An Integrated Approach To Recruiting And Retaining Appalachian Engineering Students

Gary Winn, West Virginia University, USA
Robin Hensel, West Virginia University, USA
Reagan Curtis, West Virginia University, USA
Lydotta M. Taylor, The Edventure Group, USA
Gene Cilento, West Virginia University, USA

ABSTRACT

Recruiting and retaining Appalachian engineering students is difficult for a variety of ecological and cultural reasons. At West Virginia University an NSF STEP grant[1] has allowed the development specific interventions to evolve from an ecological model we describe here. The interventions include web-based, realistic engineering design exercises linked to state and federal content standards and objectives; a week-long residential summer camp addressing social and academic challenges for rural and minority students; a full set of retention efforts including "rescue courses" targeting struggling college freshmen in early stages of academic difficulty coupled with required study labs to underscore time management and persistence skills early in a freshman's academic career. Process and impact measures suggest that this package of interventions is effective in building interest in engineering not only in high school teachers but in the high school students themselves. While freshman retention has improved remarkably to an all time high of 84%, we conclude that it may take longer than five years to establish among youth in Appalachia an "engineering identity" as a cultural norm. We discuss the key aspects of our 5 year NSF project along with findings and conclusions.*

Keywords: Engineering; Recruiting; Retention; Appalachian Students

INTRODUCTION

A dire warning was issued in 2006 regarding the current threat to economic vitality and even the research base of the United States. The National Academy of Sciences documents discussed issues and problems in increasing the numbers of females in science and engineering fields in the U.S., and it suggests, unfortunately, that "girls are lost at every transition" and that "in the transition to graduate school, more women than men with science and engineering degrees opt into other fields of study; [and] from doctorate to first position, there are proportionately fewer women than men in the applicant pool."[2]

Among the conclusions of the massive document is the caution that "The consequences of *not* acting will be detrimental to the nation's competitiveness" meaning that ignoring fully half of the nation's brain pool puts the nation's security, economic vitality and quality of life in jeopardy.

Low incomes, declining economic prospects and by almost any other measure, the difficulties in attracting high school students to STEM careers are enhanced in Appalachia, and especially in West Virginia. Tang and Russ found that for gender and career development, the literature is scarce, and partially because the "people of Appalachian culture have become an invisible minority… they do not appear outwardly different from mainstream Americans." [3] When high out-migration and low in-migration of college graduates occurs, few people really notice. In fact, McDowell County in southern West Virginia has the lowest in-migration of the 400-plus counties making up all of Appalachia. McDowell County residents have a median household income of $16,931 in the 2000 United States Census, compared to $41,994 for all U.S. residents. [4]

Over 20 percent of US residents have college degrees, but only about 14 percent of residents in Appalachia have college degrees, with West Virginia as the lowest state on this measure. In the most rural Appalachian areas (subtracting out the large metropolitan areas), the college graduation rate averages only 7.75 percent, with Lincoln and McDowell counties in West Virginia at the very lowest end of that scale at 4.72 percent and 4.59 percent, respectively. One major industry in Appalachia, coal mining, employed 229,494 workers in 1980, but dropped to 99,801 jobs by 1996. The manufacturing sector in Appalachia lost 202,173 jobs in the same period. The poorest regions in Appalachia compete with more affluent states and even Appalachian metropolitan areas in attracting the jobs of the future. [5]

For generations, the jobs that do exist in West Virginia, coal mining, timber, chemical manufacturing, and steel making, tend to be largely blue collar and male-dominated, a situation providing few engineering role models, much less female engineering role models. This problem is made even worse when cultural mores in Appalachia encourage mothers to spoil their sons to keep them in the local area, and discourage girls from having jobs or careers outside the home. Tang and Russ say, "parents are distrustful of career education programs that prepare their children for opportunities not available in their home area, and that could require them to leave the family. Many [parents] feel they are in contention with the schools over the future of their children." [6]

RESULTS OF A FIVE-YEAR PROJECT AT WEST VIRGINIA UNIVERSITY

A project funded at West Virginia University (WVU) through a Science, Technology, Engineering and Mathematics Talent Expansion Program (STEP) grant from the National Science Foundation (NSF) supported a multi-intervention initiative called "Engineers of Tomorrow" (EoT) designed to attract high school students into the career pipeline, with a focus on women and underrepresented minorities, and with a further focus on retaining them once they enroll in the respective colleges.

