2006-1578: CONNECTING GRADUATE STUDENTS WITH SECONDARY TEACHERS TO INCREASE THE MATH AND SCIENCE LITERACY OF SECONDARY STUDENTS: IMPACT ON TEACHERS, FELLOWS AND STUDENTS

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Connecting Graduate Students with Secondary Teachers to Increase the Math and Science Literacy of Secondary Students: Impact on Teachers, Fellows and Students

Each year hundreds of Fellows, undergraduate and graduate student scientists, participate in GK-12 National Science Foundation (NSF) Grants (Graduate Fellows teaming with teachers to teach in kindergarten through twelfth grade classrooms) throughout the country. One aspect of GK-12 funding focuses on the potential to make permanent changes in institutions of higher education by creating opportunities for partnerships with K-12 schools in a manner mutually beneficial to faculty, teachers, and students alike. This increased interaction between higher education and local schools provides professional development opportunities for teachers, enriched scientific learning by their students, and strengthens possible lifelong partnerships between universities and schools (http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5472).

Through participation in a NSF Fellowship, the Fellows are expected to improve communication skills, teaching proficiency, team building skills, and expand their interest in humanitarian efforts in their perspective communities [1-2]. It is up to the Principal Investigators and the community of educators to determine how these skills will be developed, but typically Fellows participate in college course work, seminars, and school activities that enrich their knowledge of educational theory and practice. Classroom assignments provide them with an opportunity to practice these skills in collaboration with teachers and students in partnerships.

Description of Project STEP

Project STEP (Science and Technology Enhancement Program) is one of over 100 similar grants within the larger GK-12 community. STEP is an innovative initiative created under GK-12 NSF guidelines in order to promote specific goals that will enhance undergraduate and graduate students' communication, teaching, and team building skills. STEP was created by seven University of Cincinnati faculty members in a collaborative effort between two colleges, College of Engineering (COE) and College of Education, Criminal Justice and Human Services (CECH). These seven faculty members partnered with four leading members from the City of Cincinnati to create an Oversight Committee, working with faculty advisors, and teachers from seven Cincinnati area schools.

Project STEP has two primary goals. The first goal is to produce scientists, engineers, and secondary science and mathematics educators who are experienced in developing and implementing authentic educational practices into current secondary science and mathematics curricula. The Fellows have brought their technical background and expertise into the classroom guided by the current experienced teachers so that the secondary students can be effectively engaged in STEM learning. Furthermore the fellows help students relate science, technology, engineering, and mathematics (STEM) knowledge to the world in which they live. The Fellows have been and continue to be exemplary in enhancing and reinforcing basic scientific and mathematical concepts by integrating inquiry-based, open-ended problems pertinent

to the student's community.

The second goal is to design, develop, and implement hands-on activities and technology-driven inquiry-based projects, which relate to the students' community issues, as vehicles to authentically teach STEM skills. The idea is to enable middle and high school students to directly experience the relevancy of their education to everyday life, society, and the world in a way that requires them to use higher-order thinking skills. The activities that have been developed during the past three years can be found at our website, http://www.eng.uc.edu/STEP/activities/.

The major activities of the grant include training graduate and undergraduate Fellows in engineering and education to work in science and math classrooms initially in 7 schools and 3 school districts, and eventually in 5 local public schools, located in one school district. During 2002-2005, the first three years of Project STEP's implementation the participants included; 18 Fellows (8 undergraduate and 10 graduate students), 32 teachers, 7 university faculty members, and the Fellow faculty advisors, a technology web designer, a Grant Coordinator, an Evaluation Fellow and an Oversight Committee. The grant is currently in its fourth year, with 8 graduate Fellows, and similar staffing, and has approved funding for continuation of an additional five years. This paper discusses the impact of Project STEP on the Fellows, teachers, and students in its first three-and-a-half years.

The teachers and Fellows have worked in teams to design, develop, and implement hands-on activities and technology-driven inquiry-based projects, which relate to the students' community issues, as vehicles to authentically teach STEM skills. Activities have been incorporated into lessons, demonstrations, laboratory exercises, individual and group projects, and field experiences to: 1) enable high school students to directly experience authentic learning practices that require them to use higher-order thinking skills; 2) encourage creative problem-solving skills that require collaborative learning, teamwork, writing, and presentation; 3) cultivate an interest in service learning, in which students are active participants, achieve outcomes that show a perceptible impact, and engage in evaluative reflection; and 4) better motivate and prepare secondary school students for advanced education. The Fellows have been and continue to be trained to create and implement these activities.

