

Board 23: RET in Functional Materials and Manufacturing

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Dr. Scott Campbell has been on the faculty of the Department of Chemical & Biomedical Engineering at the University of South Florida since 1986. He currently serves as the department undergraduate advisor. Scott was a co-PI on an NSF STEP grant for the reform of the Engineering Calculus sequence at USF. This grant required him to build relationships with engineering faculty of other departments and also faculty from the College of Arts and Sciences. Over the course of this grant, he advised over 500 individual calculus students on their course projects. He was given an Outstanding Advising Award by USF and has been the recipient of numerous teaching awards at the department, college, university (Jerome Krivanek Distinguished Teaching Award) and state (TIP award) levels. Scott is also a co-PI of a Helios-funded Middle School Residency Program for Science and Math (for which he teaches the capstone course) and is on the leadership committee for an NSF IUSE grant to transform STEM Education at USF. His research is in the areas of solution thermodynamics and environmental monitoring and modeling.

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Dr. Sylvia Wilson Thomas is currently an Associate Professor in Electrical Engineering and former Assistant Dean for the College of Engineering at the University of South Florida in Tampa, Florida. She holds several patents and has over twenty-five years of experience in industry and academia.

Research Interests

Sylvia Wilson Thomas, Ph.D. leads the Advanced Membrane/Materials Bio and Integration Research (AMBIR) laboratory at USF. Dr. Thomas' research and teaching endeavors are focused on advanced membranes/materials for alternative energy sources, sustainable environments, electronics, and bio-applications from the micro to the nano scale. Her research investigates the fabrication of inorganic and organic thin films and nanofibers for device integration. Thomas' research group specializes in characterizing, modeling, and integrating membranes that demonstrate high levels of biocompatibility, thermal reflectivity, mechanical robustness, and environmental sustainability, such as carbides, sol-gel coatings, high temperature oxides, and several polymers. Her research is interdisciplinary in nature and fosters collaborations with Chemical and Biomedical, Mechanical, and Environmental Engineering, Physics, Chemistry, Public Health, Medicine, and the Nanotechnology Research and Education Center (NREC).

RET in Functional Materials and Manufacturing

We describe the development, implementation and assessment of a Research Experiences for Teachers (RET) site in Functional Materials and Manufacturing. Between 2014 to 2018, twenty-seven high school science and math teachers, pre-service STEM teachers, and community college faculty participated in an immersive summer experience under the guidance of engineering and science faculty members of the Functional Materials and Manufacturing Institute (FMMI) at the University of South Florida (USF). Products produced by participants included a research poster (presented at an annual REU/RET Symposium) and a lesson plan (Teach Engineering format) for academic year implementation in their classrooms.

The RET focus on functional materials was chosen for three reasons. First, Materials Science and Engineering is a highly interdisciplinary field that can be addressed in many different subjects covered in high school and community colleges. Second, having a common focus allowed the participants to bond more easily and interact in peer mentoring to advise each other, both in research and lesson plan development. Finally, research in functional materials is a particular strength of the host institution with substantial laboratory and educational resources and accomplished FMMI researchers working in close collaboration in shared, non-partitioned spaces.

Program activities were designed to be synergistic and helpful to participants in producing their posters and lesson plans. These included an authentic research project guided by faculty and their associated graduate students, a course in the fundamentals of materials science, weekly lesson plan seminars, group research meetings and brown bag lunches. A variety of follow-up activities (classroom visits by faculty, extended research involvement of participants, university visits by participants) have allowed for continued collaboration between participants and faculty mentors.

Program assessment results are reported including midterm and post-program surveys of participants and pre- and post-test performance in the *Fundamentals of Materials* course. We incorporate the assessments into a discussion of lessons learned and how they will drive future RET offerings at our institution.

Introduction

Research Experiences for Teachers (RET) programs funded by the National Science Foundation support the implementation of professional development for teachers with the goal that K-12 and community college STEM teachers will collaborate with university faculty on research projects and then translate the knowledge and excitement of their research into their classrooms [1]. In addition, RET programs are expected to foster the creation of long-term collaborations between teacher-participants and university faculty.

In this paper, we report on one such program hosted by the Functional Materials and Manufacturing Institute (FMMI) at the University of South Florida between 2014 and 2018. An earlier report [2] described the rationale, structure, and activities of the program and provided assessments for the first two years. Here, we will briefly review the program for readers

unfamiliar with our previous report, provide assessment results from all four years, and describe lessons learned and their implication for future offerings of an RET at our institution.