One important part of WVU's EoT project which cuts across all of its individual interventions is mentorship, or peer influence, defined loosely as a structured, informal relationship among high school, engineering undergraduate, or graduate students for the purpose of sharing information about college life, college courses, career choices, and engineering as a profession. [7] The peer mentors were engineering undergraduate and graduate students who were *age- and major-appropriate* (currently pursuing or recently completed undergraduate Engineering degree at WVU), *culture-appropriate* (Appalachian-born and raised); and *skill-approp*riate (most struggled with, but eventually excelled in undergraduate engineering program). Evidence of the strength of the larger Social Stress Model adapted for Appalachia for the EoT project is discussed elsewhere.[8, 9,10,11,12] We used the Social Stress model precisely because it has been used in a wide variety of youth development research (alcohol and smoking prevention, for example) and we wanted to see if a similar approach could be used in STEM education among Appalachian youth.

Three separate but carefully coordinated interventions which serve as the foundation of our program's success are described here. The first intervention familiarized teachers with the importance of engineering in solving realistic societal problems through web-based, hands-on design exercises to use in teaching their classes. The second intervention introduced bright high school aged students to engineering careers through a fast-paced summer camp; and the third intervention involved intense retention efforts including required “study labs” and "rescue courses" taught by peer mentors. These three interventions are the core of our project and are presented below.

INTERVENTION #1: TOOLS TO INTEGRATE MATH AND ENGINEERING (TIME KITS)

Appalachian and West Virginia high school teachers are hard pressed to expose their students to STEM career fields because they lack first-hand knowledge of STEM careers. In fact, because of a shortage of qualified teachers, many teachers, especially science and math teachers, in the region often teach out of their field of certification or expertise, and teach in subjects without at least a minor in the subject. On this scale, West Virginia teachers rank tenth from the bottom in a recent poll.[13] As Jerald and Ingersoll show in Figure 1 extracted from their 2002 paper, almost twice as many impoverished and minority students are taught by out-of-field teachers.

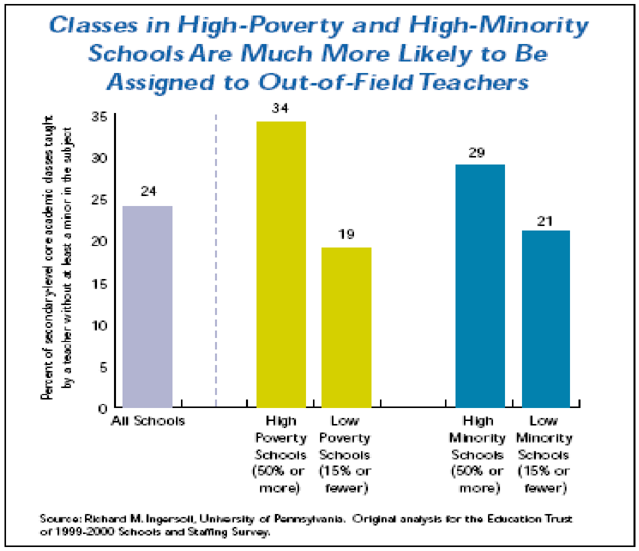


Figure 1: Out-Of Field Teachers By Poverty Level

Pre-service teachers report that they do not understand what engineers do.[14, 15] Those teachers are unlikely to take engineering courses during their undergraduate years because of the layers of engineering pre-requisites imposed by the engineering college, and policies that block registration in engineering courses to out-of-college students. A novel way to introduce engineering concepts and disciplines to high school was needed, while ensuring that "design exercises" were realistic applications of math or science within a social context of application.

Tools to Integrate Math and Engineering (TIME Kits) were created as a set of curriculum modules, available to teachers through a website, that present and use math and science content immersed in an engineering concept. These curriculum modules meet teachers' needs to address curriculum standards mandated by No Child Left Behind legislation and the West Virginia Department of Education's emphasis on 21st Century Skills (i.e., critical thinking, problem solving, interpersonal and collaborative skills, global awareness, and financial and civic literacy). Each TIME Kit was developed by a team comprised of certified secondary math or science teachers, practicing engineers, engineering professors, and undergraduate engineering majors. The curriculum units incorporate the application of math and science content and several 21st Century Skills as students work together to analyze a societal problem and design a solution. Full TIME Kit lesson plans are available at www.TheSolutionSite.com. These curriculum modules were used in high school classrooms, and student performance and attitude data was collected.

