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RET in Functional Materials

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Research Interests

Sylvia Wilson Thomas, Ph.D. leads the Advanced Materials Bio and Integration Research (AMBIR) laboratory at USF. Dr. Thomas' research and teaching endeavors are focused on advanced materials for alternative energy sources, sustainable environments, aerospace, 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 materials 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).

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RET in Functional Materials

Abstract

The structure, operation and outcomes from the first two years of a focused Research Experience for Teachers (RET) site in the interdisciplinary STEM area of functional materials and their manufacturing are reported. Eleven research groups from the Functional Materials and Manufacturing Institute (FMMI) at the University of South Florida and sixteen STEM educators at various levels, including in-service high school teachers, community college faculty members, and pre-service teachers, have participated in this research experience over the first two years. The location of this RET site in the highly-equipped and instrumented FMMI, along with its focus on a single interdisciplinary research area, allowed participants to make substantial progress in functional materials research and curriculum development. Implementation of the site resulted in (a) facilitation of teachers' research progress and lesson plan development via interrelated activities including an eight-week, common course on the fundamentals of materials science and engineering, weekly research meetings leading to brainstorming of ideas, feedback and support, and weekly lesson plan seminars and (b) a diverse and sustainable set of educational activities for translation to the home institutions of the teachers.

A major goal of any RET program is to create partnerships between the university site and participating schools that allow for translation of research experiences and new knowledge gained into classroom activities. We learnt that incorporation of lesson plans developed by the teachers into their existing courses is difficult--- there is little time to bring in new material because of demands to cover standards-based content that students need for their standardized tests. We also learnt that it is difficult because the underlying assumption, that the particular research experience each teacher engages in will fit the curriculum flow of the courses they teach in their home institution, is artificial. Rather, creative activities which are unique to their particular situation, but resulting from the research experience, were found to be the most suitable, sustainable and translatable outcomes of this RET program. By fostering an environment to conceive such outcomes, a diverse and useful set of activities resulted for translation to the home institutions of the teachers.

In this presentation, we summarize assessment results obtained from surveys of participants, report pre- and post-test scores for the *Fundamentals of Materials Science and Engineering* course, and provide a summary of translational activities resulting from participation in this site, including information on the number and diversity of students impacted from these activities.

Introduction

"It is a sad reality that other young students from across the globe are clamoring to be admitted into engineering schools, yet U.S. students, who spend much of their day talking on cell phones created by engineers, driving cars designed by engineers, and surfing the Internet made faster and more engaging by engineers, are passing us by for other opportunities." – Geoffrey C. Orsak[1.]

While many educators or workers in STEM disciplines might nod in agreement at that statement, they might not have an appreciation for how dire the situation truly is. Among other disconcerting statistics, Norman Augustine, author of "*Is America Falling Off the Flat Earth*?"[2], notes that the percentage of U.S. high school students who express an interest in becoming an engineer or scientist has decreased from 36% to 6% in recent years. While he identified many factors contributing to this, one of his two main recommendations was that, "America must repair its failing K-12 educational system, particularly in mathematics and science, in part by providing more teachers qualified to teach those subjects."[2] The Glenn Commission[3] drew similar conclusions but noted that teacher training is not just a matter of preparation but, "depends just as much—or even more—on sustained, high-quality professional development."[3] The authors of *Rising Above the Gathering Storm*[4] also recognized the importance of professional development when they noted, "High-quality, content-driven professional development has a significant effect on student performance, particularly when augmented with classroom practice, year-long mentoring, and high-quality curricular materials."[4] They proposed a series of actions that the U.S. should undertake to improve its K-12 science and math education, one of which was the development of summer institutes for teachers.

There is agreement that appropriate, high quality, professional development for teachers can result in increased enthusiasm and learning gains among their students, which will lead, in turn, to an increased number of students who will pursue careers in engineering or other STEM fields. One means to accomplish this is through the National Science Foundation's Research Experiences for Teachers (RET) program[5], which seeks to develop collaborative relationships between pre-service and in-service K12 STEM teachers, community college faculty and the engineering research community, with the goal of allowing STEM teachers to translate university-gained knowledge and research experiences into their classrooms. This paper reports on an ongoing (2014-2016) RET project at the University of South Florida (USF).

