) – Pathways to STEM

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Abstract

Four years ago, Virginia Commonwealth University's School of Engineering initiated a collaborative program called the "Dean's Early Research Initiative" (DERI) [1] with area high schools that introduced students to the exciting world of research and development. These students were placed with engineering research teams within four engineering and one computer science discipline. The students participating are culturally diverse and include a high percentage of female students. We are at the onset of the fourth cycle of this initiative and the program continues to grow in popularity. In this paper, we present the challenges and the benefits inherent in running a program like this as well as quantitative and qualitative results on the fellow and mentor experience. This will be done in the form of survey results, tracking of retention and perseverance in the program and goals for the future.

Keywords

Research, Outreach, High School, STEM, diversity.

Introduction and program description

In 2013, we initiated a research internship for area high school students. In collaboration with a local Governor's School, we developed the Dean's Early Research Initiative (DERI), which is aimed at area high school students and also fulfills the requirements of the Governor's School internship experience. This initiative provides opportunities to enhance high school and undergraduate students' exposure to engineering research, but also provides undergraduate and graduate students and postdoctoral fellows with training in mentoring [2] [3] [4]. In addition to the benefit to the students [5] [6] [7], this outreach activity is being explored as an opportunity to raise awareness of our school [8] [9].

DERI fellows are required to work a total of 60 hours during the summer, and continue their fellowship during the school year, when they are expected to work four hours a week. DERI fellows receive up to $200 to participate in a local scientific event and may also apply for a travel allowance based on financial need. Research mentors involve the high school student in their ongoing research. Each mentor receives a $500 travel grant to attend a scientific conference approved by their faculty advisor.

Program organization

Mentors propose the projects, which are developed with a view to be challenging but appropriate for a high-achieving high school senior, and that could lead to publishable results. Preferably, mentors are graduate students or post-doctoral fellows, but we also accept proposals from junior faculty. **Table 1** provides a summary of the timeline of key activities and the selection process.

High school students apply for the program through an on-line system called Qualtrics. Requirements for the application include student information, school information, GPA and SAT scores (if available), parent information, an essay outlining what their career goals are and why they want to be involved in research, an unofficial copy of their transcript, and the names and e-mail addresses of two references. Qualtrics allows us to set things up so that the students can upload the essay and a copy of their transcript, as well as send an automated message to their two references. When the references respond to the link, it is connected to the students, so that it is straightforward to organize the information for the selection process.

The selection of the students is conducted in a double-blind method. The student and school names are first redacted from the documents. An initial committee makes an assessment of the student's interest by reading their essay, and will assign them for possible selection to all relevant mentors. Each mentor then receives a packet with student information, and makes their selection of their top three candidates. The committee then places the selected student-fellows with the corresponding mentor, trying as best they can to first place all the top candidates.

Once this is accomplished, students are informed through e-mail of the status of their application, but for those selected for the program, not of the specifics of the project they will be working on, or who they will be working with.

The final reveal is performed at our May poster session and graduation ceremony for our departing fellows who completed the program. The new fellows are invited to the poster session, and have the opportunity to talk to their peers who have just completed the program. The poster session culminates with the graduation ceremony for the prior fellows and an initiation ceremony for the new fellows. It is at this ceremony that the fellow is paired up with their graduate student mentor and the faculty advisor. The expectation is that the mentors and advisors will take the time to get to know the new fellows, talk about the project, and introduce them to their lab.

Fellows start working in mid- to end-July, after school lets out. Before they are able to start work, however, the graduate mentors and faculty advisors all have to go through the university's "Safety and Protection of Minors" training. It is our requirement, given the stated restrictions of working with minors, that at least two students in any lab that is working with minors take the relevant training and are subjected to the required background checks. This is also a requirement for the faculty advisor.

The student fellows, on the other hand, are required to register with HR so that they can become affiliates of the university. This gives them a university ID card, access to the library and free transportation (necessary if they are moving between labs). In addition, they are required to take all necessary safety training before initiating their research.