Each year of the program, ten or more STEM teachers participated in an immersive eight-week experience in which they performed authentic research in functional materials under the supervision of a faculty mentor. In addition, they developed a plan to translate the experience into classroom activities that would increase their students' interest in materials science and STEM. Academic year activities allowed continued collaboration between participants and their mentors and facilitated translation into the classroom.

Participants

We designed the program for high school science or math teachers and for community college faculty teaching in a STEM discipline. High school teachers were recruited from the school districts of Hillsborough and Pinellas Counties, which are 8th and 27th largest, nationally, in student enrollment. Community college faculty were recruited from Hillsborough Community College and Polk State College, which are important feeder institutions to the university. Pre-service participants were recruited from a degree program in the College of Education for prospective STEM teachers. Information about the RET program and instructions for applying to it were provided to superintendents of both school districts, presidents of both colleges, and to the dean of the College of Education at USF. After the first year, word of mouth, either by informal communication or at professional teaching days, drove many of the applicants to the recruiting website.

Between January and early March of each year, prospective participants applied to the program through our recruiting site [3], which requested demographic data, information about grade levels and subjects taught, a personal statement, a resume, and a letter of recommendation from an administrator familiar with the applicant's work. Descriptions of research projects for the coming summer were provided on the website and applicants were asked to select, in ranked order, their top four choices. Over the four summers (2014 – 2017), a total of ninety teachers applied to the program and forty-one were selected.

Participants were selected by the three senior project personnel based on quality of application, strength of the recommendation, and a desire to maximize diversity in gender, race and STEM subject areas. We also considered whether two applicants taught at the same school and whether an applicant was applying to participate for a second year, as these characteristics were valued both by us and by NSF. The choice of research project was *not* considered in the selection process, except in one case where a particular skill in computer programming was required. Despite this, almost all selected applicants received their first or second choice of project.

We note that while there were forty-one positions opened over four years, only twenty-seven individuals participated. This is because fourteen of these twenty-seven teachers participated in the program for a second year. The demographic information presented below is for the twenty-seven unique participants.

A break down of participants by their professional position is shown in Figure 1. Twenty-two were in-service high school STEM teachers, three were community college faculty and two were pre-service teachers. We did not recruit pre-service teachers after the second year of the program, for reasons that will be discussed later. The vast majority of in-service teachers came from Hillsborough County, probably because of the strong endorsement and involvement of the Director of STEM Education for Hillsborough County Schools.

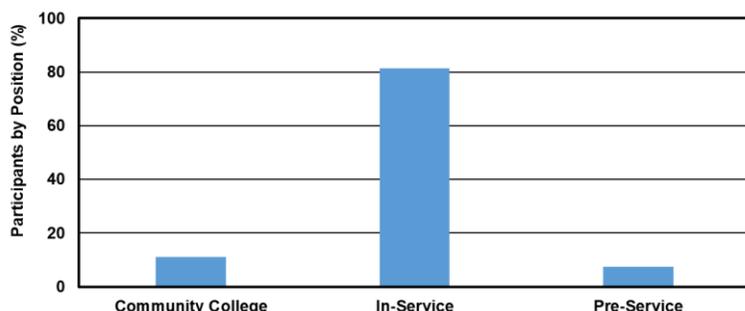


Figure 1. Number (expressed as a percent of the total) of community college faculty, in-service teachers, and pre-service students participating in the program.

The primary high school subject taught by participants is shown in Figure 2. Biology teachers comprised the largest fraction of participants and it was fortunate that many of the projects had a biological or biomedical application. Nonetheless, many chose projects in another discipline either to obtain knowledge about a new area or because they were certified to teach in multiple disciplines.

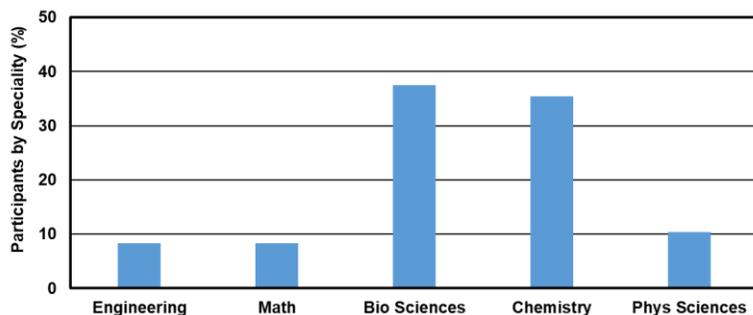


Figure 2. Primary teaching specialty of community college and in-service participants (expressed as a percent of the total).