Our approach to developing a high quality RET professional development experience for STEM teachers is based on our beliefs that: (1) The experience is more likely to lead to improved classroom instruction if teachers are exposed to and have hands-on experience with current research and technology, so that their students can learn concepts *within a current context*, (2) Teachers are more likely to be enthusiastic about teaching a subject *if they have made some contribution to the advancement of that subject*, and (3) Teachers are more likely to feel a sustained impact of the experience *if a professional network is developed that extends beyond the length of the experience*. In addition, we believe, in the context of a summer RET institute, that learning gains among teacher-participants will be maximized if the participants work within the same focus area – one that has applications to virtually every science and mathematics subject. As a result, our RET site focuses on Functional Materials and is housed in our Functional Materials and Manufacturing Institute (FMMI).

The rationale for a focus on Functional Materials is a combination of its highly interdisciplinary materials science nature, the pervasive presence of materials in our everyday world, and the Materials Science research emphasis and strengths at USF. The university has made substantial investments over the past 10 years in materials science through the hiring of 20+ materials research faculty members, establishment of a shared metrology and clean room facility, an interdisciplinary master's program in materials science and engineering, and large-scale research computing facilities (2400-processor cluster). Recently a group of self-selected faculty and their graduate students have formed a cluster in the newly renovated second floor of the Interdisciplinary Research building. A feature of this space that is relevant to this project is that it was designed to *foster collaboration through the use of non-partitioned, shared laboratories and interdisciplinary arrangement of office space*. We believe this atmosphere, which facilitates collaboration and collegiality, is the perfect environment for a RET site.

Participants

Participants in the program are in-service high school teachers, community college faculty and pre-service teachers. High school teachers are recruited by an email to all high school teachers in Hillsborough County from the Supervisor of Secondary Science Education for Hillsborough Schools. Community college faculty are recruited by emails from the authors to STEM department chairs of the colleges and pre-service teachers are recruited by personal contact between the authors and the associate dean of the College of Education at USF. All prospective recruits must apply to the program via a web site[6] that requests an application form, resume, and statement of interest. The application packet also requires one letter of recommendation from an education administrator.

The application form for in-service teachers and community college faculty requests contact information and a list of STEM subjects and grade levels taught. An abstract of each summer research project available to participants is provided on the web site and the application form requests applicants to list their top four choices. The application form for pre-service teachers requests information about subjects they are interested in teaching, rather than STEM subjects they had already taught.

Participants are selected from among the applicants by the authors, based on quality of application, strength of recommendation, a sensitivity to diversity in gender and race, and ensuring that a breadth of STEM subject areas are represented. Other selection factors include whether two of the applicants teach at the same school and whether they have participated in the program the previous year. Both of these factors are considered desirable, both by the National Science Foundation and by the authors. The applicants' lists of desired projects are not considered until the participant selection is complete. Despite this, all participants received either their first or second choice of project for the first two years of our program. We note also that pre-service teachers are assigned to projects that are also assigned to an in-service teacher, under the logic that the in-service teacher, while being mentored in research by faculty and graduate students, can simultaneously mentor a pre-service teacher in the educational aspects of the program.

Participants for summer 2014 included nine Hillsborough County high school science and math teachers, one math instructor from Hillsborough Community College and one pre-service teacher (who was completing a degree at USF in Middle School STEM Education). Seven participants were women and two were of Hispanic descent. Participants for summer 2015 included nine high school teachers and two pre-service teachers. Six participants were women, three were

Hispanic and one was African-American. Five of the teachers (four in-service and one pre-service) had participated in the program the previous summer.

A total of 11 university faculty have served as research mentors during the first two years of the program – nine from the College of Engineering and two from the College of Arts and Sciences (Department of Chemistry). Mentors were recruited from among faculty whose research is in the areas of Materials Science or Engineering, who have a strong interest in education, and who are affiliated with the Functional Materials and Manufacturing Institute. Each faculty mentor prepared an abstract of a research project that was available to RET participants and these were used by program applicants to rank-order their list of desired projects. It should be mentioned here that all of these projects pre-existed as part of the mentors' research efforts. None of them were designed with known outcomes or even a fully specified path. As we will describe, this appears to be an important feature of the program.

In addition to faculty mentors, a number of graduate students served as mentors to the participants. Generally, their graduate research was closely allied with the participants' projects.

Program Deliverables

The goal of the program is to provide a research experience to STEM teachers that allows them to translate their knowledge and experience into their classrooms. To ensure that each participant is given full opportunity to reach this goal, we require two deliverables from them by the end of the program: a poster of their research and a lesson plan that they could adopt in their classroom.