Table 1*: Timeline for DERI mentor and student fellow selection.*

Date	Activity
15-Nov	Deadline to propose project (this is through a "Common App" which covers both pre-college and undergraduate research activities)
	DERI information sent to school science teachers, math teachers and counselors
15-Jan	DERI application process opens for student fellows
	Monitor student progress; reach out to students whose application is marked "complete" if there is something missing from their application
15-Feb	Deadline for student fellows to complete application
	Send reminders to references
28-Feb	Deadline for teachers to complete and submit their reference letters
	Redact names and organize applications
15-Mar	Begin vetting process
20-Mar	Committee has slotted students according to area of interest
10-Apr	Graduate mentors have reviewed their assigned applications and chosen their top three candidates
20-Apr	Final student fellow selection made and notifications sent out with invitations to the mid-May ceremony
15-May	Graduation/initiation ceremony

Program aims

For the student fellows, the program's goal is to engage high-achieving students in research to stimulate or confirm their interest in engineering.

For the graduate mentors, the program's goals are to:

1. Engage them in innovative ways in student mentoring and development.
2. Train them to manage and mentor others in research.
3. Stimulate their interest in following an academic career.

Program assessment

Early exposure of students to scientific or engineering experiences contributes to students' embracing a scientific or engineering discipline as a career path [7]. The metrics that are currently being tracked to measure the impact and success of the initiative evaluate: (1) The student experience, (2) the mentor experience, and (3) its efficacy in generating interest in STEM of the student fellow.

The student and mentor experience were gauged qualitatively through surveys that for the students tracked the program's efficacy in improving their self-confidence in terms of independent research and their continued interest and persistence in STEM [2] [5] [6]. The mentors were asked questions that gauged their continued interest and willingness to engage again in the program (sustainability) [3] [10] [11]. The success of the program was further gauged by student persistence in the program as well as in pursuing studies in STEM. The success of the program in recruiting was gauged through tracking how many students applied to and/or accepted a position in our school or at the university.

Results

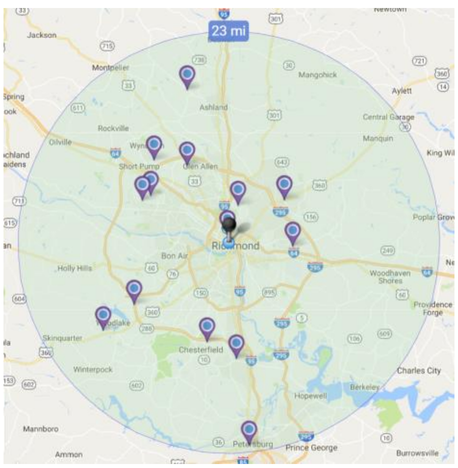


__Figure 1__: A map showing the 2016-17 participant school placement relative to our institution.

Program growth: Over the span of three years, the program grew from ten applicants from one school (all applicants were accepted) in 2014 to 44 applicants from 10 schools in 2016. Of those, 19 were admitted, 21 were not admitted and four were incomplete. A map showing the 2016 impact radius of the program can be seen in Figure 1. Finding applicants for the program is not a challenge, but care must be taken to not allow it to grow beyond our ability to administer it effectively. In the current cohort, there are 56 complete applications from a total of 26 schools. We currently plan to admit 20 students, in order to ensure we have adequate resources to make this a constructive experience for all concerned. We will grow this program consistently with our strategic growth initiatives for the school; current plans include significant growth in both the number of faculty and the number of graduate students.

Program value to student participants: *This program is attractive to male and female students, as demonstrated in*

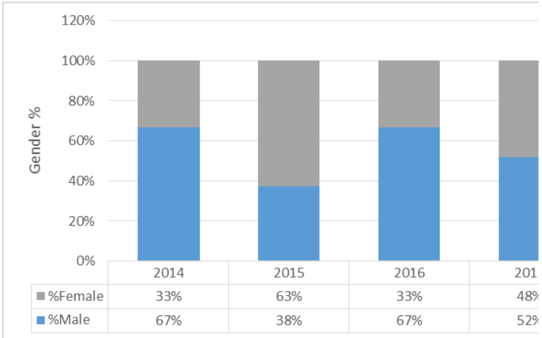


Figure 2*: Graph showing %Male and % Female in each cohort, including the current applicants.*

