Board 86: Grad Student STEM Share: From Pilot Program to Beyond STEM

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Grad Student STEM Share: From Pilot Program to Beyond STEM

Abstract

Our country has been struggling to improve teaching in K-12 classrooms and disparities in our school systems for the past three decades. There are growing challenges in K-16 Science, Technology, Engineering and Mathematics (STEM) education including the lack of student interest and role models, particularly for underrepresented minorities, and the shortage of highly qualified teachers. The goal of Grad Student STEM Share is to connect graduate students in STEM with diverse K-12 students and provide these students with role models while exciting them about new developments in science and engineering. While not all graduate students go into teaching careers, it is important that they learn how to communicate effectively and have meaningful experiences with diverse students. Grad Student STEM Share allows graduate students to have introductory classroom experiences in a guided manner.

Graduate students need to be confident that they can help improve STEM education by volunteering in schools and mentoring students, even if they do not pursue academic careers. In addition, effective communication to a general audience is a critical skill of engineers and scientists in any career path. While researchers have great specialized content knowledge, they do not all have experiences that allow them to appreciate or participate in the issues of urban education. The Grad Student STEM Share program allowed graduate students and postdoctoral fellows to introduce their research, as well as the concept of graduate studies, into secondary classrooms in the Houston area. Graduate student and postdoc participants from a variety of disciplines, mainly STEM, worked in pairs to create presentations of their current research and educational backgrounds. They also designed demonstrations, experiments or hands-on activities to make their research more approachable to the middle school or high school students. These presentations were practiced for the group during weekly seminars. After receiving feedback from peers and educators, the pairs updated their presentations and took them to classrooms to share with students. Grad Student STEM Share program provided several leadership development opportunities of specific and translatable skills including communication, teaching, coordination of meetings and events, follow-up, teamwork, planning, presentation skills, and networking, as well as optional leadership coaching. Detailed feedback from the graduate students and the teachers whose classrooms they visited was positive and will be presented in this paper, as well as details on the pilot year, full implementation, program administration, and future plans.

Introduction

For the past few decades, there have been numerous calls to improve education in the United States from cradle to career. Of particular importance is the demand for better STEM (science, technology, engineering and mathematics) educational programs at all levels. While numerous programs have been implemented across the country to address STEM education, there is still much more to be done in order to meet the STEM workforce growth, to close the

performance gap for underrepresented minorities, and the rectify the lack of quality STEM teachers [1]. The growth of science and engineering employment opportunities is predicted to outpace the growth of jobs in general [2], thus students need to excel and enjoy STEM subjects. However for the last decade, American students have consistently performed near the average on international science assessments and below average on the corresponding math exams [3]. Many blame teachers for the general lackluster student performance, yet many teachers are underqualified to be teaching STEM subjects. There is a dire shortage of quality STEM educators across the country, but especially in public school districts that primarily serve underrepresented minority students [4]. Thus, those teachers that are in the frontline of our classrooms need more support as we also seek more ways to encourage the development of future STEM teachers.

One area of positive growth in STEM education has been an increase in the graduate school enrollments in science and engineering fields [1]. However graduate school attrition rates tend to be dismal across all disciplines [5], possibly due to the isolation felt by graduate students that are tied exclusively to their research projects. Programs aimed to improve graduate school completion include national "Transformative Graduate Education Programs" (TGP); however 48% of universities do not participate in such opportunities [6]. Smaller programs that are not necessarily multi-institutional are vital to graduate students as they can provide support and professional development, especially in the area of teaching [7]. Most graduate students do not receive training in teaching, however teaching experiences do tend to produce more productive researchers [8]. Thus, engaging graduate students in activities that develop them as teachers and provide them as opportunities beyond their research could increase retention in doctoral programs, as well as improve their research abilities.

Melding these two needs of improving K-12 STEM education with increasing diverse opportunities for graduate students to engage beyond their research projects could be synergistic. This paper describes a program to take the scientific expertise of researchers, both graduate students and postdoctoral fellows, to underserved secondary classrooms by pairing researchers with teachers. The researchers share their research at the students' levels by visiting the classrooms. Ideally such program can engage the researchers to broaden their perspectives and enhance their futures as well as to teach, inspire, and motivate young students to pursue and succeed in school, STEM fields in particular.