Information about gender and race of participants is shown in Figure 3. Forty percent of participants were members of a minority group including Hispanic (22%), African-American or Mixed (11%), and Asian/Pacific Islander (7%).

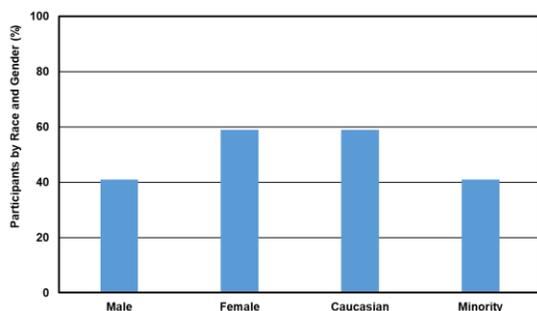


Figure 3. Gender and race characteristics of program participants (expressed as a percent of the total).

As mentioned earlier, it was desirable that, when possible, two teachers from the same school participate in the program at the same time. The logic is that they can support and encourage each other during academic year activities. For three of the four years, we had one such pair of participants. In the fourth, there were two pairs.

Over the course of the program, fourteen faculty associated with FMMI served as faculty mentors for participants. Two were from the Department of Chemistry, one from Physics, three from Electrical Engineering, one from Mechanical Engineering and the remainder were from Chemical & Biomedical Engineering. All had substantial research programs with a materials component. Each participant was also mentored by one or more graduate students, who were members of their faculty mentor's research group.

Program Activities

The goal of the program was for participants to have an authentic research experience and to translate the excitement of their work into a classroom activity that would stimulate the interest of their students in STEM. To meet this goal, participants were required to complete the program with two products: 1) A research poster that was presented at our annual RET/REU Research Symposium, and 2) A lesson plan that related to their research and that could be applied in their classrooms. These products were developed through synergistic activities that occurred during the summer portion of the program, which ran from early June until the end of July. As these activities were described in our previous report [2], only brief descriptions are given here.

Orientation

Between their acceptance of an offered position in early April and the start of the summer program in early June, participants corresponded with their faculty mentor. Generally, this involved receiving background information about their project. On the first day of the program, participants met their faculty mentors, graduate student mentors and other participants at a group breakfast. Logistical details about the program were covered including the program schedule, when and how to respond to surveys, documentation for professional development credits, and who to contact about particular issues. Participants were given a tour of the campus and provided parking stickers, identification cards, and key access to the assigned laboratories. In

the afternoon, they met individually with their faculty and graduate student mentors and were given an orientation to their project and safety training for their particular laboratory.

The following day, participants took a general class in laboratory safety offered by the Department of Environmental Health and Safety and attended a training session hosted by library personnel on electronic research resources available through the university. Following orientation, the program followed a weekly pattern of activities:

Fundamentals of Materials Course

Because participants came to the program with varied knowledge of materials science, we required first-time participants to attend a *Fundamentals of Materials* course that met twice per week for an hour. The course covered vocabulary and fundamental concepts that facilitated productive discussions with their mentors and with each other and allowed them to view their research within the context of a broader field. Topics included general concepts from materials science such as stress-strain relations, ionic, covalent and metallic bonding, phase diagrams, and crystal structures, along with content specific to metals, polymers, ceramics and semiconductors. In addition, participants attended demonstrations of x-ray diffraction and scanning electron microscopy at the Nanotechnology Research Education Center (NREC) on campus. Each year, several participants incorporated the use of these two tools into their research.

Weekly research meetings

All participants met once per week as a group to provide progress reports of their individual projects. These meetings allowed participants to view their own work within the context of other research projects, to bounce ideas off each other when they reached a stumbling block, to think about their work at a level that allowed them to explain it to others, and to understand the interdisciplinary nature of functional materials. In addition, participants spent time visiting the laboratory of other participants and engaging in hands-on demonstrations.

Weekly lesson plan seminars

First time participants met once per week to discuss their lesson plans. During the first meeting, participants were provided the Teach Engineering lesson plan template [3] and the various sections were discussed. For the next several meetings, participants who had returned for a second year presented their lesson plans from the previous year so that first timers saw examples of how the template had been applied by others working in the same research area. At subsequent meetings, participants gave progress reports of their own lesson planning and provided suggestions and advice to others.