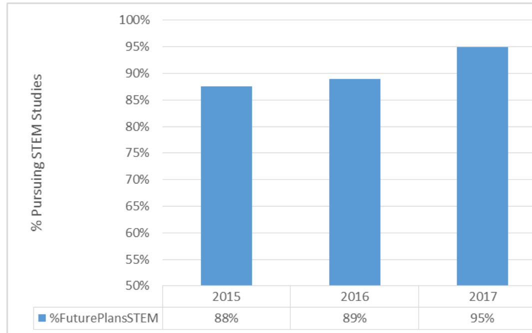


Figure 3*: % students who chose to pursue STEM disciplines in college.*

, which compares participation in the program according to gender. In addition, **Figure 3** shows the percent of students that chose to pursue studies in STEM. In all years, fellow completion of the program is in the 90%, which is high considering the time commitment involved. Most telling, however, is the feedback from the student-fellows outlining their perception of their experience as this relates to their working relationship with their mentor and their own perception of their gain in confidence and their productivity on the project by the end of the summer shown in **Figure 4**(a). All the results show a strong preference for “highly positive” in all areas. In addition, **Figure 4**(b) shows the student-fellow level of confidence in their ability to perform research at the onset of the program and after the summer term; student-fellows continue to engage with their mentors for four hours per week throughout the entire year. The graphs show the increase in confidence levels of these students, showing that this experience is effective in engaging them in a way that builds their confidence and thus their self-efficacy.

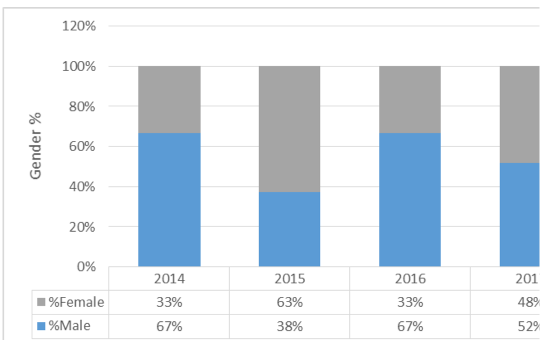
As a corollary to this data, we present **Program value to mentors:** Mentors were equally satisfied with the program; in 2016, 83% (10) were happy with the performance of their DERI fellow and 67% (8) would participate in the program again. The two mentors who were “sort of” or “not” happy had not set up a work schedule or clear expectations for their DERI fellows. For this age group especially, this is a necessity. On the mentor side, the number of projects proposed has increased from ten to 20.

The survey run for the mentors initially focused on their satisfaction with the program and their willingness to participate again. In the last survey, we added separate questions for the graduate students and the faculty.

Figure 5 shows some of the results of the survey. As can be seen in Figure 5(a), over 30% of the survey participants have participated in DERI before, while Figure 5(b) shows the composition of survey participants. Of these, the six graduate students responded to the question of their confidence in their ability to mentor students at the beginning and towards the end of the experience. Figure 6 (a) shows the confidence the graduate student had in themselves to mentor others in research, while Figure 6 (b) demonstrates the students’ evaluation of the program in terms of helping them develop their confidence in mentoring.

Table 2 which summarizes some of the statements made by the students themselves, showing how they reacted to the experiences they were provided in the laboratory setting. It is clear from their responses that the students gained a substantive experience that they would not have had the opportunity to have in the classroom. In addition, these students were able to function in an advanced setting.

One very important result is the increase in student confidence in their own abilities to do research, as demonstrated in Figure 4(a). This increase in confidence occurred within the first 60 hours of their involvement in this program. All students persisted this year and are on track to complete the program. One student presented his work at a national conference, and five students have submitted proposals to present their work at a local conference aimed at high school students engaged in research.



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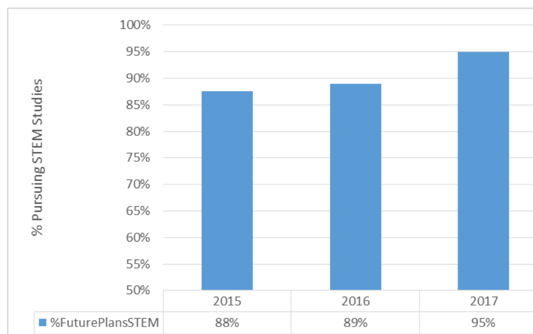