Program Design

Grad Student STEM Share was a cohort of graduate students and postdoctoral fellows that had a passion for reaching out to local students coordinated by the Rice Office of STEM Engagement (R-STEM). The cohort was recruited via emails through the campus graduate student association and postdoctoral listserve. An informational meeting was held to encourage participation and answer questions about the proposed program. The researchers formed pairs based on a shared interest or friendship and then were partnered with a local secondary school teacher. The pairs designed a presentation to share about their educational backgrounds and experiences, as well as each of their research projects. Researchers created their presentations via PowerPoint and were asked to include information about themselves such as where they grew up, their college alma mater, and why they chose to go to graduate school. Because Rice

University is situated in urban Houston with almost exclusively high-needs public schools, researchers were encouraged to explain their motivation for studying STEM and define graduate school in its many forms.

At lunch meetings on Rice's campus, each pair presented to the group to receive constructive feedback. Not only did the researchers give each other oral and written feedback, but former teachers (Rice Office of STEM Engagement staff that teach teachers) helped guide the presenters to the appropriate level for sharing technical information. Presenters were encouraged to plan specific questions to ask the students within their talks, include demonstrations to explain scientific phenomena, and, if possible, facilitate hands-on activities to engage the students with the content of their research.

The researcher pairs arranged with their local teacher for a date and time of their classroom visit. Some pairs agreed to spend up to two days at their teacher's school to reach all of the students taught on a block (every other day) schedule, whereas some only visited for a single class period or talked to a large audience (for example, all the 9th graders at a high school) at once. The coordination of when, how long, and how many students was usually done via email and was very individualized to the needs of the school and availability of the researchers.

Two distinct feedback surveys were requested to be completed online by the researchers and the teachers, but no data was collected directly from the secondary students.

Pilot Program

Participants

The pilot iteration of Grad Student STEM Share was funded by an internal grant opportunity for graduate students and postdocs to create programming that they wanted and deemed beneficial. The participants included 19 graduate students and three postdocs from the Colleges of Natural Sciences or Engineering. However only 18 total researchers fully participated by attending lunch meetings, giving a practice presentation, and visiting classrooms. From these participants, there were nine self-selected pairs. The program coordinator matched them with secondary science teachers by interest. The teachers were selected from current or past participants in teacher professional development programs provided by the Rice Office of STEM Engagement. A total of ten secondary science teachers had visits from Grad Student STEM Share, impacting hundreds of area middle and high school students.

Participant Feedback

All 18 researchers that completed the program responded to the online feedback survey. Almost all, 16 out of 18, responded, "Yes, definitely!" to the question, "Would you be interested in participating in Grad Student STEM Share again?" with the other two responding, "Maybe." The participants' ratings of numerous components of the program are shown in Fig. 1. The overall impression of the program was very positive, with the only "Below Average" responses relating to communication with the teachers. Interestingly, the researchers rated the quality of each other's presentations as "Good" more often than "Excellent," which was also the case regarding feedback on practice presentations. This might indicate that graduate students expected more from their peers both in how they presented and in how they provided comments on others' presentations. Also, non-academic level presentations are not a common experience during

graduate school, so this was often the first time most of the researchers had to condense their projects into terms understandable by secondary students.

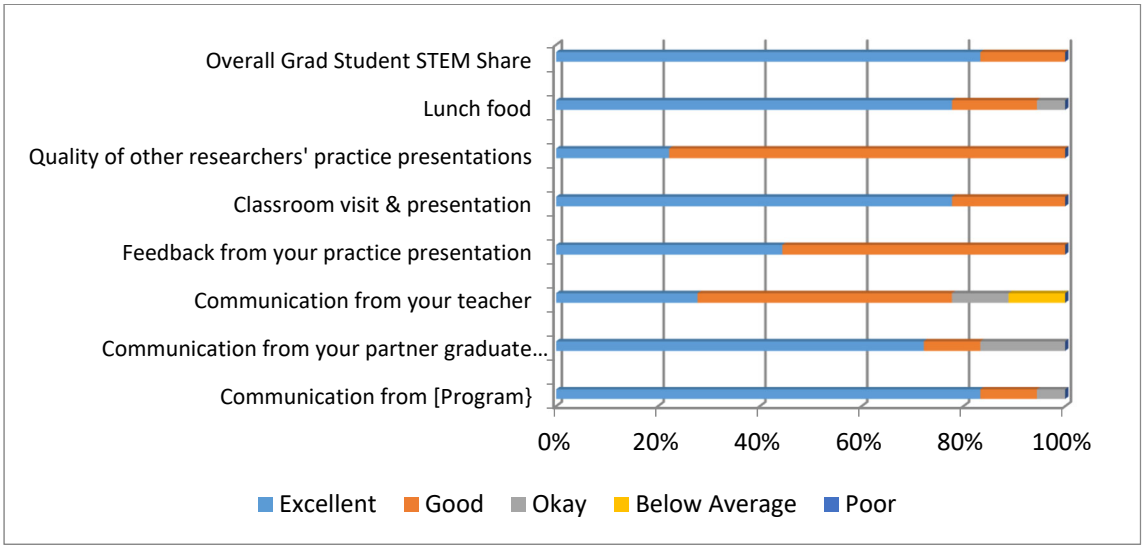

Figure 1. Participants' ratings of components of the pilot program, N=18.