Poster

Each summer there are several different REU and/or RET programs in various colleges and departments within the university. A number of years ago, the directors of the programs decided that it would be worthwhile to hold a symposium in which participants of all programs would present posters of their research to the public. We have joined with these groups with the result that each participant in our program is required to prepare a poster for presentation at the symposium. Preparing a poster can be more difficult than preparing a platform presentation because the amount of space available to present the work is very limited. This forces the participants to reflect carefully on their work so that it may be edited down to the most essential information.

In addition to being presented at the symposium, posters are also posted on Materials College[7], which is a web site developed exclusively for this program to allow dissemination of research and lesson plans in context and in an organized manner.

Lesson Plan

Each participant in the program is required to prepare a lesson plan that they could use in their classroom. We use the templates available at TeachEngineering.org[8] and allow them the option of preparing a lesson, an activity or a unit. Some creativity is generally required to develop a lesson plan that is tied to their research project but also meets the needs of their students. For instance, the research of one participant was to study sorption of organic vapors by a polymer film. The polymer film was coated onto a piezoelectric quartz crystal and the mass uptake of the organic vapor was measured by noting the frequency change of the crystal. For her lesson plan, this participant focused on piezoelectricity and designed a lesson that included an activity in which students construct an electric circuit with a piezoelectric crystal and a capacitor that would store energy in the capacitor by "pumping" the crystal, followed by discharging the capacitor through a light emitting diode.

Participants present their lesson plans on the final day of the program. The audience consists of interested members of the public (generally the faculty and graduate student mentors) and a panel of school district personnel with expertise in curriculum development that makes suggestions for revisions to the plan. Finalized lesson plans are posted on the Materials College web site.

Program Activities

The period of the program covers eight weeks, from early June until the end of July. Orientation covers the first two days and consists of procuring university ID cards and parking stickers for the participants, providing them a lab safety course and orientation to library resources, a group lunch for all participants and mentors, and one-on-one meetings between participants and mentors to give an overview of the research projects and to provide any lab-specific materials or resources. A tour of USF's Nanomaterials Research Center, which houses the most sophisticated materials preparation and characterization equipment, is provided as well as hands-on demonstrations of x-ray diffraction and scanning electron microscopy, which are used later by some of the participants in their research.

Activities for the subsequent six weeks follow a regular schedule and include the following activities:

Weekly group research meeting

The participants meet as a group once per week and each gives a progress report of his/her research. This serves multiple purposes. First, since all participants are working in the same field of materials science, they are able to extend their knowledge beyond that needed for their own research. Second, it forces the participants to reflect on their work for the past week so that they can present it. In doing so, they often get ideas for what to do next. Finally, and perhaps most useful, is that there is a wide breadth of science knowledge among the participants and they often are able to make suggestions to others ("I know where you can buy LED's cheap", "You could try busting up those globs with a sonicator. We have one in our lab"). These brainstorming sessions are found to be quite helpful – particularly for first time participants.

Weekly lesson plan meeting

During the first summer, about half-way through the program, participants attended a workshop hosted by school district curriculum experts on how to prepare lesson plans. At that point, most of them started thinking about what kind of lesson they wanted to develop and, by the next to last week of the program, they were actively developing their lessons. Post-program surveys of the participants indicated that they felt too rushed.

For the second summer, we took a different approach, in which a weekly lesson plan seminar was held from the beginning of the program. During the first few weeks, returning participants presented their lesson plans from the previous year. For the remainder of the summer, they served as consultants to the first-time participants and the lesson plan seminar gradually turned into a more free-form expression of ideas and suggestions. We will present results that indicate this approach was an improvement to the program.

Fundamentals of Materials Science and Engineering course

Since the participants do their research in a common field, we felt their learning could be facilitated by providing some classroom instruction to the group at large. We therefore developed a 2 hour/week course which covers the fundamental principles of materials science and engineering – including topics such as mechanical/electrical/thermal properties, bonding, lattices, unit cells, phase diagrams, and general characteristics of metals, polymers, ceramics and semiconductors which are essential for a basic understanding of the subject. This course helps the participants place their research within the context of the subject as a whole and provides the basic vocabulary for communicating with others within the discipline. Though we developed our own lecture content, reading from the MAST Materials Science and Technology Teacher's Workshop website[9] is suggested to reinforce concepts covered in class. Only first time participants in the program are required to take the course.