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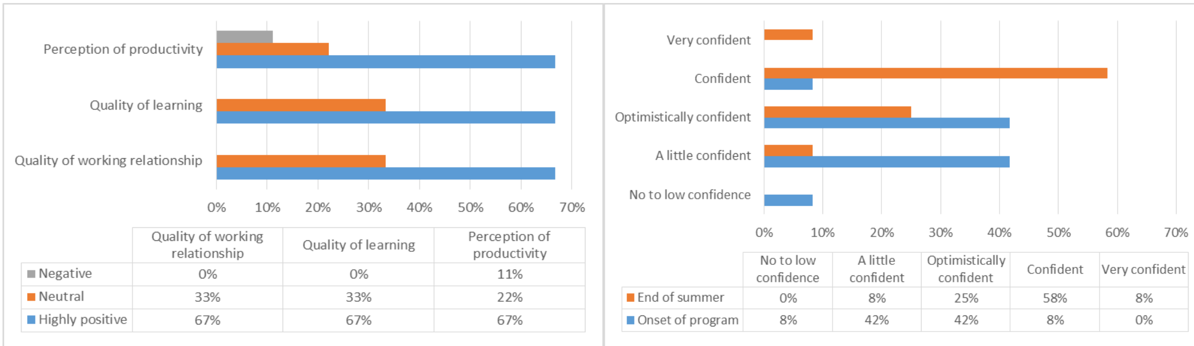
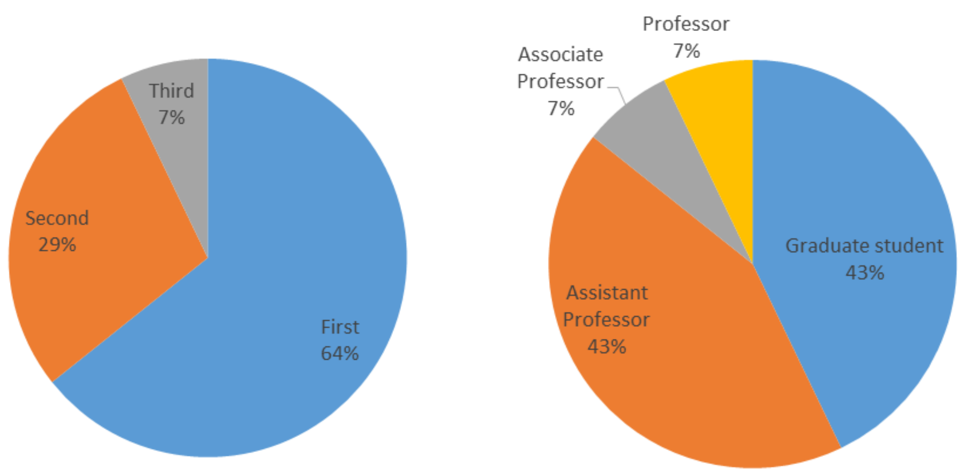
***Table 2**: Survey written responses.*

Challenges	Difficult to understand all the information Learning … how to work with Django program Knowledge [sic] between fellows and mentors Travel distance
Rewards	Being a co-author on a paper Creating a user-interface; successfully displaying data Learning details of coding Support from mentor Opportunity to work in a real lab
Relationship	Listened to each other Close working relationship Observed mentor, able to work alone while mentor worked on other projects Kept in touch via e-mail and text
What did you learn? (after 60 hours)	Important to set benchmarks for long-term projects. Many web development languages and techniques. Specifics in Electrical Engineering and about the research process. Data recovery methods. How research is done.
What did you learn (3/4 of the way through)	Laboratory techniques, osteocyte function. How to program in MATLAB, read and understand advanced mathematical constructs and papers. Proper surgical techniques, micro ct imaging, histological analysis, how to critically read and write scientific papers, working as part of a team to tackle challenges and difficulties that arise. Lab techniques, animal surgery procedure, how to behave in an actual scientific lab.... lots of stuff. How to formulate reliable experiments, do good research, and keep to the timeline. Skills in research and information about nano-particle technology. A lot about chemical engineering and research life. A great deal of information about the field of Computer Science and Computer Engineering as well as the process of doing research at the graduate level.