The grad students were asked three open-ended questions about the program. Responses to "How did Grad Student STEM Share impact you?" were almost exclusively related to the opportunity to participate in outreach, being able to refine presentation skills, and networking with other grad students across disciplines, listed in order of prevalence of response. Similar responses were given to the question asking, "What was the most valuable thing about Grad Student STEM Share?" Example responses to both questions, respectively, are shown below.

- *It was a great experience to see what other graduate students study. Interacting with [school district] teachers was an eye-opening experience. I do think that this program is a great way to introduce students to graduate school and get them excited about science.*
- *It's a platform for grad students to expose the younger generation to opportunities they may not be aware of. This is absolutely necessary.*

One response to the "most valuable" question that did not fit easily into the outreach, presentation skills, or networking categories was very moving. The researcher wrote, "*Presenting research in appealing and accessible manner to middle/high school students puts one's work into a different perspective."* Participants were also probed on what changes could be made to improve the program. The most common theme was to improve the communication and commitment from teachers. Secondly, researchers commented on the time involved in the program with two suggesting the program should involve multiple school visits and one saying the program was too "*time-intensive*" already. Another student suggested have funding for demonstration or activity supplies. The feedback from researcher participants was very positive and reflected a high level of commitment and interest in continuing the program.

Teacher Feedback

All ten of the participating teachers responded, "Yes, definitely!" to the question, "Would you be interested in participating in Grad Student STEM Share again?" The teachers also unanimously selected "Excellent" to describe the following components of the program.

- Overall value of Grad Student STEM Share
- Quality of presentations for students' interest in graduate school
- Quality of presentation for students' interest in science
- Ability of researchers to fully answer student questions
- Engagement of researcher with students during presentation
- Communication from Rice Office of STEM Engagement

There was close agreement for the following two components with nine out of ten selecting "Excellent" and one teacher indicating "Good."

- Promptness and first impression of researchers for presentation date
- Communication from your pair or researchers

The teachers also had an opportunity to provide open-ended feedback to three questions, similar to those asked of the participants. When asked what was most valuable about Grad Student STEM Share, 60% of teacher responses included some mention of the researchers sharing about their educational backgrounds and the importance of school. For example, one teacher wrote, *"[They shared] how education revolutionizes our abilities and future*." Two teachers also specifically mentioned that the classroom visits expanded students' understanding of science by noting, "*Knowing there is science everywhere! Even outside the laboratory,*" and, "*They showed my students how scientific concepts are applied in the world outside the classroom.*" The teachers replied with similar responses to the question, "How did Grad Student STEM Share impact your students?" One teacher noted, "*Not only did they inform the students about their research, but they also motivated the students to become interested in the science field*." The other main impact mentioned was about graduate studies being an attainable option for students. When asked about changes that could be made to improve the program, the majority of teachers suggested more time via more visits to the classrooms by the researchers. Individual teachers also noted that the presentations should involve more student engagement, researchers should bring samples, or they would like to be able to select which researchers to come by specific topic. Overall, the feedback from the teachers was tremendously positive, especially for a pilot program.

Lessons Learned

The pilot allowed for a full implementation of the program with a lot of lessons learned. Communicating with the teachers ahead of time to get commitment to the program was challenging. Numerous teachers were interested initially, but then they would not respond to emails or chose not to participate when faced with the myriad of restraints at the end of the school year with testing and school demands. In the future, classroom visits will be initiated in the fall semester and completed before spring break to avoid issues with state and national testing days. Another issue was that not all researchers were able to fulfill their commitment to participate. When two graduate students dropped out in the last month of the program, their partners stepped up to form a new team and visit BOTH of their teachers' classes. This commitment level from these two participants was above and beyond the expectation and allowed for no classes that had committed to host researchers being left out. At first some researchers were unsure about the goals of the program or what to expect visiting classrooms. As the program progressed, the researchers that scheduled their visits first were able to share their experiences with the others during lunch practice sessions. Ideally, for each new school year, past participants would share their experiences and presentations at the beginning and make it easier for new participants.