Through the course of each year, the Fellows complete a specially tailored educational methods course, one instructional planning course, a Field Practicum course, Instructional Technology Across the Curriculum course, and Instructional Teaching & Learning Styles course. The education courses train them in: 1) methods, concepts, theory, and assessment of instruction; 2) design and implementation of science and mathematics curricula with an emphasis on instructional technology; 3) local, state and national curriculum standards, educational practices, and pragmatic and logistical secondary education issues; and 4) advanced technology, time management and classroom management techniques for technology use in classrooms [2-6]. Each year, the graduate Fellows present a one- or two-day "Teaching with Technology" workshop for teachers who participate in Project STEP as well as others interested in increasing their

technology knowledge. The participants are given one graduate credit if they develop and teach a lesson using this technology. The graduate Fellows also participate in an advanced instructional technology course during the summer in order to train them in the use of electronic media, specifically Dreamweaver.

Lessons

Fellows work with educators to develop inquiry-based, technology-driven lessons to incorporate the learning of STEM skills while linking to real-world emerging applications, technology, and careers. Fellows currently teach in science or math classrooms and start the lesson development process by reviewing curriculum standards to be covered with their cooperating teachers. The Fellow then researches the topic and develops a motivating lesson using their advanced content and technology knowledge to be implemented within the classroom. The lesson includes clear objectives that will meet the Ohio State Standards. The Fellow works with the cooperating teacher's team members to facilitate relevant interdisciplinary activities into the lesson. Fellows design all components of the lesson including appropriate assessments. Fellows also incorporate community resources whenever possible in the way of field trips, expert visits to the classroom, and lesson consulting.

A lesson does not merely teach specific skills or concepts. Lessons are designed to create maximum student interest and participation. An introductory activity is designed to hook student interest including links to advanced technology and relevant skills and content. The introductory activity also allows the teacher and Fellow to identify and fill in gaps in student background knowledge. Students are then immersed in researching and discussing of real-life problems, teaming with peers to develop solutions to problems that will incorporate the skills and concepts to be learned, and then work using tools and new skills in ways that scientists, technologists, engineers, or mathematicians would to test their solutions. Students are immersed into lessons in a way that they do not feel like students; they feel as if they are in the specific career role of scientist, technologist, engineer, or mathematician. Teacher and Fellow participate as collaborators and facilitators throughout the lessons. Students learn skills and concepts through lessons that mirror real-world experience gaining a more in-depth knowledge of the content. Examples are provided in Table 1. The first column provides the lesson name, the second column indicates the connection between the real-world experience of the curricular area it fits in and the type of role students experience during that lesson.

Table 1. Examples of inquiry based, technology-driven lessons developed that integrate the teaching of standard-based skills to raise interest in STEM skills.

Lesson Name	**Curricular Area/Cognitive Apprenticeship Role of Student**
Bone Up on Tissue Engineering	Biology – Biomedical Engineer
Build a Bridge - Brent Spence Bridge	Mathematics – Civil Engineer

City Plan Catastrophe	Mathematics – Industrial Engineer
Crash Test Dummies	Mathematics – Mechanical Engineer
Medical Devices	Mathematics –Biomedical Engineer
Experimenting with Sound	Physical Science - Physicist
Food Production & Distribution	Environmental Science –Environmental, Manufacturer Engineer
Gene Corn Project	Environmental Science – Environmental, Agriculture & Bio Engineer
Hurricane Tracker	Mathematics – Meteorologist/Operational Engineer
Movers & Shakers (Buildings & Earthquakes)	Physical Science – Architectural/Civil Engineer
Natural Selection	Life Science - Bioengineer
Need Another Lane	Mathematics –Operation/ Industrial Engineer
Photosynthesis through Satellite Eyes	Biology – Aerospace/Electrical Engineer
Rocket Cars	Mathematics – Aerospace Engineer
Rocket Launch	Mathematics – Aerospace Engineer
Runaway Surveyors	Mathematics – Geometry – Civil/Industrial Engineer
Skid Marks (an Accident Scene)	Physics – Forensic Scientist
Toy Maker	Mathematics – Computer/Mechanical/Electrical Engineer
Viva Las Vegas – An Energy Project	Physical Science – Electrical/Nuclear Engineer

Here is an example of what one of the Teachers involved in the project said about their experience with a Project STEP lesson:

"I've been teaching twenty-seven years so the kids love to see a young person in there instead of this old fogy and I'm old school too so, you know, we do things the old fashioned way a lot of times but they come in with the new technology and the new designs of different things and showing them ways that they can do things. For example, I gave the Fellows a challenge. We were on the standard of talking a little bit about DNA and I wanted them to do some kind of lab rat activity where they extract DNA and see it and I had some things to do in the past but I wanted to know if there was something new and modern out there they could do. They took it and ran with it and presented a lab, it took about two days, and they gave them all the history behind it and basis for it and how it's used today and that kind of thing so it not only educated me to new things but the kids were really excited about it too because they thought they were like Colombo or somebody, you know, and that was great."