Weekly brown bag lunches

A group brown bag lunch is held each week and serves several purposes. Mostly, it is a way for the participants to socialize with each other. On occasion, we invite guest speakers, including the Associate Dean of the College of Education at USF and the Director of STEM education for Hillsborough Schools. Finally, we note that the program is short and it is undesirable for any participant to be held up on research because of logistical reasons. The brown bag lunch forms a fifth weekly group meeting (one on each day of the week) which gives the participants a daily interaction with project personnel so that they may express any concerns or difficulties without delay.

At times other than when the above activities were taking place, participants work on their research under the supervision of their faculty and graduate student mentors. During the final week of the program, participants finalize their lesson plans and posters for presentation later in the week.

Program Assessments

Results of program assessments are provided below. Discussion of the results is deferred until all have been presented.

Pre- and post-test results for the Fundamentals of Materials course

Students were given a pre-test during the first meeting of the Fundamentals of Materials Science and Engineering course and an identical post-test during the last course meeting. The "closed book" test consisted of 20 short answer items that the instructor scored on a scale of four points per item. The items probed factual knowledge rather than problem solving ability. Since the responses were short answer rather than multiple choice, there was some amount of subjectivity in scoring, which we attempted to minimize by using the same scorer for all pre- and post-test papers. Participants were asked to make up and remember an ID number and use it in lieu of a name on both exams so that the scorer could not identify the test takers. Pre- and post-test results for both summers are shown in Table 1 below.

Table 1. Pre- and Post-Test Results for the Fundamentals of Materials Course

	2014		**2015**	
	Pre-test	**Post-test**	**Pre-test**	**Post-test**
Mean score (out of 80)	26.2	48.7	22.3	43.7
Mean % Correct	32.8	60.8	27.9	54.6
Standard Dev of Scores	11.8	16.3	14.0	21.6

Midterm survey of program participants

Participants were asked to respond to a web-based survey at the half-way point of the program. The purpose of this survey was to determine whether any midstream corrections in the program activities should be made. The survey items are shown in Figure 1 and the results for items in which the responses were numerical are shown in Table 2. The reader is reminded that all teachers in 2014 were participating for the first time.

Figure 1. Midterm Survey of RET Program Participants (Responses for items 1-6 are on a scale from 1 = Very Satisfied to 5 = Very Dissatisfied)

1. Rate your satisfaction with the program so far:

2. Are you getting enough time with your supervisor? Additional comments, if any:

3. Do you feel you are gaining the knowledge needed to prepare a lesson / plan for your students?

4. Do you feel that you have the knowledge needed to complete the research? Comments?

5. Do you have enough resources to complete the project by the end of eight weeks? Additional comments, if any:

6. Rate the mixture of activities (curricular, research, social) in the program.
Additional comments, if any:

7. How has the on-campus experience been? (comfort, amenities, etc):

8. How much time are you spending on this project? a. More than expected, b. Less than expected, c. About what I expected

Table 2. Participant Responses to Items 1 – 6 of the Midterm Survey (1 = Very Satisfied to 5 = Very dissatisfied)

	Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**
2014 Average	1.7	2.1	1.9	2.0	2.2	1.4
2015 Average (Returnees)	1.3	1.3	1.5	1.8	1.3	1.7
2015 Average (1st timers)	1.6	2.0	1.8	2.2	2.2	2.0

Written responses to item 7 were uniformly positive with no complaints or negative comments. Responses to item 8 were evenly split between a and c for 2014 and, except for one returnee who answered a, were all response c for 2015 participants.

Post program survey of participants

Participants were asked to respond to a web-based survey after the program was completed. One purpose of this survey was to determine whether any corrections in the program activities should be made for the following year. Another was to determine their confidence level in translating the experience to their classrooms. The survey items are shown in Figure 2 and the results for items in which the responses were numerical are shown in Table 3. Again, the reader is reminded that all teachers in 2014 were participating for the first time.

Figure 2. Post-Program Survey of RET Program Participants (Responses for items 9-14 are on a scale from 1 = Very Dissatisfied to 10 = Very Satisfied)

1. How did the program impact your instructional practices? (1=very significant to 5 = not at all). Provide details:

2. How comfortable are you in introducing an engineering topic in your classroom? (1=least comfortable to 10 = most comfortable).

