Impact of Infusing Information Technology Rich Engineering and Science Curriculum at the Elementary and Middle School Level

Abstract

This paper documents the development, implementation efforts, and results of SUNRISE (Schools, University 'N' (and) Resources In the Sciences and Engineering-A National Science Foundation (NSF)/George Mason University (GMU) GK-12 Fellows Project), a unique graduate Fellowship program at GMU that targets graduate students working in the grade 4-6 school environment. SUNRISE is a new GK-12 project aimed at partnering STEM (Science, Technology, Engineering, and Mathematics) graduate students (Fellows) with school teachers from three different school divisions in Northern Virginia. The objective of this project is to build a unique model of collaboration among elementary and middle schools, school division administration, and GMU to foster systemic efforts in implementing Information Technology (IT) rich STEM content-knowledge into grades 4-6 education by graduate Fellows, with the potential to enhance the delivery of science instruction and provide long term professional development for teachers. This is achieved by constructing a framework that provides training, exchange of information, and integration of scientific research from diverse disciplines with teaching to make science exciting for students. Sponsored by NSF's GK-12 program, the GMU implementation serves as an exemplary model for the emerging trends in STEM education at the elementary school level. This paper presents evidences of increased student learning of fundamental science when the classroom topics are enriched with and related to IT rich real world examples.

Introduction

Several reports indicate lack of proficient performance of America's children in science and mathematics. The reports also indicated the need to give teachers the tools they need to enrich the learning opportunities for K-12 students in science and mathematics. Particularly, these tools include the professional development and training on content materials to the teachers. Below, we first summarize a few of the findings from these reports which motivate our educational research. Further, we provide details of our research and observations.

"Recent reports of the performance of America's children and youth from both the Third International Mathematics and Science Study (TIMSS, 1999[1] and 2004[2]) and the National Assessment of Educational Progress (NAEP, 2000[3]) echo a dismal message of lackluster performance"[4]. For example, TIMSS (2004 [2]) report "suggests that the performance of U.S. fourth-graders in both mathematics and science was lower in 2003 than in 1995 relative to the 14 other countries that also participated in both studies". According to the National Commission on Mathematics and Science Teaching for the 21st Century, the learning shortfalls are due in part to a shortage of qualified science and math teachers (Sterling, 2004[5]). Another report by the National Science Board notes that in the period 1990-2003, most students in grades 4, 8 and 12 did not reach proficient performance levels in both mathematics and science (NSF 2006[6]). Furthermore, under the No Child Left Behind (NCLB) act of 2002, policy makers have relegated science to the backburner by directing a majority of the resources to reading and mathematics-the first areas to be assessed and reported with adequate yearly progress (AYP) (Slutskin, 2005[7]).

Science is slated for testing only in 2007-2008, and only a few school divisions have started monitoring their competency in science. In the State of Virginia, only 48% of school divisions met the AYP requirement for 2004-05[8].

A recent report by the BHEF[9] (Business-Higher Education Forum 2007) states "…chronic low student interest and achievement in mathematics and science poses an acute challenge to American economic competitiveness." The BHEF membership is made up of members from business and academia.

"Now three decades old; it is time that the nation heeded it - *before it is too late*" [4]. A National Research Council panel (Brunkhorst and Lewis, 2000[10]) issued a report that urged increased cooperation between universities and GK-12 schools in teacher education and professional development for teachers of science and mathematics. The NSF GK-12 program offers a unique opportunity to address this need.

Implementation

The implementation started with the recruitment of Fellows and Teachers in 2007. The program supports eight Fellows from STEM disciplines who are paired one-on-one with eight teachers, one pair per school. 65% of the Fellows are women graduate students. One of the eight spoke a language other than English at home. The fellows were given a two month long training program by the project co-PI from the College of Education and Human Development. The training included an understanding of the Virginia State Science Standards of Learning (SOL) [11], preparing and delivering of sample lessons, and discussing general topics on pedagogy particular to elementary school teaching. The Fellows worked out a schedule with the teacher. The Fellows began their visits to classroom, identified the science needs with the teacher and began contributing to the enrichment of the lessons and discussing the science behind the lessons. The Fellows were introduced to the children as Scientist, Researcher, or an Engineer. Thus, a strong foundation was laid for a long-lasting partnership between the school and the university.

Ongoing Activities

One of the key activities of the Fellows is the enrichment of existing curriculum and leading the discussion of the science behind the experiments. The Fellow and the teacher plan the activities a week ahead so that there is sufficient time to enrich and test the lesson before they are presented to the classroom. Another activity consists of bringing lessons from their engineering and science research, and graduate education into K-12 environment. These new lessons are tied to the SOL and the IT theme is emphasized where applicable. Fellows also act as guest lecturers in other science classes who are not participating directly in the SUNRISE project. The Fellows help with field trips, judge science projects, and answer general science questions that are dropped in a question box.