Beyond STEM Implementation

After the success of the pilot program, more funding was requested from the Doerr Institute for New Leaders to continue the program and to add a leadership component. The new funding allowed for expansion to up to 30 grad students/postdocs, as well as to go beyond the bounds of STEM to any discipline at the university. Money was also allotted for supplies for the researchers to share demonstrations or complementary lab activities with the students, as well as provide the teachers with needed classroom supplies. Participants were also offered individual leadership coaching sessions from the university institute experts, as well as an honorarium for their participation. The basic structure of the program with pairs of researchers visiting local secondary schools and practicing their presentation during lunch meetings remained the same.

Leadership Component

Grad Student STEM Share (re-branded as Grad Student Show & Tell to incorporate the non-STEM participants) provided graduate student and postdoc participants with inherent opportunities to develop multiple skills essential to leadership. First, they could practice and improve their communication skills both in terms of negotiating a time and strategy with the teacher and by presenting their research to a general audience in a simplified way. Communication is a skill required by all researchers, no matter the discipline. Effective communication is also required for success in every post-graduation profession. Other skills that graduate students developed as related to leadership through this program included managing a budget (funds for demonstrations and classroom supplies), delegating tasks, critiquing peers, working as a team, networking with other graduate students and postdocs, and inspiring the next generation of researchers.

While this program facilitated natural leadership development, particularly in effective communication, individual coaching also offered a much more direct avenue for leadership skill enhancement. Participants in the program were offered one-on-one coaching sessions with certified leadership coaches. Leadership coaching not only to provided support for the grad students in relation to the program but also allowed for leadership growth in general. Graduate students are not often offered such professional development opportunities in the normal course of their studies and research-driven goals.

Participants

The full implementation of Grad Student STEM share had more participants than planned, with 34 graduate students and postdoctoral fellows participating. The distribution of disciplines represented in the group is shown in Fig. 2. While the cohort was still mainly STEM, there was a broad range of disciplines within Natural Sciences and Engineering. Music and Social Sciences made up a small fraction of the cohort, with two Masters students in music and one Ph.D. student in sociology. The music students were partnered together and visited an underserved school's orchestra class. Rather than discussing their research, they each did a "master class" in their particular instrument for the students. The sociology student's research aligned with that of a graduate student in chemistry, as both studied differing aspects related to disease and human health, and they visited a biology classroom.

The 34 Grad Student STEM Share participants visited the classrooms of 15 different teachers, with two pairs visiting the same teacher and two groups comprised of three researchers. A total of 1219 students (according to the teacher survey) participated in these presentations. All of the teachers were in secondary schools in the largest school district in the Houston metropolitan area, Houston Independent School District, which is also the largest district in Texas and the 7th largest district in the country. Houston Independent School District has a student population of 62% Hispanic, 24% African America, 4% Asian, and 9% white students, with 75% of students considered economically disadvantaged [9].