Overall Findings

During the first year of the grant, there was successfully engagement of the Fellows in meaningful, productive, and innovative educational instruction and activities and they had become excited about and motivated to teach STEM skills in K-12 math and science classrooms. As a result of this instruction, the Fellows realized and understood that the facets of education, research, and professional activities overlap and that this overlap can help them to be more successful in future careers. Because of the training the Fellows received in the first year, they were able to design, develop, and implement secondary level authentic, inquiry-based learning activities based on their technical expertise and knowledge.

During the second year of the grant, the Fellows had been trained in the development and implementation of more comprehensive projects and activities centered around two focal areas, mechanics and chemistry, with mathematics threading between the two. This provided an opportunity to show how math and science (physics, chemistry, biology and earth science) are inter-related – which was identified as a need by the teachers who participated the first year.

In year three, the grant gained even more success in regards to the teachers, students, and schools. Through the implementation of the activities and the presence of the Fellows in the classrooms, we recognized an increased interest in math and science. Many Fellows indicated that their students were learning and asking for them to teach more often. Fellows have told us that they often heard comments like, "I really enjoyed that activity and learned a lot from it." Or "That is a different way of looking at that, I am glad you taught today." The Fellows conducted pre- and post-evaluations for the activities they implemented in year three to assess the impact these activities had on student learning and comprehension. Fellows developed electronic portfolios available through the project website, http://www.eng.uc.edu/STEP/people/gf/. The portfolio incorporated the goals and objectives of the activity they implemented, standards addressed, description of the activity, implementation details, evaluation rubric used, evaluation results, and personal reflections. Many Fellows commented that the students were more involved in the activities developed as a result of this grant than in other activities throughout the school year. The secondary math and science teachers were instrumental in the training of the Fellows; the Fellows spent three quarters (over 180 hours) with the teachers in their classrooms observing, learning, and participating. Through this interaction with the teachers the Fellows were able to design, develop, and implement activities that were directly related to the school, state, and national curricula for science and math.

The activities in the fourth year continue even more strongly. At mid-year the Fellows have implemented twenty quality lessons with 92% of students reporting that they have learned something new. Fellows indicate the new training offered to them on assessment selection and development increased their expertise in creating lessons and in aligning assessments to objectives. Fellows continue to build strong bonds with teachers, students, and university faculty. Teachers indicate that Fellows continue to outperform their expectations and those who have been with STEP for several years are reporting that there is a rise in number of graduating students returning to tell them that they are majoring or selecting minors in engineering in college. Teachers also indicate that they

realize that the program is affecting a change in their style of teaching to be in line with the STEP methodology and that they are finding themselves reinvigorated towards teaching. Students continue to positively respond to the authentic, inquiry-based, technology-driven style of teaching the Fellows are implementing as reflected through student feedback surveys.

In the rest of this paper the impact that Project STEP has had on the Fellows, the Teachers, and the Students is examined.

Fellows

STEP created specific objectives that related to the Fellows, these were designed to:

- Engage Fellows in meaningful, productive, and innovative educational instruction and activities so they will become excited about, and motivated to teach STEM (science, technology, engineering and math) skills.
- Help Fellows realize and understand that the facets of education, research, and professional activities overlap; and they can be more successful in their career when they overlap these activities.
- Have university faculty and staff, as well as secondary teachers, provide guidance, instruction, and mentoring to Fellows in the practice of instructional approaches, and best teaching practices.
- Provide Fellows practical and direct experience in teaching middle and high school students.
- Have Fellows design, develop, and implement secondary-level, authentic, inquiry-based learning activities and projects that are based on their technical expertise and knowledge.
- Train Fellows in the development and implementation of computer modules using current electronic multimedia and web-based tools. (STEP Website http://www.eng.uc.edu/STEP/overview/objectives.html).

Fellows have participated in a wide variety of professional development activities focused on improving their teaching practices for middle and high school classrooms as well as improving their educational technology literacy. A series of courses were developed in order to focus on educational theory and practice and its implementation into science and math classrooms [2]. Each quarter consisted of in-depth, seminar style classes that enabled the Fellows to construct knowledge concerning teaching and learning. In the fall quarter, a course called Instructional Planning enabled the Fellows to understand and apply effective teaching strategies in the design, development and implementation of authentic, hands-on, inquiry based lessons in middle and high school classrooms. This course also focused on classroom management, national and state standards, and national, state and school administrative policies. These concepts were further personified by the Fellows spending an average of 10 hours in the classroom a week working with middle and high school math and science teachers and their students as well as spending an average of 10 hours a week researching and developing lessons. This ongoing seminar, Field Practicum, continued on throughout the winter and spring quarters that included guest speakers focusing on specific topics such as lesson

assessment, application of research, and current issues raised by the Fellows in order to better address their ongoing needs (http://www.eng.uc.edu/STEP/training/courses/).