Examples of lessons that were enhanced with a deeper understanding of the science behind it include waveforms, light's electromagnetic spectrum, alternative fuel energy, earth science and so on. Some highlights of the advanced engineering and science lessons that are not part of the textbook include discussing and showing videos about Sun's electromagnetic spectrum and solar winds while discussing Earth science lessons, demonstrating protein bonding forces while introducing lessons on force and motion, demonstrating an infra-red camera and night vision while discussing light and sound lessons, and discussing RADAR and its uses along with lessons related to weather.

Observations from Program Evaluation on the Impact of the GK-12 program

The data sources used for this report include open-ended fellow interviews, a fellow survey with email follow-up, a teachers' survey administered in 2007-2008, interviews with participating teachers and administrators in the schools, observations and participant observation (assisting with lab activities) of fellows in the classrooms, examination of print and on-line documents including worksheets, fellow presentations, project memos, consent forms, publicity materials (brochures and posters). The program evaluator also met on numerous times with the PI and one of the Co-PI's and has done a survey of the views and activities of the project manager. The evaluation examined web sites and materials produced to date by the project and on-line project documents and forms. In addition, artifacts used in the hands-on activities in schools have been the subjects of analysis.

The data analysis has been qualitative and has generally followed the methods outlined by Strauss (Strauss et al. 1985[12], Strauss and Corbin 1991[13], Strauss and Corbin 1997[14]). The theoretical perspective used as a "place to see from" (Haraway 1991[15], Suchman 1994[16]) is that of situated cognition (Henning 2003a[17]) and activity theory (Engeström et al. 1999[18]). The premise is that learning takes place primarily in social situations using an assortment of resources that are both verbal and nonverbal. The situated nature of learning implies that the routines used to accomplish learning are constantly evolving and fluid, fitting the goals of the learner to the situated activity at hand. Situated learning looks at the social arrangements that are a part of learning, and is of particular value in examining the impact of interventions that flow from the scientifically trained graduate students who are working with teachers who are trained primarily in educational practice. This approach takes into account the social and professional orientation of the change agents (fellows), which differs in important ways from that of the professional science teachers in the schools.

Indicators of Project Effectiveness

This first year project had gotten off to a very strong start with in-depth activities that include effective links between schools and university in the early stages of the project, a whole school approach that includes innovative fellow produced lesson and curriculum development, strong mentoring activities, establishment by the fellows of strong teacher partnerships and school wide ties, a solid base for project administration including timely and sensitive communication by the PI, a good start on the integration of fellow research into school lessons, and a very high quality fellow paper submission to ASEE 2008[19] as well as representation at AAAS and the annual GK-12 meeting.

Innovative fellow developed lessons

Evidence of innovation in lesson development and the integration of graduate fellow research into the classroom presentations were found in classroom visits by the evaluator, fellow interviews and surveys and in reports and papers produced by the fellows as verbal reports at project meetings attended by the evaluator. The evaluator observed a very effective presentation of a lesson by a fellow in physics doing Ph.D. research in magnetic reconnection at the heliopause that integrated her research into a lesson on light and sound. Images of the sun from the Big Bear and SOHO solar observatory sites were used to show the electromagnetic spectrum. Student interest in the presentation was palpable during this lesson with high attention, exploration and questions. The students had a rare opportunity to see these images of the sun and to interact with a fellow who is obviously very enthusiastic about her research in this area and knows the territory well. Another fellow borrowed an infrared camera from a friend and brought it into class. He commented "There is basically no part of my research that is covered by the SOLs (science standards of learning)… Despite this, my wider scientific knowledge and varied experiences are always helpful in the area of relating an elementary scientific idea to the real world, translating it from something they are being forced to do, to something that they might care about." This infusion of energy, optimism, and love of scientific work by the fellows is at the very heart of the success nationwide of the GK-12 program and will go a long way in helping to recruit students into science and engineering.

In addition to a number of new fellow created lessons, fellows reported that they were able to modify existing lessons. One fellow in a middle school observed that "the text book for 6^{th} grade science…is a fairly good text and has some interesting labs. I try to use these whenever they are applicable because I know that my teacher will be able to duplicate them for years to come." This fellow modified a lab on physical and chemical weathering, greatly improving it. Another fellow substituted high refractive index glass prisms for plastic for a lab in the county lab kit on primary and secondary colors to better accomplish the objectives of the lab. There are numerous other examples of fellow modifications of existing labs and lessons. These modifications are significant from a sustainability perspective as the teachers will be able to use these modifications within the existing framework of their school.