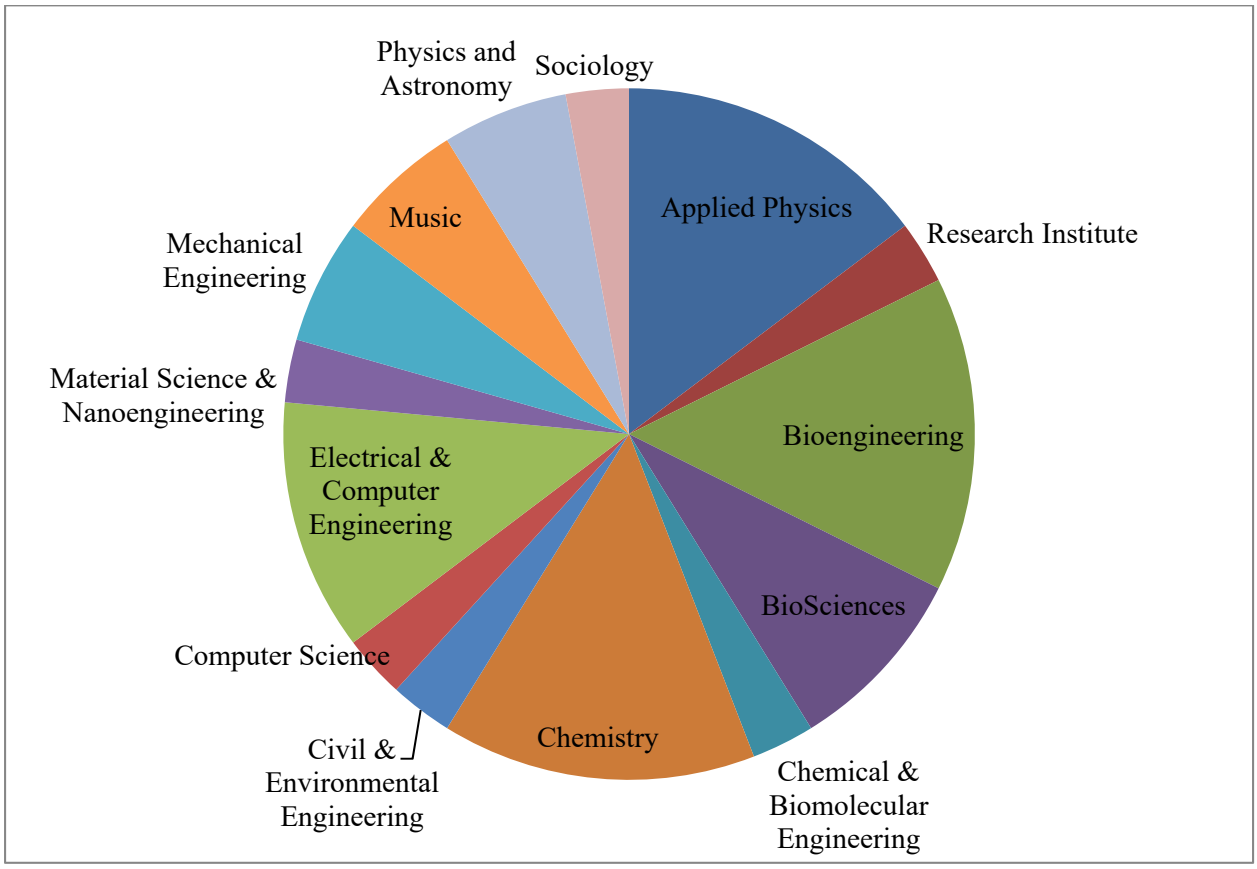

Figure 2. Distribution of graduate student and postdoc participants by department, N=34.

Outcomes

Online feedback surveys were administered to both the researchers and the teachers, again with a 100% response rate for both. Only 65% of participants responded "Yes" to their desire to participate in the program again, which was less than the pilot program responses. However, from getting to know the participants throughout the program, a good portion of the graduate students were going to graduate or focus solely on writing their dissertations soon. Thus, it was not surprising to the authors that fewer researchers would commit to the program again. The feedback was generally positive, as shown in Fig. 3, with the exception of "Feedback from your practice presentation" being rated as "Excellent" or "Good" by only half of the respondents. The ratings for "Communication from your teacher" improved, with almost all

saying “Excellent” or “Good” and only two responding, “Okay.” There was a similar response to the “Experience visiting the classroom,” with all positive responses except three responding with only “Okay.” One of the new portions of the program included a budget of $500 per teacher to be managed by the researcher groups in order to buy supplies for demonstrations or labs to accompany the visit, as well as classroom supplies needed by the teacher. The feedback regarding that ordering of supplies was all positive. The other new portion was the option of having individual leadership coaching sessions, which was also seen as valuable by the 30 researchers that took advantage of this opportunity. However, the leadership coaching seemed to have minimal impact on the program itself.

Graduate student and postdoctoral fellows provided open-ended feedback regarding the program with questions and responses similar to that of the pilot program. When asked how did the program “impact you?” the most insightful responses include the following.

- *It reignited my passion for my research, when I saw how enthusiastic the students were to engage with me about it.*
- *It helped me to realize how important it is to grow the next generation's interests in STEM-related fields.*
- *I enjoyed the experience of making a detailed and high level research understandable to high school students. This is an essential skill that scientists need to be able to make their science accessible to general public and I am happy I had the opportunity to practice it.*
- *It forced me to work on skills outside of research that I believe will be useful in the future - planning, time management, and coordinating with group members were the major ones.*

Multiple graduate students noted that Grad Student STEM Share allowed them a “first” opportunity, one saying, “*This was my first time actually being in the role of a teacher.*” Another researcher said the program was “*my first opportunity for science outreach and community involvement. It encouraged me to more actively participate in leadership roles in my community.*” Similar to the pilot program, researchers felt that participating in outreach with local students, having practice with presenting and communication, and networking with other graduate students were the most valuable parts of the program. New responses that were noted by at least two participants included leadership coaching, being forced to distill one’s research into an understandable format, and the opportunity to work with teachers.