Year 3 of the STEP grant involved 9 graduate Fellows (including the evaluation Fellow), 1 undergraduate Fellow and 17 teachers from 5 schools. One Fellow resigned in mid-February of 2005 from the project citing the need to focus more on her research and progress towards her degree. Year 4 of the grant, involves 9 graduate Fellows (including the evaluation Fellow) and 9 teachers from 5 schools. These two years provide the strongest data to date, and are the focus of the analyses in the rest of this paper.

The Fellows were engaged primarily in lesson planning, collaboration with teachers and instruction of students. In year 3, the graduate Fellows have spent a weekly average of 7.6 hours in planning, 2.1 hours with teachers and 8.5 hours with students in the classroom. The undergraduate Fellow (whose hourly expectation was lower, spent an average of 3.1 hours in planning, 3.2 hours with students and 2.1 hours with teachers. So far in year 4, the graduate Fellows have spent a weekly average of 8.4 hours in planning, 2.5 hours with teachers, and 8.6 hours with students in the classroom. In addition, there is other time in years 3 and 4 spent on miscellaneous activities related to STEP including meeting with other Fellows, and PI's and completing administrative tasks associated with the grant such as evaluation instruments.

The impact of the grant on these Fellows has been assessed through a variety of means including focus groups, classroom observations and weekly reports that require reflection on the week's challenges and accomplishments. Additional data continues to be collected at the close of the year when the Fellows have completed their assignments and submitted post project measures specifically on skills and confidence and attitudes towards science teaching. Additionally Fellows post their lesson plans, including assessments and student feedback measures at the project website www.eng.uc.edu/step.

The impact of the grant in relation to the project's goals and objectives reported here is based on data collected from the focus groups and weekly reports. Fellows have indicated important gains in the overall project goal of becoming scientists and educators as well as the related project objectives. Their comments indicate that they have been engaged in meaningful, productive and educational instruction and been given guidance in best practices and instructional approaches. Fellows have also demonstrated that they are able to connect career success to connections they make between their education and research experiences. They have extended this to the work they have done with the students in the classroom by helping them make connections between what they are studying and possible careers they might pursue. This has included offering sessions about college as well as serving as a role model of successful college students for the students they are teaching. In Year 3, Fellows had developed 36 modules and in Year 4, Fellows have developed 24 modules, which have incorporated technology to varying degrees including the use of geometer sketchpads, calculators based labs and graphing calculators. The Fellows have also required students to use power point in presentations and have involved them in web based searches as a part of various activities. Finally, overall the Fellows report very positive experiences with team dynamics in the group.

They indicate that they collaborate with other Fellows regularly, often feel a part of the team of teachers at the schools where they are assigned and work with PI's to varying levels.

These findings are supported by the classroom observations done by the Grant Coordinator. Each Fellow is observed at least twice and shown some form of progression in teaching skills from the first to the second observation. In addition, Fellows are observed and provided feedback by their teacher on every lesson they teach. Each Fellow showed a positive response to any suggestions or concerns raised in the initial observation. These observations specifically document skill in the following areas for the Fellows although skill level may vary between Fellows (number of Fellows, for whom the skill was explicitly stated by the observer, is shown in parentheses):

- Ability to create and implement well organized lesson plans (7)
- Use of authentic teaching method (6)
- Good rapport with students (7)
- Ability to engage students (6)
- Use of effective questioning techniques (7)
- Effective classroom management techniques (7)
- Integrated practical applications/engineering (6)

While the Fellows have reported an overall positive experience on project STEP, and shown continual improvement in their skills as teachers, they have encountered several challenges to fulfilling their role in the classroom. These have been documented in the weekly reports and discussed in the focus group. Several of these challenges were also observed by the coordinator. Most of them are in the category of student behavior and classroom management issues. The Fellows have worked throughout the year to overcome these challenges. One result of dealing with these has been to identify lessons learned by the Fellows in the processing of overcoming these challenges. Table 2 is chart showing the challenges and lessons learned as documented in the weekly reports.

Table 2. Challenges and Lessons Learned for Fellows in Schools

Challenges	**No. of Fellows Reporting**	**Lessons Learned**
Conflict with research time	5	• Open communication with PI and advisor • Time management is essential
Schedule changes at schools	7	• Be prepared to make modifications to lesson
Motivating students/getting incomplete work	8	• Positive reinforcement is important • Develop lessons around student interests • Hands on activities engage students • Get feedback from students as lessons progress
Poor reading and writing skills	5	• NA