TIME KIT FINDINGS

Student data provided by The Edventure Group (the expert contractor on this project) in 2010, are considered the first true impact data. Evaluation of the TIME Kit intervention during the 5th and final year of the Engineers of Tomorrow project involved a pretest-posttest comparison group design for student knowledge outcomes plus open-ended survey items for teachers to complete regarding their fidelity of implementation. In 2009, 25 high school teachers were trained and developed TIME Kits. During Spring 2010, 5 of these teachers provided data from two classes each: a) one class where they delivered TIME Kits and b) one class where they delivered non-TIME Kit comparison lessons covering the same West Virginia Content Standards and Objectives (WVCSOs). Three of the teachers completed open-ended survey items indicating strong fidelity of implementation of TIME Kit instruction and appropriate procedures for collection of comparison data. All 5 teachers administered a content knowledge test prior to instruction, delivered instruction on the same WVCSOs in a TIME Kit class and a comparison class, and then administered the same content knowledge test post-instruction (i.e., pretest-posttest-comparison group design). Data were provided from a total of 197 students: 90 who received TIME Kit instruction and 107 who received comparison lessons.

Figure 2 displays learning gains for Comparison and TIME Kit instruction for each teacher. Some teachers elicited substantially greater learning from their students with TIME Kits relative to comparison lessons, but other teachers did not see dramatic differences. Independent t-tests conducted separately by teacher (with Bonferonni correction for multiple comparisons) revealed that learning gain differences reached statistical significance for teacher 2 [$t(42)=5.50$, $p<.05$] and teacher 4 [$t(22)=11.17$, $p<.05$], but not for teachers 1, 3, or 5.

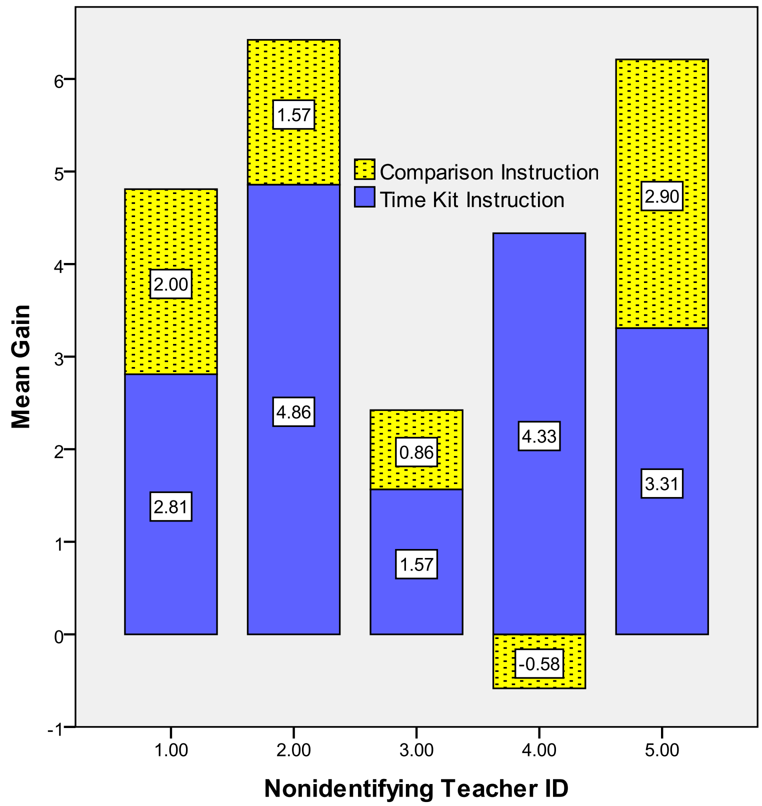


Figure 2: Mean Student Learning Gains by Teacher and Instructional Method

While the magnitude of learning gains was not consistent, gains were always in the expected direction (larger gains for TIME Kit classes) so data were aggregated across teachers and displayed visually in the figure above. Across teachers, students who received TIME Kits scored about 15% higher at posttest after scoring essentially the same as comparison students at pretest.

INTERVENTION #2: ENGINEERING SUMMER CAMP

Over 5 years, our week-long summer program at WVU's College of Engineering and Mineral Resources was designed to expose high school students to college life and to high-tech career opportunities in engineering and technology fields. The program focused on high school students, particularly females and minorities, but was open to all high school students. Highlights of engineering summer camp include:

- Participants stayed in the WVU residence halls under adult supervision. WVU engineering faculty and students acted as chaperones and mentors. Lodging, meals, and linens were provided at no cost. Students interacted with engineering college undergraduates and shared meals with them all week, day and night.