3. Have you participated in a RET before? If yes, how did this one compare?

4. Did the program meet your expectations? (1=strongly agree to 5 = strongly disagree)

5. Would you want to do this program again? (1=very likely to 5=very unlikely). Provide details:

6. What was the MOST valuable element of the program? ________________

7. What was the LEAST valuable element of the program? ________________

8. What should be added (or removed) from the program? ________________

9. Please rate your satisfaction with the program Orientation (1-10 scale)

10. Please rate your satisfaction with the teacher-faculty interaction. (1-10 scale)

11. Please rate your satisfaction with the classroom component. (1-10 scale)

12. Please rate your satisfaction with the teacher-teacher interactions. (1-10 scale)

13. Please rate your satisfaction with the Lesson Plan Component (1-10 scale)

14. Please rate your satisfaction with the Research Component(1-10 scale)

15. Other general comments: _________________

16. How much time did you spend on this project? a. More than expected, b. Less than expected, c. About what I expected

Table 3. Participant Numerical Responses to the Post-Program Survey

		Q1	Q2	Q4	Q5	Q9	Q10	Q11	Q12	Q13	Q14
2014	Average	1.6	8.6	1.6	1.1	8.9	8.9	9.4	8.9	7.4	9.1
2015	Returnees	1.5	8.8	1.0	1.0	9.0	9.7	N/A	9.0	8.5	9.8
2015	1st timers	1.5	7.3	1.0	1.0	9.0	7.8	7.7	9.0	8.8	9.0

Written responses to the post-survey are too long to reproduce here. However, we provide the detailed responses to item 1 because translation of the knowledge gained during the program into the participants' classrooms is the major goal of the program. All responses to item 1 are included with only minor edits for grammar.

1. How did the program impact your instructional practices? Provide details:

I was uncomfortable with the concepts of engineering and did not think that engineering had a place in my biology classroom. Now that I see real application, engineering practices will be commonplace in my classroom.

This program impacted my instructional practice in several ways. I plan on incorporating the engineering design process into my classroom. I plan on incorporating real life applications and research topics into my lesson plans. I also plan on having more hands on activities that allow students to better understand concepts.

It has provided me with experience to bring back to the classroom real world topics and innovative ideas and practices to enhance the classroom experience.

Answers the typical student question, "When am I going to use this?" Real application of science and math that will translate into real life examples for the classroom lessons.

In school classrooms we always do experiments where we know the expected outcome. In research, an outcome is usually not expected and is in some cases surprising. I want to focus on doing more open ended experiences where students can conduct experiments where outcomes are not expected.

My classroom instruction will be more hands on and real world orientated.

I think being exposed to university level research will boost the research experiences I provide for my students. I will also incorporate the idea that sometimes research doesn't work and multiple trials are needed to get accurate results. I think that idea has been missing from my classroom.

The experience working in an engineering lab is invaluable but we are still driven by poor curriculum designs and are expected to teach certain ways by the evaluation system. Thus, I *hope to incorporate some of my experience within my teaching practices but not to the extent I would like.*

The lesson plan created under RET is being used as part of the annual curriculum.

I've learned how to consider and include engineering concepts in my lessons.

I'm revising labs so they are not so much like a recipe to follow.

I learned areas of emerging science that I was previously oblivious to that I will share with my students. I will be utilizing my lesson plan developed during the experience to help me do so.

It inspired me to redo an entire unit, not just a lesson in my AP Curriculum.

It gave me insight into actual lab work and the environment of research.

Not only did the experience renew my love for research as well as laboratory work but also the lesson plan I created will be funded by the school district so that my students can use it and experience some of the work I performed this summer. This was an all-around extraordinary summer and I can't wait to do it again next summer.

Written responses to other items will be summarized. When returnees were asked to compare their previous RET experience with the current one, one responded that they were equivalent and three responded that the second time was far less stressful.

In response to question 6, the Materials Science course, the lesson plan development, the mentoring and the general intellectual challenge were cited by single respondents as being most valuable. The answer given by the remaining (majority) of respondents, however, was that the research experience was the most valuable part of the program.

During 2014, several participants responded that the least valuable aspect (question 7) of the program was that there were too many group research meetings. (In 2014 there were two group research meeting per week. In 2015, there was one per week and one lesson plan seminar per week). For 2015, only the lesson plan meetings were cited by more than one (in this case, two) respondent. Other single responses included the poster presentation, the NREC tour, and the downtime between experiments. Generally, the responses to item 7 translated directly over to recommendations for item 8.