Researchers were asked for ideas of what could be changed to improve the program. The only response that was reiterated more than twice (eight times!) was to have better communication with the teachers. Getting email responses from teachers was very challenging for some groups, which is a major issue when planning a visit to a classroom, needing to define an age range and time frame, as well as getting a list of desired supplies to order. The other feedback varied from requesting partners be assigned, requiring multiple visits, and minimizing the time commitment of the program. The feedback regarding the leadership coaching, for those 30 that participated, was generally very positive. However, the coaching did not seem to be aligned with the main program goals or outcomes for most participants, as one noted saying that leadership coaching, *“Relatively independent, but improved me in general, including [within the program].”*

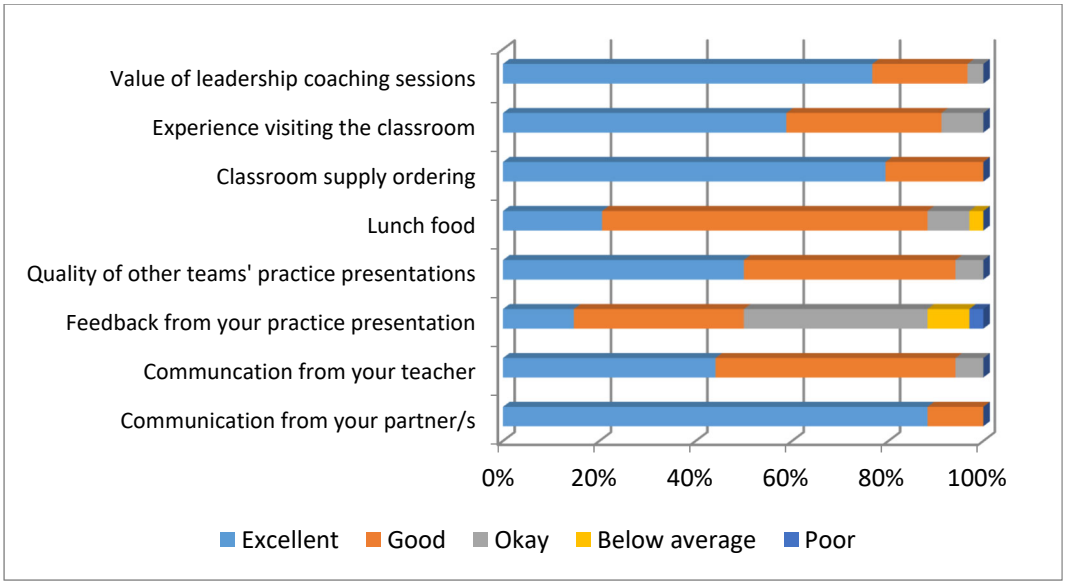

Figure 3. Participants' ratings of components of the program, N=34.

The 15 teachers were also asked about individual components of the program. The feedback was completely positive ("Excellent" or "Good" for all components) except from one of the teachers. This teacher explained the negative feedback saying, "*Students were bored with the lecture, but enjoyed the hands-on."* In spite of feedback from the practice presentation, this group of researchers gave an hour long PowerPoint presentation to a class of 24 7th grade students. While the students did not pay attention to the lecture, at least there was an active component and the teacher noted, "*Many of my students did not know there was something past a college degree."*

The feedback from the rest of the teachers was very positive about all of the aspects of the program. Teachers noted that impact on the students was greater interest graduate school and career opportunities and increased motivation in class. One teacher said, *"They were able to learn about doing research which something they don't hear about a lot."* When asked about the value of the program, teachers mentioned it was good for their students to meet actual graduate students as role models and to learn about the opportunities afforded by college. One teacher noted, *"The most valuable lesson was that there is not just one way to get to grad school. This resonated really well with my students a lot of whom now have more hope."* When asked about potential changes, the suggestions from the teachers included having the graduate students come more often or stay longer, as well as including more interactive activities with the presentations. Teachers were all positive about the lab and classroom supplies, though at the time of the survey not all had requested the specific supplies desired. Teachers that had gotten supplies already were using them for laboratory activities they could not have done otherwise. The teachers were interested in participating in the program again, as well as it expanding into more subject areas. A returning teacher from the pilot program noted, "*It was even better than before. Loved [the researchers'] interactions and lab."*

Example Presentations

The general format of the presentations was to start with the researchers posing a question to the students to start a dialogue. For example, one group started with "*What's your favorite topic in biology? What's your favorite dessert?"* They engaged with the students answers and then went on to answer the questions about themselves. They shared pictures to show where they grew up, where they went to high school and college, as well as for this team, their favorite topics in biology and favorite desserts. At some point in the conversation, the researchers shared their motivation for studying their selected disciplines, as well as for continuing to graduate school. Almost all groups took at least a few slides to guide a discussion with the students about "*What is graduate school*?" and discuss the multiple types and routes to graduate studies, as shown in Figure 4. They also talked about the career paths and job opportunities available with different degrees.