Brown bag lunches

All participants met once per week for a brown bag lunch. These lunches provided another opportunity for the teachers to socialize with each other and with project personnel.

Research

Whenever teachers were not participating in one of the activities described above, they were working on their research projects. We deliberately decided against developing projects that were not authentic, but were guaranteed for success, in favor of research projects that were integral to the mentors' research programs. This arose from a conviction that participants would become excited about their research only if it was authentic, and contributed to the base of scientific or engineering knowledge.

Each project was directed by a faculty mentor and was supported by one or more graduate student mentors. Participants met daily with their mentors, to keep their research on track and to discuss translation of their research experience into a lesson plan.

Final week activities

During the final week of the summer program, teachers participated in two events. On Wednesday, they presented a poster of their research at our annual RET/REU Symposium. This public event is attended by faculty and graduate student mentors, department and college administrators, interested university students and faculty, and the participants' families.

On Friday, participants were required to present their lesson plans for critique to a board comprised of Hillsborough County educators and College of Education faculty. Faculty and graduate student mentors were present as well. Suggestions made by the board were incorporated by participants before their lesson plans were published.

Research posters and lesson plans were published on the project's *Materials College* website [5] designed by project personnel and the summer 2014 participants. The website presents lesson plans within context by providing additional content about Materials Science and Engineering.

Academic year activities

The expectation of the senior personnel for the program was that the teachers would return to their classrooms after the summer program and implement their lesson plans. In general, meeting this expectation was difficult for participants. The content in high school STEM courses in Florida is highly prescribed and most participants did not feel that they would be able to carve out enough time to implement the lesson plans they prepared as part of the RET.

Nevertheless, five participants implemented their complete lesson plan in one of their classrooms. Others [2] found less intrusive ways to utilize RET-inspired content in their courses, including modifying laboratory exercises to be more inquiry-driven, adding one inquiry based part of their lesson plan to an existing lesson, developing a new pre-engineering course, and implementing an "after school" interdisciplinary project. Still, others have incorporated their research experience into activities of student clubs.

A goal of the program is to maintain long-term collaborations and interactions between participants and their mentors. In practice, this happens in a variety of ways. One participant is

testing learning software in his classroom that was developed with his faculty mentor. Another faculty-participant pair has collaborated in preparing education-based proposals for funding. Other participants have been invited to bring their students to campus for laboratory tours. Several participants continue to meet with their mentors in preparing articles for publication and a number of faculty mentors have been guest speakers in participants' classrooms.

Research Experiences for High School Students

One of our 2015 participants, working with the RET-PI, implemented a Research Experiences for High School Students (REHSS) program as an add-on to our 2016 RET program. This participant, a chemistry teacher, recruited ten students from his high school to perform research alongside the 2016 RET participants. During the summer, he taught a class in research methods to the students, who were required to write a research paper at the end of the summer rather than a lesson plan.

The high school students presented posters at the RET/REU Symposium and their posters and research papers are posted on the *Materials College* website. Two of the students continued to work with their faculty mentor after the program ended. Another has recently become a co-author, with his faculty mentors, on a refereed journal article.

Program Assessments

We provide results of various program assessments below, without discussion. Interpretation of the results is included in the *Lessons Learned* section.

Fundamentals of Materials course

First time participants taking the *Fundamentals of Materials Course* completed a pre-test during the first class meeting. During the final class meeting, they took a post-test that was identical to the pre-test. The test consisted of 20 items requiring short written responses and focused on factual knowledge rather than problem solving. The pre- and post-tests were scored by the same individual during all four years of the program and the same test was used each year.

Mean test scores and 95% confidence intervals of the means are shown in Figure 4. A paired two-sample t-test ($p < 0.001$) indicates that participants significantly improved their knowledge of materials science fundamentals over the course of the summer.

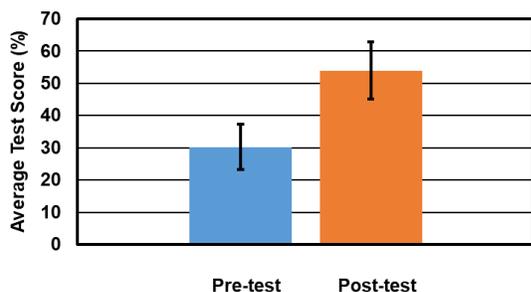


Figure 4. Pre-test and post-test results for the *Fundamentals of Materials* course.