- Students learned introductory engineering concepts; used Excel®, AutoCAD® (later, ProEngineer®), and Visual Basic® software; practiced time management and study skills; and engaged in ACT/SAT preparation, "what to expect from the first year of college" discussions, and honest Q & A sessions about college life without adults or faculty in the room.
- Students worked in teams to produce an actual engineering design, going through an engineer's "design cycle" to solve a real-world problem, establishing budgets, testing a prototype solution, and arriving at a conclusion. In 2005, summer camp labs were taught by senior faculty and were judged anecdotally by campers as pretty basic and even mundane. During 2007, we added a substantial in-depth engineering lab activity thanks to outside funding from the Benedum Foundation, and we decided to greatly enhance the in-depth lab idea; campers have responded enthusiastically. By 2010, our in-depth labs revolved around demonstrations that would resonate with the 'I-Phone generation': smart materials, green energy, robotics, bioengineering, mechatronics and coal mining safety. These labs became exceedingly popular once they were taught by peer mentors (engineering students).
- Group activities included campus tours, laboratory tours, Personal Rapid Transit (PRT) rides, WVU residence hall visits, and trips to WVU's Student Recreation Center where campers could swim or play ball with college engineering students serving as chaperones and teams for pick-up basketball. Figure 3 shows students engaged in a typical summer camp design activity.

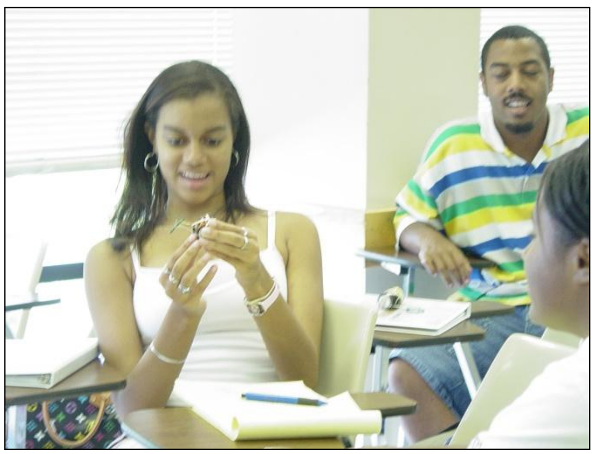


Figure 3: Summer Camp Design Project: "Electric Motor For A Buck", 2006

ENGINEERING SUMMER CAMP FINDINGS

Participant evaluation of the summer camp overall was consistently high (Table 1). The average across years was 8.26 out of 10 with 341 participants responding. Evaluations of the summer camp only once dipped below 8 out of 10 in 2007 when we dramatically increased the number of participants for the first time.

Table 1: Aggregate Satisfaction Scores For Engineering Summer Camp, 2006 - 2010

Year	Mean	SD	N
2006	8.205	1.5420	39
2007	7.698	1.5705	86
2008	8.616	1.1316	86
2009	8.741	1.0481	58
2010	8.125	1.2096	72
Total	8.255	1.3594	341

On a scale of 1-10 (10=Excellent; 1=Poor) I'd give this week's program

As shown in Figure 4, participants consistently reported a positive impact of summer camp activities on their understanding of engineering careers, math study skills, ability to use software emphasized (Excel, Visual Basic, AutoCAD), study skills, time management, and understanding of the SAT and ACT tests. The strongest impacts across years appeared on understanding engineering careers (Mean = 4.39) and the SAT/ACT tests (Mean = 4.11), followed by AutoCAD (Mean = 3.96), Study Skills (Mean = 3.85), and Time Management (Mean = 3.71). The lowest evaluations (Mean = 3) were for the use of Excel software in 2007 when we more than doubled the number of summer camp participants. Following examination of this data, we recognized that Visual Basic software would add more value for participants given that they generally entered summer camp already familiar with Excel.