Figure 4. Example presentation slide on types of graduate studies.

Researchers also shared about their own research but at the level of the students. This portion of the presentation was key for the on campus practice lunches, as most graduate students rarely get a chance to share their work with a general audience. Distilling very specialized research to the level to share with a young student can be challenging. Graduate students usually only present to their own department in seminars or a professional society meetings of peers. All included pictures related to their research, often of the laboratory or interesting equipment, and many included videos. Researchers were also encouraged to explain what they did all day to convey a more realistic view of scientific research to students.

The researchers planned out student questions to include in their presentations. Some also did demonstrations or student activities. For example, one group demonstrated the Meissner effect by dramatically levitating a magnet upon super-cooling. Another group had students do a

hands-on activity of folding printed paper amino acid chains via interactions to show the secondary and tertiary structure of proteins. One group brought a water table and implemented an interactive lesson, as shown in Figure 5. The music students did an interactive master class for each of their instruments to demonstrate and discuss aspects of music theory. Both the presentations and the interactions with students varied by group, as each researcher at the graduate level has their own distinct area of work and expertise.

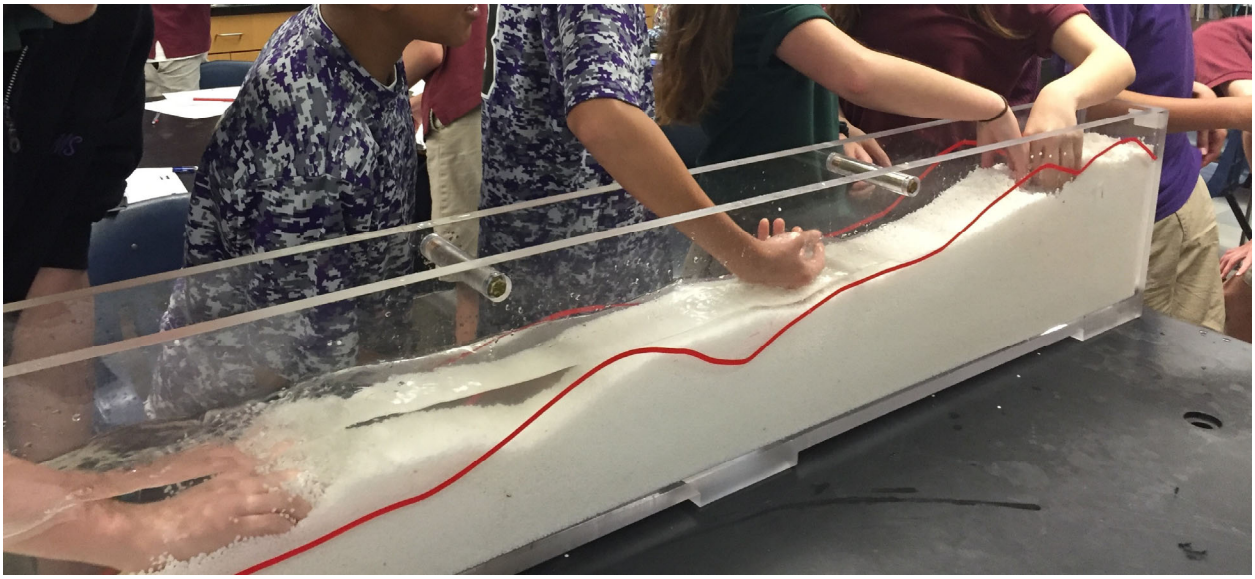

Figure 5. Students engage in a researcher designed lesson using a water table.

Discussion and Future Direction

Grad Student STEM Share was successfully implemented as a pilot program with 18 researchers and again beyond only STEM fields with 34 graduate students and postdoctoral fellows. While the pilot was in the spring semester, the full implementation began in the fall with some classroom visits extending into the spring. Having the main portion of the program in the fall was beneficial for both the researchers and for scheduling with the classroom teachers when there was no conflict with standardized testing. Having the ability to set visits in December and January when graduate students teaching responsibilities had concluded or not yet started also helped with scheduling.