Midterm survey

Participants completed a midterm survey during the fourth week of the summer portion of the program. The purpose of the survey was to provide formative feedback to the project personnel so that they could make adjustments if needed. Survey items solicited numerical responses, except for one that requested comments.

Numerical response items included (1 = strongly disagree to 5 = strongly agree):

- I1 I am satisfied with the program so far.
- I2 I am getting enough time with my supervisor.
- I3 I am gaining the knowledge needed to prepare a lesson plan for my students.
- I4 I am gaining the knowledge needed to complete the research.
- I5 I have enough resources to complete the project by the end of eight weeks.
- I6 I am satisfied with the mixture of activities (curricular, research, social) in the program.

Survey responses aggregated over all four years are summarized in Figure 5 and indicate that participants were satisfied with the rate that they gained knowledge, the amount of time they spent with their mentors, the resources they had for their research, and the program as a whole. It *does* appear that the level of satisfaction is higher for returnees than for first-time participants, though the differences are significant only for items 2 ($p = 0.01$) and 3 ($p = 0.03$).

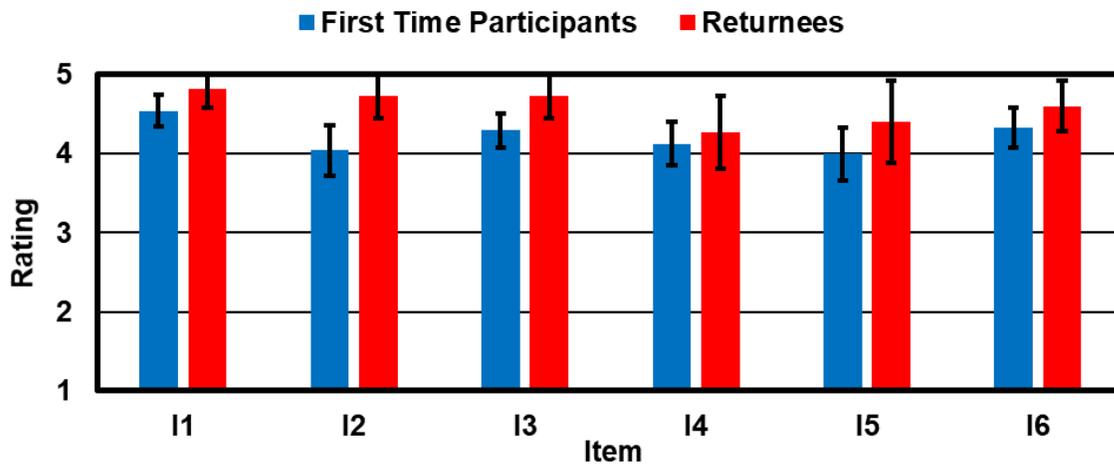


Figure 5. Midterm survey results for program participants.

Participants were prompted to comment on the quality of the campus experience. Responses were generally enthusiastic though two participants indicated they initially had some logistical difficulties with laboratory access and identification cards.

Participants were also asked to report their impression of the time commitment required by the program. About a quarter indicated they were spending more time than they expected, only one

participant reported spending less time than expected, and the remainder indicated they were spending about as much time as they expected.

Post-program survey

Participants were required to respond to a post-program survey administered during the last day of the summer program. The survey included items requiring a numerical response and others that requested comments.

Numerical response items included (1 = low to 10 = high):

- I1 Comfort in introducing an engineering topic in your classroom
- I2 Satisfaction with the program orientation
- I3 Satisfaction with the teacher-faculty interaction
- I4 Satisfaction with the classroom component (first time participants only)
- I5 Satisfaction with the teacher-teacher interactions
- I6 Satisfaction with the lesson plan component
- I7 Satisfaction with the research component

Survey responses to these items aggregated for all four years of the program are shown in Figure 6 and indicate high satisfaction with all aspects of the program.