Getting students to follow directions	6	• Put things in writing • Be explicit, clear and concise in directions
Student attendance	8	• Be prepared to make modifications to lesson
Student behavior	8	• More engaged students cause less problems • Respect students and be respected • Give students structured feedback
Time to implement lesson	6	• Practice lesson, make changes after first presentation • Be prepared to make modifications to lesson
Students not prepared	7	• Redesign lesson based on student comprehension • Use pretests to help students access prior knowledge
Inadequate resources, equipment	4	• Be prepared to make modifications, fill in with equipment and supplies where possible • Check ahead of time to make sure supplies, equipment are available
Absent teacher	4	• Communicate with PI and coordinator; get support working with school

During the second year we observed a change in the professional goal with an undergraduate Fellow, who graduated from Civil Engineering and decided to pursue a Masters in Education. As this individual continued as a Fellow in Years 3 and 4, she has been able to overlap many of the engineering concepts as well as educational strategies into her program as well as STEP activities. With her engineering background, she will be an excellent teacher in the near future. We have also observed a change in another fellow's professional goals. As a third year Fellow, this person graduated with a Masters in Electrical Engineering but has decided to pursue an Alternative Educators License (AEL) through the Ohio Department of Education. [NOTE: The Fellow training courses fulfill Ohio requirements to become AEL teachers if they take an adolescent psychology course and a teaching field content test.] This fellow has decided to teach math for several years before working in the engineering field.

Students

Project STEP recognizes that effective science and mathematics education requires authentic and inquiry-based learning. Students must be able to link the relevance of their education with events and issues occurring within their community. They must be able to experience how it allows them to participate as effective citizens in a technology-driven society. This secondary goal is achieved through these objectives relating to the middle and high school students which are to:

- Increase student learning and interest in math and science.
- Directly incorporate secondary school teachers into the teaching and mentoring of the Fellows.

- Implement hands-on, inquiry based activities into the secondary school science and mathematics curriculum that enhance and reinforce basic concepts already taught in the secondary curriculum.
- Motivate secondary school students, through real-world experiments, observations, and measurements, to study problems that affect their daily lives.
- Use these activities at various grade levels from different classes and schools, via peer teaching, collaborations, and the Internet, as they focus on common themes and learning tasks.
- Include computers, up-to-date sampling probes, and laboratory equipment in activities so students gain experience with current technology.
- Incorporate computer-based self-paced learning modules that will assist individual student learning needs, and supply background information and data that help facilitate execution of the projects.

How Project STEP has affected the students in the secondary classrooms is demonstrated through the impact they experience of the lessons, which is the focus of the next part of this paper.

Lesson Plan Impact

Fellows interact with teachers to implement authentic educational experiences for students in the classrooms through innovative real-world, community-linked lessons development integrating STEM skills to motivate students. The Fellows have developed a total of 66 high quality lessons over the past 3 ½ years. A lesson plan booklet was developed which gives a one page summary of each lesson. These indicate the overall content of the lesson, the standards addressed by the lesson and the extent to which technology was incorporated. This booklet is posted at the project website. Additionally, each Fellow has an online portfolio that documents their lesson and its implementation. They also document the way in which the lesson was assessed and the impact it had on the students in terms of learning as well as any impact it had on their interest in science and math. The lesson plans, booklet, and portfolios can be accessed via the project website http://www.eng.uc.edu/step/.

Each lesson developed is evaluated by the Grant Coordinator and the teacher to check that the performance objectives and teaching strategies are appropriate for the student population and that objectives are tied to content standards. Lessons are tied to state standards and local curriculum. In addition, when the lesson is taught, the teacher evaluates the implementation of the lesson by the Fellow. Students are asked to give valuable input on each lesson through an activity feedback survey where they assess the lesson and knowledge gained. Fellows gather evidence of student work, analyze data, and write a lesson reflection including supporting documentation for successful lessons, which once compiled is disseminated to other educators through the program website mentioned above.

Overall, the Fellows report getting positive feedback from students and teachers about their lesson plans. In the weekly reports thus far they have reported a total of 32 incidents

where students offered positive feedback about the role of the Fellow in the classroom. In addition, each Fellow recorded observations of students being motivated by the hands-on aspects of the lessons. In their lesson plan assessments, Fellow gathered feedback from students about the impact of the lesson on their interest in engineering/science/math, level of learning, and confidence in science and math. Results from the student activity feedback surveys for 29 of the 66 lessons from the past 3 ½ years are listed in Table 3. This table shows that overall the lessons positively affect students' interest in the field of engineering; that the level of learning from the lessons is high; and that they feel confident about their ability to learn mathematics and science from the lessons.