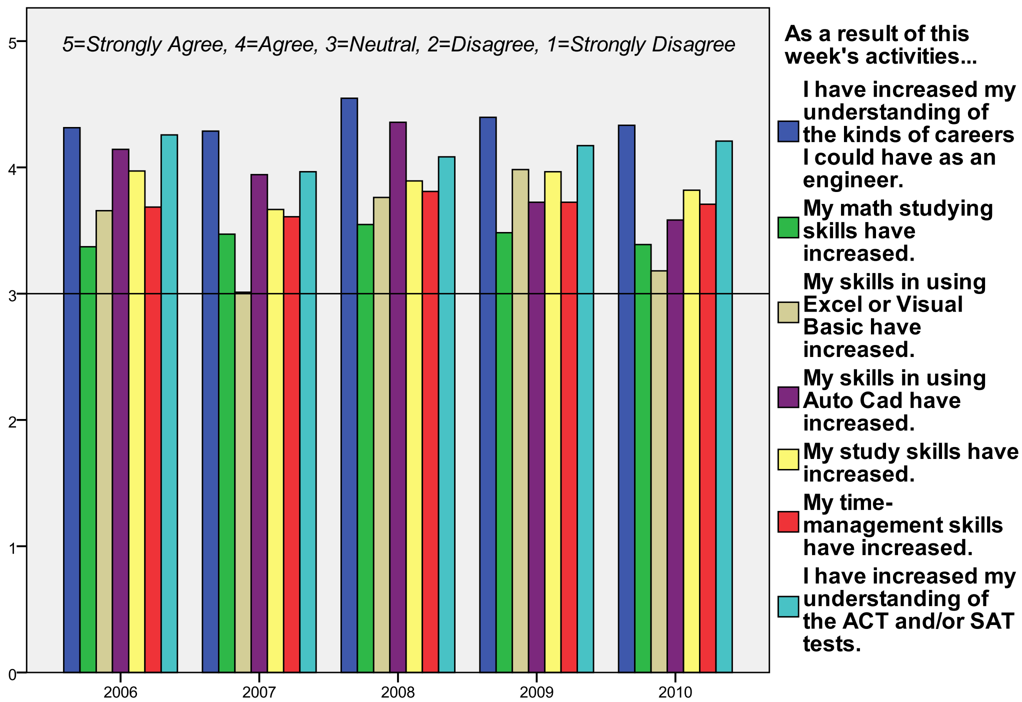


Figure 4: Student Perceptions Of Camp Activities Over Ten Years

We also asked summer campers about preferences for presentations about engineering at their high school. Student preferences appear to be split by gender. Females clearly want to hear about engineering and related career choices from other females, and especially from those who are currently working in the field, while male high school students prefer to hear presentations from male professors, students, and engineers.

Figure 5 shows, however, students of both genders agree on the type of presentation they would like to see in their high school. There was no significant difference between males and females regarding their preference for what types of activities in their high schools would most interest them in engineering at WVU [$\chi(1) = 2.47$, $p = 0.12$] All students prefer realistic, hands-on projects in which they can actively participate over a lecture about engineering and its related careers.

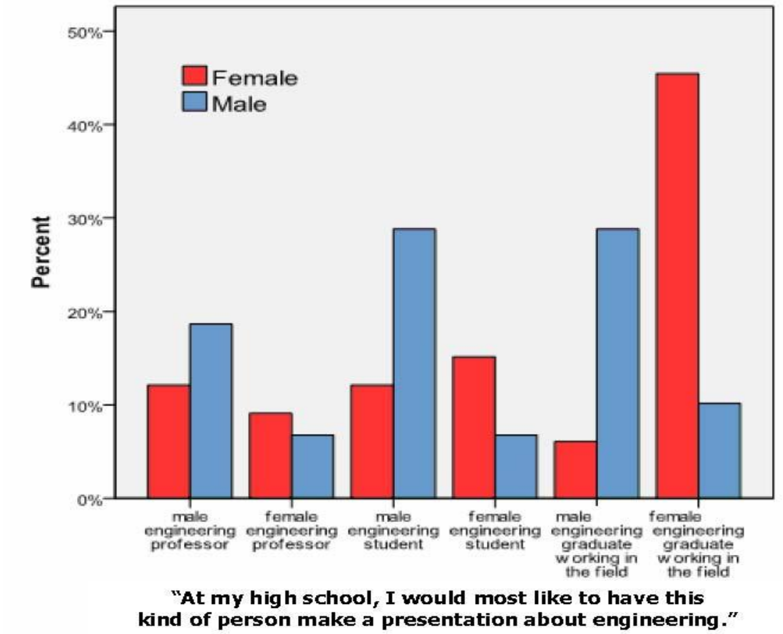


Figure 5: Gender Preferences for High School Engineering Presentations

Summer camp results presented indicate the students' preference and need for information, mentoring, and support from current engineering students and professionals with similar backgrounds. These results are especially true for female students and important for anyone who wished to recruit or retain females in STEM fields. While the research focused on gender differences in communication preferences, the student sample was from Appalachian students who participated in an engineering summer camp, so these results are also relevant to and significant for anyone trying to recruit Appalachian females into STEM programs and to retain them once enrolled. We think that Appalachian universities for engineering students should provide gender and age-matched recruiters, preferably with an Appalachian heritage. Schools trying to recruit and retain Appalachian females must invest in providing Appalachian or regional female role models to go to high schools to lead interesting and realistic, hands-on, engineering activities to groups of students, and to encourage and mentor students to continue to pursue math and science in preparation for potentially rewarding STEM careers. On-site programs at universities designed to give students a "taste" of engineering, such as the popular summer camps run by many universities, must employ female student and faculty role models to teach content and to interact with students as much as possible.