The incorporation of the leadership component into the program was new. While most of the graduate students took advantage of the individual leadership coaching, it did not seem to directly impact the outcomes of the program. Those that did multiple coaching sessions found them to be very beneficial professionally and personally, but not related to Grad Student STEM Share. In the future, leadership coaching should be offered through another avenue and not coincide with this program.

The feedback from the teachers was almost exclusively positive. The teachers want more classroom visits and more time with graduate students. The teachers need the content experts and engagement in order to enhance their classes and inspire their students. However, the program is time intensive for already stressed and busy graduate students. Finding a balance is essential to

keeping this program positive for all involved participants. Graduate students need outlets beyond their individual research in order to develop into successful researchers, communicators, and leaders in their field. Whether or not a Ph.D. goes into industry, government, or academia, communication to the general public is an essential skill. Graduate students also need opportunities to expand their research silos and professional community across disciplines.

The future direction of Grad Student STEM Share is to integrate the program within a Research Experience for Teachers (RET) program at Rice University. In this model, graduate students or postdoctoral fellows that mentor teachers on campus in the research labs all summer would then be invited to be part of the program. These researchers that spend seven weeks in the summer mentoring classroom teachers would have built a professional relationship with the teachers. This relationship would help overcome the communication difficulties often encountered in researchers working with teachers previously unknown to each other. If mentors cannot commit to the program, other researchers in the same group who also got to know the RET teacher would be invited to participate. Again, the idea would be to have a relationship between the researcher and teacher established prior to the classroom visit to provide better communication and hopefully more teacher input regarding the content of the interactions.

Overall, Grad Student STEM Share is a program that has achieved the goals of impacting graduate students and secondary students (from responses provided by the secondary students' teachers). More detailed program evaluation should be included in the future including tracking of the impact on the graduate students via graduation rates and future employment. Ideas to assess the impact on the secondary students should also be explored, although it can be very difficult to measure the influence of one interaction on student outcomes. Though sometimes it is just one interaction that does change a student for life, as might be the case as shared by one researcher participant:

> *I truly enjoyed the experience of talking to high school students in person and discussing their concerns and passion about pursuing higher degrees in science and engineering. I think giving the high school students this opportunity to talk to and hear from someone who has experienced the path is extremely valuable. One of the most enjoyable moments I had at my high school visit was when a female student who was passionate about going to STEM field came to me after the presentation and told me that her classmates told her that "I am her in future!" We had conversation about her interests and I was so happy that I could inspire her.*

References

[1] B. Granovskiy, "Science, Technology, Engineering, and Mathematics (STEM) Education: An Overview Analyst in Education Policy," *CRS Report for Congress,* 2018. [Online]. Available: https://fas.org/sgp/crs/misc/R45223.pdf. [Accessed: Feb. 4, 2019].

[2]National Science Board, *Science and Engineering Indicators 2014*. Arlington VA: National Science Foundation (NSB 14-01), 2014.

[3] National Science Board, *Science and Engineering Indicators 2018*. Alexandria, VA: National Science Foundation (NSB-2018-1), 2018.

[4] M. Moritz, "The U.S. Doesn't Have Enough STEM Teachers to Prepare Students for Our High-Tech Economy. 4 Steps Toward Addressing That Shortage," The 74, 2018. [Online.] Available: https://www.the74million.org/article/opinion-the-u-s-doesnt-have-enough-stem-teachers-to-prepare-students-for-our-high-tech-economy-4-steps-toward-addressing-that-shortage/. [Accessed: Feb. 4, 2019].

[5] Council of Graduate Schools, *Ph.D. Completion and Attrition: Analysis of Baseline Demographic Data from the PhD Completion Project.* Ph.D. Completion Project, 2008.

[6] D. Kniola, M. Chang, D. Olsen, "Transformative graduate education programs: An analysis of impact on STEM and non-STEM Ph.D. completion," *Higher Education*, vol. 63, pp. 473-495, 2012.

[7] Council of Graduate Schools, *Ph.D. Completion and Attrition: Policies and Practices to Promote Student Success.* Ph.D. Completion Project, 2010.

[8] D. F. Feldon, J. Peugh, B. E. Timmerman, M. A. Maher, M. Hurst, D. Strickland, J. A. Gilmore, C. Stiegelmeyer, "Graduate Students' Teaching Experiences Improve Their Methodological Research Skills," *Science*, vol. 333, pp. 1037-1039, Aug. 2011.

[9] Houston Independent School District. General Information: HISD At A Glance. [Online.] Available: https://www.houstonisd.org/domain/7908. [Accessed: Feb. 4, 2019].