(a) (b)

***Figure 4**: From the 2016 cohort: (a) Student perception of: (1) the quality of their working relationship with their mentor, (2) the quality of learning, and (3) their perception of their own productivity at the end of the summer. (b) student-fellow level of confidence in their ability to engage in research at the program onset and after 60 hours working with their mentor.*



(a) (b)

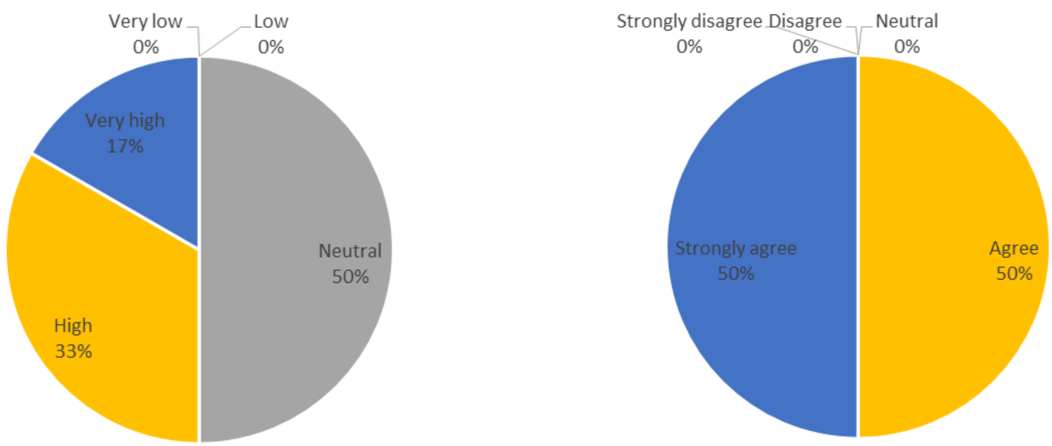
***Figure 5**: Faculty and graduate student participation in DERI.*

On the faculty side, Figure 7 (a) demonstrates that most faculty participants agree that this program provides a good mechanism for them to participate in outreach and Figure 7 (b) that most of them also agree that is provides a good mechanism for training graduate students to mentor others. Figure 7 (c) shows a similar percentage agreeing that this experience is a substantive research experience for the high school fellows. In terms of what they learned, the mentor feedback is similar to the fellow feedback and is summarized in

Table 3.

Table 3*: Cohort of 2016: Faculty feedback on what the fellows learned.*

How to conduct experiments on materials synthesis
The basic structure and pace of academic research.
How the academic lab works, how to read research papers, a few laboratory skills
The students have broad exposure to instruments and techniques.
Unfortunately, the time dedicated for research is very limited and the students cannot be exposed to many of the normal experiments but just portions of them.
Activities in lab and molecular biology knowledge and technics
fiber spinning, polymer processing



(a) (b)

Figure 6*: Graduate student feedback: (a) Confidence level of graduate students in their ability to mentor before their participation in the program. (b) Graduate students' assessment of the program's efficacy in helping them develop their confidence in mentoring.*

In summary, both the faculty and graduate student mentors had positive feedback, both in terms of their experience as well as in terms of the fellow's experience. Of note is that all the graduate students felt that the program helped them develop as mentors while there were faculty that disagreed that the program provided value in this area. It is important to note that faculty and graduate student satisfaction is the key factor that will allow us to sustain and grow the program.

Program Administration: In order to maintain and grow this program, it is imperative to examine all the resources necessary for its administration. The units at the school that are involved in some manner in the administration of our DERI program include our Office of Enrollment Management, our Marketing and Communications office, our Human Resources office, our Director of Diversity and Student Programs, our Associate Dean of Undergraduate Studies, our Graduate Office, and our Student Services Office.