We discovered that among Appalachian high school girls attending engineering summer camp, having an engineer in the family is not especially important to career selection, especially since most of their relative engineers are male. It is unclear in this investigation whether Appalachian high school girls, or any high school girls, would be influenced differentially by having female engineers in their family. Since there is such a low percentage of female engineers, in general, and an even lower percentage of female engineers in Appalachian families, this effect cannot yet be measured. Perhaps, if programs to recruit and retain more females into STEM fields, and especially in to engineering, are successful, this problem can be investigated at some future date.

Of the 341 high school students to come through engineering summer camp, 44 have enrolled in engineering, for a success rate of 12.8 per cent. One difficulty of the project has been to track high school students that have gone on from summer camp to one of the nine NSF-approved STEM fields such as physics, chemistry, biology, and so forth. Partly because of significant FERPA restrictions (Family Educational Rights and Privacy Act), we never were able to devise a good way to track summer campers outside of engineering and this remains a problem for others to resolve.

Finally, all students preferred to have engineering career information delivered through a realistic engineering design project at the high school, having those activities be led by a working female engineering graduate or female engineering student may positively influence more female students to consider pursuing engineering. Simply stated, all students want to see “engineering in action” from someone with whom they can relate, which is, in theory, someone who shares several characteristics with themselves. Hence, to encourage female students to consider engineering careers, it makes sense to have female engineering students or young graduates visit high schools to lead hands-on “engineering in action” activities for all students. This result may be relevant and important to all colleges with outreach programs designed to increase females to enroll in STEM fields.

Maybe the most surprising result about our engineering summer camp is that the results are *not* especially surprising after all. Potential Appalachian engineering students want to see realistic design demonstrations offered by peers and preferably undergraduates or professionals with similar heritages. These students have high confidence levels, especially girls; they come prepared to learn; and they report that they do learn in summer camp while they build social and technical skills. This model-based approach suggests that engineering recruiting simply can’t continue to be an experienced male faculty member using overhead transparencies with copious tables and graphs talking about building rockets and making cars go fast. Instead, our data suggest that recruiting should look more like a junior or senior engineering student, herself heavily involved in a professor’s smart material research, doing a fast-paced, hands-on design demonstration of non-Newtonian fluids at the local high school while the experienced engineering faculty member merely looks on. Based on sample data represented here, we must move toward the latter model of recruiting.

INTERVENTION #3: INTENSIVE FRESHMAN RETENTION PROGRAM

The Freshman Engineering Program at West Virginia University is focused on retention. Primary activities have involved mentoring and tutoring of all engineering freshmen and special early intervention programs for college freshmen having difficulty with chemistry, physics, and Calculus. Several interventions have been implemented, impacting several hundred students. These have included 1) required Study Labs, 2) appropriate placement in initial college math and chemistry courses, 3) a slower paced “Calculus 1 with Review” course option, and 4) a mid-semester Math Review/Calculus-Readiness Course. In addition, the project staff worked closely with Freshman Engineering faculty and staff as well as with faculty and staff from the Math, Chemistry, and Physics departments to implement these and other initiatives designed to facilitate student success.

(1) Study Labs. All first-year engineering students are required to participate in “Study Labs” that require them to study or work on homework at least two hours per week in a “tutored” environment. Students meet this requirement by studying or doing homework in “Study Labs” (classrooms that are reserved for studying in the evening and are staffed by undergraduate and graduate student tutors), the new Engineering Learning Center (ELC) that has replaced the classroom-based “Study Labs,” or in the Math or Chemistry Learning Centers on the downtown campus. The requirement can also be met by participating in faculty-led review sessions, “Peer-Led Team-Learning” sessions for Chemistry, or engineering Resident Assistant (RA)-led study sessions at various times throughout the week in the engineering and Honors College residence halls. In each of these cases, student participation information is reported to the Freshman Engineering Office where it is recorded and distributed to the Freshman Engineering Faculty at mid-term and at the end of each semester. The Study Lab requirement is part of every Freshman Engineering course.