Written responses to item 15 were almost exclusively enthusiastic about the program. One 2014 participant indicated that lesson plan development should be started earlier.

Discussion of Assessment Results

Table 3, question 11 indicates high satisfaction with the Fundamentals of Materials Science and Engineering course for 2014 participants and satisfaction among 2015 participants. Pre and post-test scores (Table 1) indicate that learning occurred, though perhaps not to the level that the instructor hoped for. A clue to a reason for the apparent disconnect between (somewhat low) performance on the post-test and (somewhat high) satisfaction with the course might be explained by looking at the standard deviations in Table 1. The spread in knowledge of course material among participants actually increased from the pre-test to the post-test. Under the logic that people enter the program with different amounts of knowledge but then are all exposed to the same material, one would expect these standard deviations to decrease. We believe the results obtained here might be explained by the fact that there was neither a consequence to doing poorly on the post-test nor an incentive to do well. The participants were generally enthusiastic and very participatory during the class meetings. When it came time to take the test however, they (based on conversations) took two different approaches. One group saw any test as a personal challenge and studied so that they performed well. The other group simply felt that they had more important pressing matters (preparing their lesson plans and posters) and, since there was no course grade anyway, did not bother studying for the test.

Responses to the midterm survey in Table 2 indicate about the same level of satisfaction among 2014 participants (all participating for the first time) and the first time participants in 2015. A slightly higher level of satisfaction among 2015 returnees probably indicates that they were more comfortable in what they were doing the second time around.

Responses to the post-program survey summarized in Table 3 indicate fairly high satisfaction among all participants. Satisfaction with aspects probed in items 2, 10 and 11 (related to interactions with mentors and the Materials course) are a bit lower for 2015 first time participants though the numbers of participants are too small to draw any firm conclusions. No response of any participant in any item was lower than neutral though and comments suggest that, despite a few recommendations for improvement, enthusiasm for the program was high. The 2015 satisfaction level with the lesson plan component (item 13) was higher than the 2014 responses, both among returnees and first time participants, indicating that the emphasis on lesson plans early on was a benefit. Written responses suggest that the weekly lesson plan seminar might best be held from the beginning but suspended part way through the program after participants have been given the format and have seen some examples. Several participants expressed the opinion that, at that point, they could seek advice on an as-needed basis as opposed to needing a regular meeting.

The main goal of the program is that participants translate some aspect of their experience into the classroom and it is the detailed responses to item 1 that provide the most insight into this. Before delving into these responses we provide some background. As noted earlier, the research projects are not made up for the purpose of this program – rather they are integral parts of ongoing research efforts by university faculty. Over the course of both summers, the authors have noted a level of frustration among many of the participants. They have tried something logical to solve a problem in their research only to find that it did not yield the desired results. So they thought some more and tried something else that often didn’t work either. One of the desirable features about the group meetings is that frustrated participants realize they are not alone and, in fact, begin to realize that this two steps forward and one step back process is the nature of the beast in research. By the end of the program, the participants have all obtained results that they could present at the symposium. But they have also gained an appreciation for the nature of engineering research and the constant problem solving that it requires.

In light of this, the detailed responses to item 1 of the post-program survey are interesting. Several of the participants indicate with some variation on the theme that they plan to expose their students to more open-ended experiments, experiments that might not work as intended or experiments that don't follow a recipe. The least charitable interpretation here would be that the teachers want to share the misery of their research experience with their students. We believe a more accurate interpretation is that they see value in the frustrating but ultimately rewarding problem solving nature of real research and see value in exposing their students to it. If this is the case, their plans to modify rote lessons to include more active learning or guided inquiry might very well be the most valuable outcome of our program.

Post Program Activities

Ideally, each of the participants would return to their school, implement their lesson plans in the classroom, and collect data to determine whether student learning gains (or at least students' interest levels in STEM) were enhanced as a result of using the plan. Unfortunately, several factors make this difficult. First, the emphasis on high stakes standardized testing makes it difficult for teachers to either introduce a new topic or to expand significantly on current one – they simply can't spare the classroom time. Second, it is not an easy task for all participants to translate a research experience into a lesson that fits the curriculum flow and content standards of their course. Finally, students are already undergoing a tremendous amount of testing and assessment and adding even one more is undesirable.