Table 3. Student Feedback Surveys on Lessons
3 ½ Years – Sampling of 29 Lessons

Statement (Total Students Providing Feedback)	**No Interest At All** % students (# of students)	**Not Sure** % students (# of students)	**Somewhat Interested** % students (# of students)	**Very Interested** % students (# of students)
How would you rate your interest in the field of Engineering (428)	12% (53)	20% (84)	40% (173)	28% (118)
Statement	**Did not affect interest**	**Decreased interest**	**Increased interest**	
Did this program affect you interest in engineering in any way? (399)	54% (216)	5% (21)	41% (162)	
Statement	**Nothing new**	**A little**	**A lot**	
How would you rate your level of learning today? (325)	8% (25)	55% (179)	37% (121)	
Statement	**No**	**Not sure**	**Sort of**	**Definitely**
Did this program make you feel more confident about your ability to learn science or math? (436)	12% (54)	14% (61)	46% (201)	28% (120)

Student Feedback on the lessons has been very positive. Here are comments that students have made after participating in a STEP lesson:

"I liked that it was a challenge and didn't come as easy as everything else."
"I liked that I was able to participate in something fun and educational."
"I thought it was good to see vectors related to what we were doing."
"Today's activity was good because it combined math that we learned before with real world situations."
"What I liked most about this project was that I actually learned and took an interest about something that I'd never bother to do research about."

"I liked that we got to look deep inside the situation and think on our own and develop an advertisement that would interest consumers."
"What I like the most about today's activity is that it gave me an understanding of what a truss bridge is."
"It opened up our minds to a whole new different way of doing things. And we learned the background of what it takes to make something"
"The thing I liked the most was figuring out the graphs and finding out how to improve the roadway."
"What I like most about the portfolio project was actually working out the equations. And I like the graph's and charts."

Additional data on the impact of Project STEP on students' attitudes towards science and mathematics showed increased interest, confidence, and motivation toward STEM learning.

Fellows also provided reflections that recorded their own observations about the lessons. The following samples exemplify what the Fellows were observing about the impact of their lessons on students:

"It was nice to see that the students' knowledge of the concepts increased following the activity. Remarkably, we didn't concentrate on teaching them these concepts; rather the students increased their knowledge through active learning. No time was spent by the STEP Fellows on how to better think about these terms, but the activity forced them to utilize the meaning of the terms to prove the value of various angles."

"Project Biome was a great experience. I was able to see many of the students everyday and this helped us get to know each other that much better... This was definitely a learning experience for me! I will take everything I have learned into consideration when I am developing my next lesson."

"Allowing the students to create their own rockets helps them digest the engineering design principles, and it encourages critical thinking with a limited supply set."

"Overall, I was very pleased with the outcome of this lesson. The didactic portion of the lesson was aided with the power point presentation and the students responded to me as if I was the regular teacher. After giving the students the task of building the vehicle with the fixed set of supplies, many looked at me as if I was kidding. It didn't take but a few minutes for some group to really start cranking on their design work, which was mostly done by pulling out the parts we gave them and looking at them (most did little or no paper & pencil sketches for their designs)."

"Over all this was a fun lesson for the students and myself. One of the students said, "Miss. D, this lesson is ingenious." I took it as a compliment. Also as an engineer I really feel that it give students a good idea of the struggle engineers encounter between design, cost, and aesthetics."

Feedback on Project Implementation

One significant area of the grant is Fellow training to prepare them to teach in the classroom. This year the Fellows completed an Instructional Planning course and a Teaching Practicum with the Grant Coordinator. The course evaluations for both these courses indicated the Fellows felt these courses were effective in helping them develop good teaching skills and giving them exposure to best practices. For the Instructional Planning course, Fellows reported the following;

100% The course provided useful information about best teaching practices and instructional approaches.
86% Have a greater understanding of how education, research and professional activities can overlap to affect my own success.
86% Helped develop authentic learning modules for middle and secondary classrooms.

Fellows rated the impact of this course on specific teaching skills. The majority (two-thirds or more) said the course increased their confidence in the following areas;

- Knowledge of relevant content
- Design and implement inquiry based lesson plans
- Design and implement procedural lesson plan
- Design and implement hands-on activities
- Use of computer based presentations
- Design and implement inductive lesson plans
- Design and implement deductive lesson plans
- Use of Bloom's taxonomy
- Use Cooperative learning strategies
- Design standards-based goals and objectives
- Use of appropriate questioning strategies
- Use levels of understanding to design teaching units

In evaluating the teaching practicum course the Fellows reported the following:

100% At the conclusion of both practica, I was able to design secondary-level, authentic, inquiry-based learning activities and projects that are based on technical expertise and knowledge.
100% I fell I have an adequate understanding of educational methods and theory and can apply this to my lesson planning for Project STEP.
86% I have greater confidence in my ability to prepare and present lesson plans as a result to taking these courses.
71% I can see how my experience with these courses will help my professional development as an engineer.

The Fellows reported that both courses made them better prepared to teach and helped them to connect their engineering study with teaching in the classroom.