Acting upon the positive student performance and retention data resulting, in part, from the freshman “Study Lab” requirement, the College has demonstrated its commitment to continuing and expanding this academic assistance to freshmen by building a Freshman Engineering Learning Center, which opened in the fall of 2008. The Engineering Learning Center (ELC) is staffed by graduate and undergraduate student tutors who provide free tutoring in Math, Chemistry, Physics, and freshman Engineering courses 55 hours per week, (M-R 9:00AM – 8:00 PM; F 9:00 AM – 4:00 PM; and Sunday 4:00 – 8:00 PM). This availability represents a significant expansion from the 10 hours provided (2 hours, 5 nights/week) by the classroom-based “Study Labs” in previous years. The undergraduate and graduate student tutors in the ELC consist of Appalachian students as well as other underrepresented populations, which provides a diverse representation of the backgrounds and discipline majors of our College. These tutors serve as informal mentors and role models for the freshmen students.

(2) Math Placement Testing. A major contributor to student failure in Calculus is lack of mathematical preparation. Based on a year-long university-wide assessment effort through the "Foundations of Excellence" program, the WVU Department of Mathematics reviewed student performance data, along with an EoT project staff member, and determined that Math ACT/SAT scores were not predictive of student success in those courses. After researching alternatives used at other institutions, WVU implemented a mandatory "Quantitative Reasoning Assessment (QRA)" to be given to all incoming students, beginning with the Fall 2008 entering class. The QRA is a nationally validated test which measures a student's mathematical skill level and recommends appropriate math course placement. The results of that assessment are currently used to place students into the appropriate initial math class. During the first year of implementation, the DFW rate in Calculus 1 fell over 20%.

(3) "Calculus 1 with Review" Course. This two-semester Calculus 1 course, in which algebra and trigonometric concepts are reviewed in a "just-in-time" format, was developed in response to the need for a Calculus course for students whose preparation is weak. Such students are encouraged to move to this two-semester Calculus 1 course. It provides them with a better chance of being successful, laying a good foundation for later courses. This project was not on our proposed list of interventions, but was added through collaboration of the Math Department and Engineering to address issues related to appropriate mathematical placement. Since its first offering in Fall 2008, the first course of the two course sequence enjoys an annual enrollment of approximately 450 students and the second course has an average enrollment of approximately 240 students.

(4) Mid-Semester Math Review/Calculus-Readiness Course. Engineering Math is a one-credit hour, six-week "Engineering Math" course designed to teach essential pre-Calculus skills for those who dropped or are failing Math 155 (current semester) in order to better prepare them to re-attempt MATH 155 in the next semester. When the course was first developed, it was taught in a traditional style of lecture and student problem-solving practice. Students entering this course were at very different levels of math competency, which made effective and efficient instruction difficult. To accommodate the diversity of student skill level and to accommodate a growing interest in this course with limited faculty resources, the course was converted to an "online" course, using a commercially available course software product, beginning, Spring 2007.

INTENSIVE FRESHMAN ENGINEERING PROGRAM RETENTION FINDINGS

While there are many initiatives designed to improve freshman engineering retention, the direct effect of each initiative cannot be measured. The question must be asked, however, has Freshman Retention improved since the implemention of these interventions?

As Figure 6 shows, retention gains in both *general engineering* (not Calculus-ready) and *engineering* (Calculus-ready) is nearly 15 percent each, against a comparison group University wide at 3 percent. Specifically, retention of *engineering* (calculus-ready) students rose 14% from 70% in AY 2004-05 to 84% in AY 2008-2009 and retention of general engineering (not calculus-ready) students rose 12% from 55% in AY 2004-05 to 67% in AY 2008-09. Combining these two groups, overall retention in the College of Engineering and Mineral Resources (CEMR) rose 12% from 63% in AY 2004-05 to 75% in AY 2008-09. Many of those students who left engineering stayed at WVU in a different major.