While discussing standards issues with a fellow, she admitted that they can be limiting in terms of the scope and time for additional science topics. However she accepted these standards and told the evaluator, "This is what we are here for, to help." The willingness to integrate fellow lessons into the framework of the standards (SOLs) is beneficial to the long term viability of project efforts.

Curriculum development and a whole school approach

An interesting early success for the project is the development of a number of curriculum projects, a teacher-fellow developed weather station, a fellow created inter-session project on simple machines, magnetism and electricity that included a visit to a electronics lab at the University and a series of modules on force, motion, and energy. The weather station was an idea of the participating teacher who enlisted the help of the fellow whose research area involves solar weather. The evaluator's observation notes, "Very funky weather station on an old stump, has their interest and attention, very special to be with this fellow just as the three students and fellow go out to carry out this task (of making observations). I feel fortunate to have gotten here just as they came out of the building." Students and the fellow make daily observations. Inside the school in the main hall just outside the cafeteria is a chart, bar graphs and other colorful and artistically arranged information where the students record their observations. Students from all three fifth grades participate together with students in 4th grade. The whole school plus parents and other visitors get to see the results in the lobby.

A fellow working in cooperation with his elementary school teacher developed an inter-session program on simple machines, magnetism and electricity. The Fellow quoted "The inter-session was great. I did science all day. There were two groups (morning and afternoon) and I would teach the same thing in the morning as the afternoon. This was interesting for me because it let me try different ways of explaining the same material, honing my methods." This fellow was very sensitive to staging the learning and providing challenges. He started with introductory exercises to get every one talking that weren't too heavy. He told the evaluator that "I bridged into the much harder energy lab with and exercise requiring data recording, a simple formula, and graphing."

Another fellow developed a lesson for the light and sound topic in cooperation with the band director. This fellow reported that " The band director and I gave various concepts and definitions they were covering in class as the band director played various instruments to demonstrate topics such as pitch, echoes, how instrument size and frequency are related, etc. I found that using instruments to teach the concepts was very effective in showing practical everyday uses of class material." Again, a whole school approach effectively ties in teachers from various disciplines. Another example of this approach is a fellow who began posting weekly science updates in the restrooms that the teachers use. On a school visit the fellow was showing me various school activities and took me down to the teachers rest room, saying "… this is little weird but I post these updates here." These updates have text and pictures and include information on questions students have been asking and other information on the current lessons. The fellow has gotten a very positive response from the teachers on these. Innovative, whole school approaches such as these are solidifying and extending the accomplishment of project goals at a school wide level.

Another fellow developed project involving a series of modules on force, motion and energy (Advanced FME (Force, Motion, and Energy Module)that also involved the fellow's research in protein folding (Shrestha et al. 2008) [19]. This project demonstrated the utility of challenging the students with advanced material early in their academic careers.

In some schools a question box (drop box) system has been introduced where students leave their science related questions for the fellows. These are answered by the fellows either via classroom experiment or just via an oral explanation. One of the teachers at another school claimed that her quarterly scores went up because of the GK-12 program in her classroom. While it's hard to quantitatively prove, it can certainly be inferred that the fellow has had a very positive influence on the children. Fellows also participated in judging Alexandria City Public Schools and Fairfax County Public Schools science fair projects and conducing field trips in Fairfax County Public Schools and Manassas Park City Public Schools.

Overall, the project has been successful in creating strong fellow-teacher partnerships as can be seen from the various activities at the schools. The fellows were introduced to the students as an engineer or a scientist and they created an impression of a role model among the students. K-12 children whose classrooms are visited by fellows have been engaged in these new and often enriched lessons. There are several evidences where students ask the fellow about the next week science lesson which shows their level of excitement and engagement.

Conclusions

The paper summarized some of the results from the baseline evaluation conducted through surveys, and challenges that lay ahead for the SUNRISE GK-12 project. From what we have seen so far we make two important conclusions. 1) Our GK-12 project has already laid a strong Fellow-Teacher partnership since its inception in September 2007, which we conclude, is the key ingredient to the success of any effort such as introducing new modules, identifying the STEM needs of the schools, and delivering the assistance that will better prepare the teachers to teach STEM topics. 2) One of the important focal points of the project, which is also a challenge to implement, is to continually emphasize on the importance of the discussion behind the science in each experiment that is conducted. This was noted from the initial surveys that teachers first wanted assistance in deeper understanding of the science behind their existing lessons through more hands on modules. Results from the pretest and post-test conducted by Fellows in the classroom (not presented here) have indicated a substantial gain in knowledge by children particularly when the science behind the experiments is thoroughly discussed. We strongly believe that the SUNRISE GK-12 project serves as one source of evidence that demonstrates the importance and the process of building partnerships among university’s engineering/technology departments, schools of education, and the K-12 STEM education that would strengthen the nation’s educational enterprise.

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