In April of Year 3, the Annual Open House was held to present summaries of the activities developed thus far and the overall progress on the grant. There were 24 in attendance; including UC faculty, administrators and graduate students and CPS teachers. Participants were asked to complete a survey after they heard the program and reviewed the Fellows' posters on display. The response was overwhelmingly positive.

Respondents indicated that the Fellows did a good job presenting their lessons in the poster session as indicated by the high level of agreement with each of the following statements:

100% The posters were clear and easy to understand.
100% The activities include authentic, inquiry-based learning.
93% The activities included learning assessment.
85% The activities are consistent with the goals of the grant.
100% The activities seem to engage the students and the teachers in a meaningful way.
100% The activities reflected creative ways to approach science instruction that helps the student relate science to their own lives. 100% It is clear that the activities address science, math and/or technology standards.

Most agreed that the grant implementation was going well, demonstrated the use of teamwork and consistent with the stated goals and objectives. However, one area of concern was the involvement of the teachers and the level of understanding they have about the grant.

91% There appears to be an effective working relationship amongst the members of the grant team.
83% The implementation of the grant has proceeded in a timely and effective manner.
72% Collaboration with teachers in the schools is evident from the activities presented.
91% The Fellows have been engaged in the grant in a way that is consistent with the goals of the grant.
81% The accomplishments of the grant have met or exceeded my expectations based on my knowledge of the grant.
45% The teachers seem to have a good understanding of the benefits this grant will bring to their classrooms and schools.
82% Overall, the implementation of the grant is consistent with the goals and objectives of the grant.

<u>Teachers</u>

Focus groups during each year of the grant gave teachers the opportunity to provide further input as to the strengths and weaknesses of the Fellow-teacher interaction. Teachers expressed that they viewed the interaction with the Fellow as positive collaboration with a colleague and a motivator for them. Teachers said it was an experience that they rarely participated in with teacher colleagues within their own

schools. The collaboration occurs in the form of lesson development, content sharing, classroom best practices, and knowledge sharing at school, through email, and sometimes over the phone after regular school hours. The motivation occurs in the form of reciprocal mentoring between the teacher and Fellow, the Fellow also was seen as a motivator for the teacher to become reinvigorated to learning, teaching, and in attempting new strategies within their classrooms.

The effects on students of the lessons developed collaboratively or individually by Fellows and critiqued by teachers were best realized over several years of exposure. The teachers who had been in the program for three years with their students reported that students had a strong understanding of what a career in engineering meant and that higher numbers of students who had graduated were returning to say they were majoring in engineering or pursuing a minor in engineering to keep that career option open. During the focus groups, one teacher mentioned she had 20 students from the most recent graduating class return to discuss how they were majoring or taking a minor in engineering in college.

Through working with the Fellows, teachers had realizations about their own weaknesses in integrating STEM skills through inquiry-based, real-world lessons. Some of the teachers had been out of school for a while and knew that the Fellows were teaching them content and skills that they lacked. The Fellows were able to assist them in learning new methods, new content, and new ways of thinking to embrace skills for development of lessons to motivate students to learn STEM concepts in a fast-evolving, global economy where the need for the skills rise daily.

Fellows in the classroom were motivators for the students and teachers stated that students also looked at teachers differently due to the teacher-Fellow interaction students witnessed. The teachers felt that the students respected their knowledge after seeing how they were able to interact with the Fellow successfully. The Fellow was an engineer and the teacher was able to understand the engineer and sometimes taught the engineer. Many teachers started co-teaching with their Fellows and found that they were changing their style of teaching. Teachers indicated that meeting state standards mandated that the focus on teaching skills and concepts to students and that the demand to meet standards hindered their attempts to develop and implement the types of lessons that they were able to accomplish with the Fellow. Teachers mentioned that they did not realize at first the value of the real-world inquiry-based, technology driven lessons that the Fellows were implementing. As the school year progressed, teachers found that they were able to refer back to these lessons to teach new skills or concepts. Student interest level and excitement to attend class was high on days these lessons were implemented.

Focus group analysis also indicated there is never enough time for the teacher-Fellow team to do all that they would like to accomplish and that Fellows are over eager to teach and to interact with students and teachers. Fellows need to be managed through the planning and administrative phases of their work closely so that paperwork is completed timely. Teachers would like to meet the behind-the scenes university faculty and coordinator team members earlier in the year and would like additional networking

opportunities. Although most Fellows exceeded their teachers' expectations, frustrations did arise for teachers when they were paired with Fellows who lacked initiative and necessary diversity skills needed for working with students. Teachers also indicated it was important to keep the amount of administrative duties to just those necessary so as not to over-burden the Fellow and reduce the number of hours contact in the classroom.