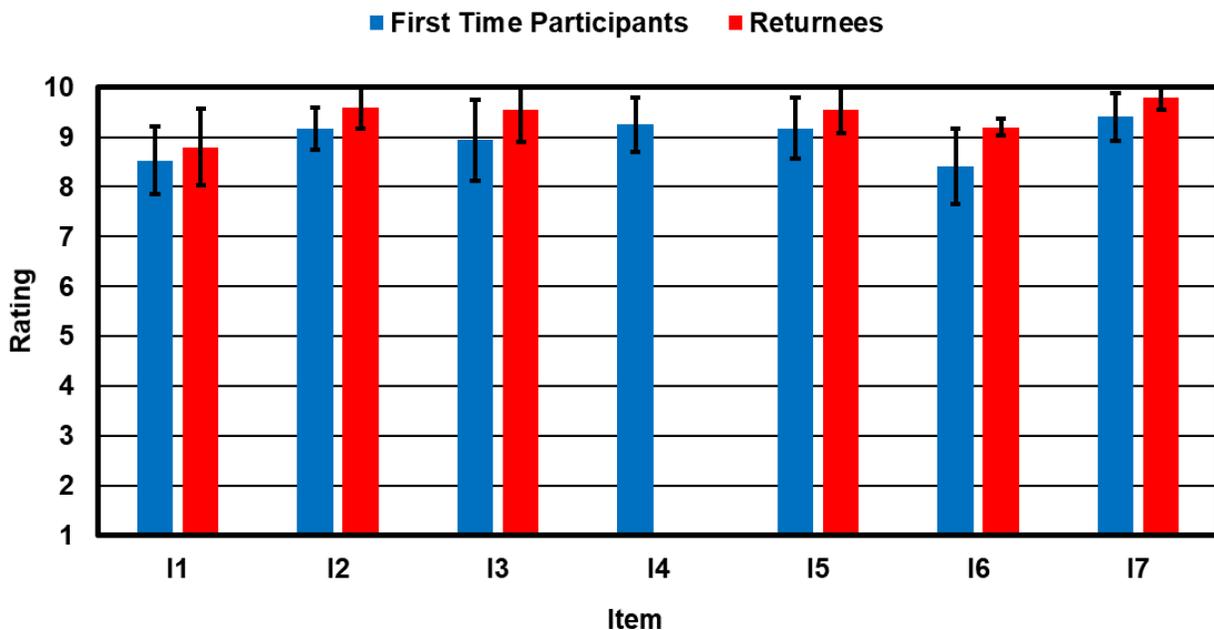


Figure 6. Post-program survey results for program participants.

There is no significant difference in responses to any one item between returnees and first time participants. However, if responses to items 2-7 are lumped (as a measure of overall satisfaction), the satisfaction level of returnees is significantly higher ($p = 0.02$) than that of first-timers.

In comment boxes, participants were asked to identify the aspects of the program that were least valuable to them and most valuable to them. Participants overwhelmingly indicated that the chance to do research was the most valuable aspect of the program. Other aspects considered to be most valuable by at least three participants were the lesson plan component, the people they worked with (faculty, graduate students, other participants), and the intellectual challenge.

Only two aspects were identified as “least valuable” by more than a single participant. Two participants suggested that there were too many research group meetings and three saw little value in the lesson plan seminar, believing the time would be better spent in informal discussions.

Participants were asked to comment on how their instructional practices were impacted by the program. Some responses were shared earlier [2], but a few additional ones are given below, including this one from a returnee who participated in 2014 and 2016:

I completed the lesson plan that I made two years ago with the FMRI RET for my Chemistry classes. It went extremely well and I plan on continuing to use it. This year I was able to create a lesson plan for my AP Biology class, which I also plan on differentiating for my Biology classes. This program helped me to incorporate the engineering design process into my classroom and to encourage my students into a STEM career field.

Two responses shown below for first time participants suggest their instructional practices might be influenced by more than just preparing a lesson plan:

The opportunity to get to know other STEM teachers from a variety of schools over such a long period of time simply cannot be found elsewhere. Getting to know these teachers and then being able to see their lesson plan ideas at the end of the program has had a big impact on me as a teacher.

As a teacher, I am able to bring back personal experience and knowledge about the STEM fields to my students. I learned how to guide my students to enter the science fair.

A comment box on the post-program survey solicited general comments about the program. A few provided below indicate the general enthusiasm level of the participants:

Great program! Loved the daily interaction; liked the overall milestones for the projects (report, posters and lesson plans); feedback provided by third party individuals was great; the projects were not cookie-cutter projects which made them exciting and challenging.

Working with the students and faculty at USF this summer was a fun and rewarding experience. The most useful aspect of the program to me was just to be exposed to this high level of research that I would otherwise not have had the access to.

It is a great program and I wish we could have more opportunities like this.

Finally, responders were asked whether they would want to participate in the program again. They unanimously indicated that they would.