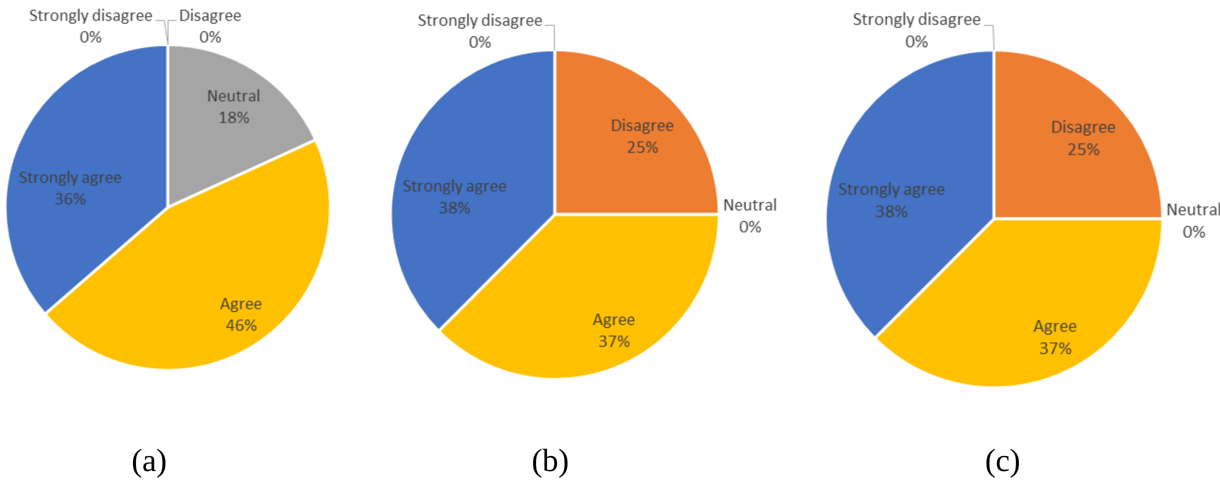


***Figure 7**: Faculty feedback: (a) Does this program provide a good mechanism for participating in outreach? (b) Does this program provide a good mechanism for training graduate students to mentor? (c) Does this program provide a substantive research experience for the high school student?*

Enrollment Management (5% FTE): In 2016, we found it beneficial to involve the office of enrollment management both in the outreach to the schools as well as in the gathering of the student data. All students who applied to DERI are now part of our outreach efforts and the recruiting office has provided invaluable insight on both the application process and in recruiting strategies for these students. The office of enrollment management runs the Qualtrics process and aids in the gathering of the student information.

Marketing and Communications (5% FTE): Is involved with developing professional brochures and informational e-mail messaging. In addition, they are involved with promoting any student stories that come out of this program. For example, one of our student fellows was accepted to deliver an oral presentation at the International Association of Dental Research in San Francisco (March 22-25).

***Table 4**: Statistics of DERI students who subsequently applied to the school of engineering.*

	GPA	SAT V	SATM	SATT	ACT
Average	4.41	681	691	1372	28
25%	4.27	623	638	1285	24
75%	4.59	748	775	1523	33

Human Resources (5% FTE): Handles all the on-boarding of the student-fellows, including the background checks of all employees who might need to be alone with the fellows, as well as confirming everyone has gone through the appropriate training. They also gather all the necessary information from the students and confirm they have gone through all the standardized training. Individual mentors are responsible for ensuring students have appropriate training for their labs.

Graduate students (120 hours per project): One graduate student per student-fellow. They will be engaged with their fellow for 60 hours over the summer and four hours a week during the academic year, for a total of at least 120 hours.

Faculty (60 hours per project): One faculty member can sponsor more than one fellow, but has to then serve as an advisor to each one of the graduate student mentors.

Administrative staff (20 hours per project): Data management, primarily during the application cycle.

Student Services (5% FTE): On the rare occasions when a student does not persist or there is an issue the mentor is uncomfortable handling, our designated advisor steps in to help. For example, this year, one of our mentors had to go on maternity leave and did not have someone to handle her fellow in her absence. The advisor was able to talk to the fellow and devise a schedule that involved a break in their attendance that was to the benefit of both (the student is also an athlete, and the break coincided with his sport).

Conclusion

The main direct benefits of the program are to the HS student-fellows and to the mentors, most of whom are graduate students. Surveys gathered from students and mentors emphasize their satisfaction with the program and the student-fellows' ultimate goal to study STEM. In addition, through their year-long involvement, the fellows are able to engage in a substantive research experience and are given ample time to develop their confidence, their creativity and other 21st-century skills [2] [12] [13] [14]. In addition, through this program, graduate student mentors have the opportunity to engage in proposal submission and student mentoring. Since they are under the direct supervision of their research advisor, this gives them valuable training for a career in academia [4] [7] [11] [15] [16].