Here are samples of Teacher responses to working with the Fellows in Project STEP:

"I just find my job overwhelming, so much to do, so much to read and so much to keep up with, it just keeps pushing me to, you know, alright I can do this lesson but they come by with that's even better and it pushes me and it makes me want to do better also. They really inspire. They inspire me. It's like, 'Oh, I've been teaching for twenty years and they're coming in and doing that.' It's like, 'Oh, this is great.' It really keeps us moving too. It's good. "

"One other thing too that our Fellows have done, we did a biome project, of course Tom's alluded to, and when we did that they actually assigned me a biome by the way too, so I had the same project the kids were doing. So as I went through it I noticed that I was using the websites and using the computer and doing the Power Point and things that I had not really done that much of myself in the past too so they were teaching an old dog some new tricks."

"I can add one other thing and that is that they teach us a lot. Some of us have been out of school for a while…."

Technology Workshop

Technology workshops were designed by Fellows to provide relevant hands-on technological training on technology skills and technology integration. Starting in year 3 of the grant, Fellows analyzed the need of teachers and classrooms they work with when deciding on what hands-on workshops to offer. Workshops in year 4 included designing and using web quests, Internet resources, concept mapping, digital story telling, excel, word and graphics. STEP teachers are required to attend, other teachers are invited as well. Workshops provide teachers with information for using technology; skills to align integrate technology standards, and provide relevant skills and resources that they will be able to utilize in their classrooms.

The workshop allows teachers time to learn and practice technology skills with guided help outside of the classroom. Advancement of technology integration into the teachers' classrooms is assisted by the Fellows guidance as the year progresses. The technology workshop parallels the technology skills between teacher and Fellow allowing them to be able to collaborate together more effectively to integrate technology into lessons to motivate students and to meet national and state technology standards.

Upon completion of the workshop, teachers evaluate all facets of the workshop immediately and evaluate integration of technology into classroom through focus groups.

Analysis of their input is important for STEP in creating and improving workshops to meet the needs of teachers. Table 4 presents an analyses of this year's technology workshop indicating that overall the participants agreed or strongly agreed that Fellows had developed quality training.

Table 4. Technology Workshop Satisfaction Ratings Year 4 1-Strongly Agree, 2-Agree, 3-Disagree, 4-Strongly Disagree	
Statement	**Mean**
The purpose of this workshop was clear.	1.21
The workshop fulfilled this purpose.	1.32
The workshop was well organized.	1.16
The information sent in advance of the workshop was effective.	1.39
The facilities were sufficient for the workshop.	1.16
This workshop has given me valuable information for using technology in my classroom.	1.26
The work sessions were a valuable use of my time.	1.26
The workshop is aligned with the technology standards or will help address one or more of those standards in my classroom.	1.42
I will be able to use what I learned in the workshop in my classroom.	1.32
The material would be relevant to most science classrooms.	1.19
I would recommend this workshop to other educators.	1.21
The presenters were informative and well prepared.	1.16
This was a good time to offer the workshop.	1.44
The material was presented in a way that makes it easy to apply to my own classroom situation.	1.26

Here are examples of what Teachers reported about the workshop:

"I really learned a lot of things to share in the classroom. I've already shared some of the web quest and free resource information with the math department! Overall the workshop was excellent with very applicable and valuable information. I was impressed!"

"There was no one thing that I would say I couldn't find very helpful with teaching. It was a GREAT workshop (Especially the Digital Story Telling)!"

"Everyone did a great job and the time and effort involved in the preparation and presentation was obvious."

Summary

We conclude this paper by providing the highlights of the results of Project STEP. We find that when we connect Fellows with Secondary Teachers with the goal of increasing the math and science literacy of secondary students, the following is found:

Graduate Fellows have:

- Gained direct teaching experience in secondary classrooms.
- Improved their teaching skills by continuing to design, develop, implement, and assess authentic learning and inquiry based activities.
- Applied their scientific and technical knowledge towards education.
- Developed, implemented and assessed standards-based, hands-on lessons activities.
- Practiced best teaching methods.
- Raised awareness of education as a career option for the future.

Secondary students have:

- Interacted with their community while learning science and mathematics.
- Participated in higher-order thinking and problem-solving skills.
- Received mentoring from Fellows and university faculty.

Teachers have:

- Interacted with university facilities and faculty.
- Constructed new knowledge and new educational pedagogy.
- Gained professional advancement through the presentation of results at professional conferences and through publishing papers.
- Improved their own teaching skills.
- Nurtured future educators through their involvement with the Fellows.

Through each of these accomplishments, the efforts of the grant have encouraged secondary students to enter into engineering careers and have a more positive attitude about science and math. In addition, the fellows have learned a tremendous amount about education and teaching. The goals of this grant are to influence secondary science and math students and the above accomplishments are steps toward this goal.

Formative and summative evaluation have been and will continue to be conducted to assess the project's effectiveness on Fellows' teaching skills and its impact on high school science and mathematics education, and to continually improve the program as it develops.

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