Post-program surveys of REHSS high school students

The high school students who participated in the Research Experience for High School Students program during the summer of 2016 were surveyed at the end of their program. Numerical response items included (1 = low to 10 = high):

- I1 Satisfaction with the program orientation
- I2 Satisfaction with the interactions between you and the high school teacher assigned to your project
- I3 Satisfaction with the interactions between you and the USF faculty and graduate students involved in your project
- I4 Satisfaction with the classroom component
- I5 Satisfaction with the interactions between you and other students participating in the program
- I6 Satisfaction with the research component

The results of the survey shown in Figure 7 indicate strong satisfaction with the REHSS program, with the possible exception of item 4, which relates to the classroom component of their program. It seems that some high school students do not like summer classes.

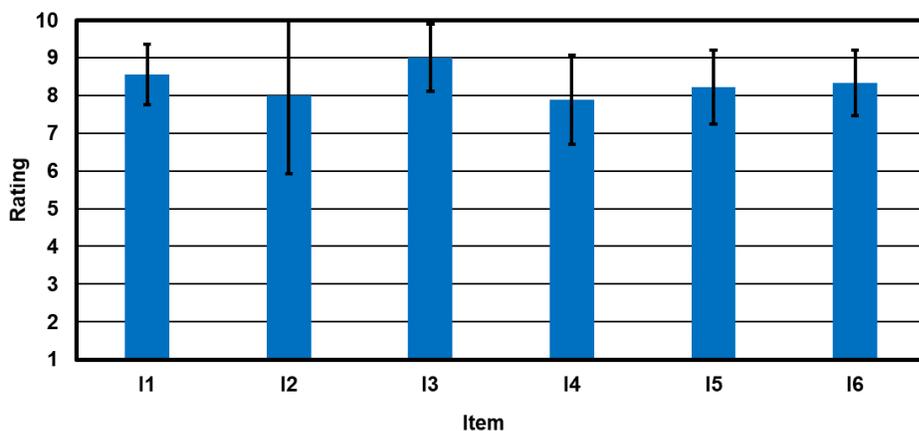


Figure 7. Post-program survey results for high school students participating in the 2016 REHSS program.

Students were asked to indicate which aspects of the program were least and most valuable. Almost exclusively, they indicated that the opportunity to learn about and perform research in a university setting was the most valuable aspect. Interestingly, no two students agreed on the least valuable aspect of the program and responses included the research paper, the research class, the Fundamentals of Materials class, and the group meetings. One student complained that he/she would not get a refereed publication after spending the entire summer in the laboratory.

About a third of the students reported spending more time than they expected on their research with the remainder reporting they spent as much time as they expected.

During the same summer, we included an item on the post-program survey for RET participants probing their satisfaction with working with a high school student. All of the responses were at the level of 9 or 10 except for one, which was 3. We also note that item 2 on the survey of students, which related to the satisfaction of working with the high school teacher, had the largest standard deviation. Only two written comments on this issue were offered by the teachers. One indicated that working with a high school student was highly rewarding and that they learned much from each other. The other believed that working with a high school student was awkward because they were unsure of their roles and relationship in this environment. If an REHSS program is included in future programs, we will most likely have each participant select one of his/her own students, so that the teacher-student relationship is in place before the program begins.

Lessons Learned

We hope to offer another RET program in FMMI and will use the assessments reported here to make improvements to better meet the program goals.

As noted above, only a few participants were able to implement their RET lesson plans as written – while others found less intrusive ways to introduce their lesson plan content into the classroom. Because they are teaching in a high-stakes testing environment, participants believe their course content is largely fixed and that time is not available for implementing their lesson plan in full. In addition, we observed that participants struggled to create lesson plans that were both related to their research and covered state standards for their course.

In future program offerings, we plan to hold lesson plan workshops facilitated by STEM Coordinators in the local school district who have experience in developing integrated STEM lesson plans. In particular, they have expertise in developing lessons that are engaging to the students but *still address* the content and standards that teachers are expected to cover. In addition to facilitating the workshops, the STEM Coordinators will consult individually with the participants and provide feedback on their finalized lesson plans. Finally, they, along with faculty mentors, will assess the academic year implementation of the lessons.

Pre- and post-test scores in the *Fundamentals of Engineering* course indicate significant learning occurred in the course. However, the average post-test score is less than 60%, so not nearly as much learning occurred as the senior personnel hoped for. In fact, the standard deviation in test scores is larger on the post-test, which opposes the notion that the course should have a leveling effect.