What we've found is that most participants in our program don't use their lesson plans, but find creative ways, unique to their own situation, of implementing activities that translate their research experience to their students. In this section, we provide some diverse examples.

First, despite the difficulties listed above, three of our program participants have presented their lesson plans as written and two more have carved out time to present their plans this spring.

Erica presented a unit on solutions to her Honors Chemistry class culminating in an activity in which students create fibers from polystyrene in solution and an engineering design project to filter contaminants from water using charcoal. Seventy-five students were impacted, of which half were female and 70% were minority. In addition, she shared the polymer activity with 20 students in her AP Biology course.

Pedro developed a lesson plan on Monte Carlo simulation and implemented it in his computer programming course of 30 students (10% female, 14% minority). He notes that student performance on subsequent programming assignments has increased.

Jesse implemented a lesson activity in number sense, in which practical examples related to how ions of positive and negative charge combine to form neutral molecules. He reports that the 200 students exposed to the activity (60% female, 80% minority) were more engaged in the activity than when it was a purely mathematical exercise.

Megan was unable to implement her lesson plan in her biology course but she completely revamped the way students did their laboratory exercises, moving away from rote memorization in favor of captivating students with new ideas, new research, and inquiry-based activities and lessons. So far, this has affected about 70 students (65% female, 30% minority).

Cristina and Gwen each carved one activity from their lesson plans to apply in their classrooms. Cristina engaged her students (about half female and 40% minority) in a laboratory activity requiring the capture and detection of bacteria at low concentrations. She reports most students were highly engaged in the activity, with one student extending it for a science fair project and placing at the state-level STEM fair. Students in Gwen's archaeology course manufactured their own adobe bricks and then participated in a guided inquiry lab for their preservation. She reports that many of her 21 students (57% female, 80% minority) have inquired about careers in research as a result of the activity.

Art, who teaches Physics at his school, is developing a pre-engineering course as a result of participating in the RET program. In addition, he has had two engineers as guest speakers in his classroom and is arranging for his students to tour the labs he did his RET research in. So far, 28 students (40% female, 50% minority) have been impacted by these activities.

Andria has spoken about scientific and engineering research to the 50 students (half female, 25% minority) in the Marine Club at her school, reporting that many of their questions related to what fields of study/jobs would involve such hands-on research (and how much one would be paid in those jobs).

James modified his RET lesson plan to create an interdisciplinary project at his school involving physics, chemistry, and biology students in the construction of an inexpensive colorimeter to test phosphate content in a local river. Students worked on their own time and came in after school for testing samples. The project involved over 150 students (about half female and most minority) in their junior and senior year. According to James, because of the project's interdisciplinary nature, students had to work together. Generally physics students taught the other students how to build the circuit, chemistry students taught the others how to use Beer's law and create an absorbance plot using standards, and biology students explored the ecological effects of phosphate runoff in different areas of the river.

In addition, James, working with one of the authors, has decided to implement a Research Experiences for High School Students (REHSS) program next summer, as an add-on to our RET program. Specifically, 10 high school students will be selected to do research alongside a high school teacher and faculty and graduate student mentors. The plan is for students to continue their work over the following school year and possibly even return to the research program the next summer. It is hoped that this work will form the basis of their STEM fair projects as well as projects in other higher-level competitions (Intel, Siemens, ISWEEEP).

In addition to the activities described above, several of the participants in our RET programs have had their faculty mentors give guest lectures in their classes, and a number have presented about their RET experiences to other educators at professional days, which leads to easier recruitment the following year.

Conclusion

The RET in Functional Materials, in the two years of its existence at USF, has directly impacted sixteen educators by allowing them to participate in actual science and engineering research and by providing a framework that encourages them to reflect on how they might translate their new knowledge and experience into their classroom. Based on assessment results and the enthusiasm with which the participants engage students upon return to their classrooms, the RET site is effective in stimulating interest in the intersection between research and teaching in STEM disciplines.

Although some of the participants have implemented a lesson plan that they prepared as part of the RET experience, the majority have exercised additional creativity to share their RET knowledge and experience within the constraints of their own unique situations. What these different approaches have in common is that they expose students to real world problems and research – where creativity and problem solving are essential and the outcomes are not guaranteed. As of the second year of the program, several hundred high school students have been impacted by the RET experiences of these educators.

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