The main challenges of this program are administrative and financial. The main administrative challenges involve rules and training around working with minors. This was alleviated by the fact that the school has its own HR department, but still proved a significant hurdle. Concerns on safety and absenteeism were dealt with through rigorous training and by restricting the program to high school seniors. This also curtails absenteeism, as the students are not dependent on their parents to drive them to and from the school.

The program needs to grow in a sustainable way. Currently, besides the very real cost of engaging a high school student in research, there is the time spent by the graduate student in mentoring and leading the research effort, as well as the HR and other administrative resources necessary in on-boarding the student fellows. We also assign one of our professional advisors as a resource in case there are conflicts between a student fellow and their mentor. This process was established in 2016, to ensure that simple conflicts or difficulties do not lead to a student abandoning the program. Our advisors have thus far alleviated concerns in two cases and managed to help the mentor develop a working plan that would allow the student to continue their work on their research. Given all the benefits outlined in this paper, the school will continue to engage in this outreach activity that has proven to be of such great benefit to the student fellows and to their graduate and faculty mentors and will grow the program in relationship to the growth of the school.

References

[1] A. V. Filippas and L. M. Parker, "Dean's Early Research Initiative - Pathways to STEM," in *ASEE Zone 2 Conference,* San Juan, Puerto Rico, 2017.

[2] D. Lopatto, "Undergraduate research as a high-impact student experience," *Peer Review,* vol. 12, pp. 27-30, 2010.

[3] L. Hoffman, K. D. Taylor and R. A. Aubrey, "Mentoring For Success," in *ASEE Conference*, Seattle, Washington. https://peer.asee.org/7280, 1998, June.

[4] E. C. Voyles, R. K. Kowalchuk, J. W. Nicklow and R. Ricks, "Residential Peer Mentoring Benefits Mentees: What about Mentors?," in *ASEE Annual Conference & Exposition*, Vancouver, BC. https://peer.asee.org/18705, 2011, June.

[5] M. T. Jones, A. E. L. Barlow and M. Villarejo, "Importance of undergraduate research for minority persistence," *Journal of Higher Education*, vol. 81, pp. 82-115, 2010.

[6] G. Regev, D. C. Gause and A. Wegman, "Experiential learning approach for requirements engineering education," Springer-Verlag, London, 2008.

[7] G. D. Kuh, "High-Impact Educational Practices: What they are, who has access to them, and why they matter," *American Association of Colleges and Universities*, 2008.

[8] D. Schwartz, C. Norton and S. Schwartz, "Outreach With Game Design Education," in *ASEE Annual Conference & Exposition*, Honolulu, Hawaii., 2007, June.

[9] C. Vallas, W. Williams PhD and P. (. Guan, "Adventures For Future Engineers: K 12 Outreach Strategies," in *ASEE Conference*, Louisville, Kentucky; https://peer.asee.org/16981, 2010, June.

[10] T. Karacolak, E. Moreland and E. Topsakal, "Summer Research Opportunities (STARS)," *Microwave and Optical Technology Papers,* vol. 55, no. 5, pp. 1160-1164, 2013.

[11] R. M. Reis, Preparing for Careers in Science and Engineering, Hoboken: Wiley, 2012.

[12] "Education Reform," 25 8 2016. [Online]. Available: http://edglossary.org/21st-century-skills/. [Accessed 26 12 2017].

[13] T. Wagner, "Rigor Redefined," *Educational Leadership,* vol. 2, no. 66, pp. 20-24, October 2008.

[14] S. Laursen, A. Hunter, E. Seymour, H. Thiry and G. Melton, "Undergraduate research in the sciences:," in *Jossey-Bass*, San Francisco, 2010.

[15] H. F. Summers MF, "Preparing minority scientists and engineers," *Science*, vol. 311, pp. 1870-1871, 2006.

[16] F. Lewitter, "Moving education forward," *PLoS Computational Biology*, vol. 3, pp. 1-2, 2007.

[17] D. Lopatto, "Science in solution: The impact of undergraduate research on student learning," in *Research Corporation for Science Advancement*, Tucson, AZ, 2010.