We believe the lower-than-desired post-test scores arise simply because there is no consequence to the participants in scoring poorly. The widening effect in performance is consistent with our observation that there were two types of test takers: Those whose nature was to do well on any test they took (whether or not there were consequences) and those who wouldn't invest time in

studying for a test when there was no consequence to failing – particularly when there were other deadlines they had to meet.

In future offerings, we will provide incentive to participants by awarding professional development credit only to those who score 70% or more on the post-test. On the other hand, we recognize that participants are finalizing their lesson plans and preparing their research posters during the time of the post-test. With this in mind, we will adjust the offering of the course to meet for three hours per week rather than two and have it end earlier in the program, when participants aren't feeling quite so much pressure.

Midterm and post-program surveys suggest that satisfaction with the program is higher among returning participants than first-time participants. Midterm survey results indicate that first-time participants are significantly less satisfied with the amount of time they spend with their mentors and less confident that they are gaining enough knowledge to develop their lesson plans. Post-program results indicate that while all participants are highly satisfied with the program, returnees are significantly *more* satisfied.

We believe this to be a consequence of the type of research projects selected for the program. As mentioned earlier, the projects are integral parts of the mentors' research programs. As such, they require authentic research, where the answers aren't already known and success is not guaranteed. We observe that most first-time participants have a somewhat high level of frustration with the open-ended "two steps forward, one step back" nature of research and that this is reflected in the survey results.

However, it is important to note that, in every instance, participants have had something scientifically new to report in their presentations at the program's end. More importantly, they find their ability to progress in the face of difficulties to be highly rewarding, confidence-building, and an effective way to learn. This is reflected in their many comments that indicate they want to expose their students to more authentic, open-ended, inquiry-based exercises.

Since we consider this to be a valuable (perhaps *the* most valuable) aspect of our program, we don't anticipate making any changes beyond reminding mentors that first-time participants require more face time than returnees do.

We noted earlier that we did not pre-service participants after the second year. In fact, it was quite challenging to recruit *any* for the first two years. High school teachers are fairly easy to recruit because many of them are actively seeking a professional development opportunity over summer. On the other hand, pre-service participants are university students who hold jobs while they are going to school and those jobs don't go away during summers. Understandably, they are unwilling to quit their jobs for an eight-week experience, no matter how interesting it might be. Consequently, in future offerings, we will not recruit pre-service teachers into the program but will give stronger consideration to applicants who are in their first two years of teaching.

Finally, we learned that RET programs can have effects that neither the participants nor project personnel can anticipate. For instance, one participant reports that she is on a statewide committee for textbook adoption and, as a result of her RET experience, is recommending books

that are inquiry-based. Another participant reports that the program has inspired her to return to school for a graduate degree. One wrote that she was accepted into the NOAA Teacher at Sea program and that she would not have had the confidence to apply if she hadn't participated in our RET. Stories such as these are gratifying, but also remind us that we have an awesome responsibility in implementing these programs.

Conclusion

For each of four years, our RET in Functional Materials and Manufacturing at University of South Florida invited ten or more high school science or math teachers and community college STEM faculty to participate in an immersive professional development experience with university faculty. Participants worked on authentic projects integral to their mentors' research programs and developed a related lesson plan that was applicable to a course they were teaching. They presented their work at a research symposium, and their lesson plans and research posters were published on our *Materials College* website.

Survey results suggest that the participants found the program to be of high value and that they found various ways to both translate their gained knowledge and skills to their students and maintain ties to their RET program mentors. The assessment results also suggest several modifications that would make the program more effective in meeting its goals. The most important of these is to involve educators with expertise in STEM lesson development as workshop facilitators, individual consultants and classroom observers.

Acknowledgement

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References

- [1]. National Science Foundation, *Research Experiences for Teachers (RET) in Engineering and Computer Science*, https://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf17575, Accessed 1/19/19.
- [2]. S.W. Campbell, S. W. Thomas, and V.R. Bhethanabotla, "RET in Functional Materials", 2016 ASEE Annual Conference & Exposition, New Orleans, Louisiana, June 26-29, 2016.10.18260/p.26095, New Orleans, LA,
- [3]. <http://fmri-ret.eng.usf.edu/>
- [4]. TeachEngineering, STEM Curriculum for k-12, <https://www.teachengineering.org/index.php>
- [5]. <http://fmri-materials-college.eng.usf.edu/index.html>