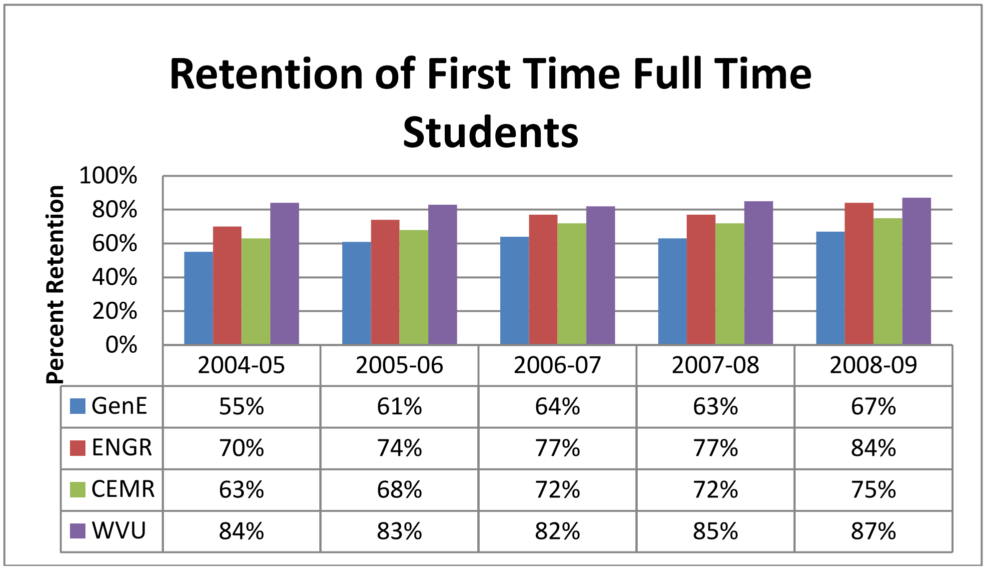


Figure 6: Retention Of First Time Full-Time Students: Engineering (ENGR), General Program Engineering (GenE), College Of Engineering And Mineral Resources (CEMR), Overall, And West Virginia University (WVU)

While there are many variables involved in freshman retention and several interventions were implemented, specific program evaluation focused on student participation in the required weekly study labs and on the effect of the mid-semester math review course These results are presented below.

Figure 7 shows the average number of times each student met the weekly study lab requirement from AY 2004-05 through AY 2009-2010.

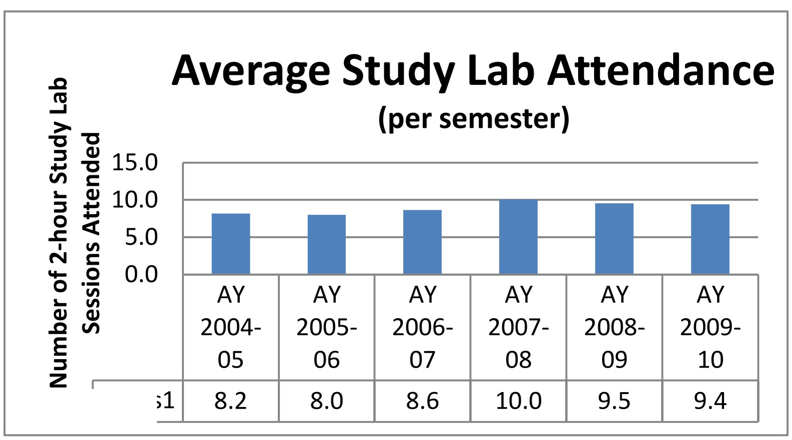


Figure 7: Average Number Of 2-Hour Study Labs Attended By Freshman Engineering Students Each Semester Per Academic Year

While we would like more participation, this data represents the average number of times each student met the weekly study lab requirement, not the number of hours spent studying or working on homework or projects in the Engineering Learning Center or other campus learning center. Many students stop recording their attendance once they meet the minimum 2-hour weekly requirement. The data does indicate, however, that the typical freshman engineering student spends approximately 18 hours each semester in an environment that offers free tutoring. An analysis of the grades of freshman engineering students in the key courses of math, chemistry, and physics, indicate, that while there is variability from semester to semester and year to year, there is an overall increasing trend in achievement.

Four distinct measures were used to discover the effectiveness of the mid-semester Math Review/Calculus Readiness course: (1) the mastery of pre-calculus skills indicated by success in the course; (2) the grade distribution of course completers in their next Calculus 1 course; (3) the retention rate of course completers; and (4) the retention rate of course completers who subsequently earned a C or better in Calculus 1. These data are presented below.

Basic course data indicates that, on average, students completing this one-credit course spent 19 hours working on mathematical problem-solving and improved 24% in their basic knowledge and ability to solve problems using pre-calculus skills to reach a mastery level of 84%. These numbers indicate the course is successful in increasing students' basic knowledge and ability in pre-calculus skills.

The second measure of course effectiveness is to analyze the grade distribution of those students who first completed the mid-semester review course and the re-attempted Calculus 1 the next semester. Figure 8 shows the grade distribution for students who successfully completed the mid-term course and then re-attempted Calculus 1 in the next semester.

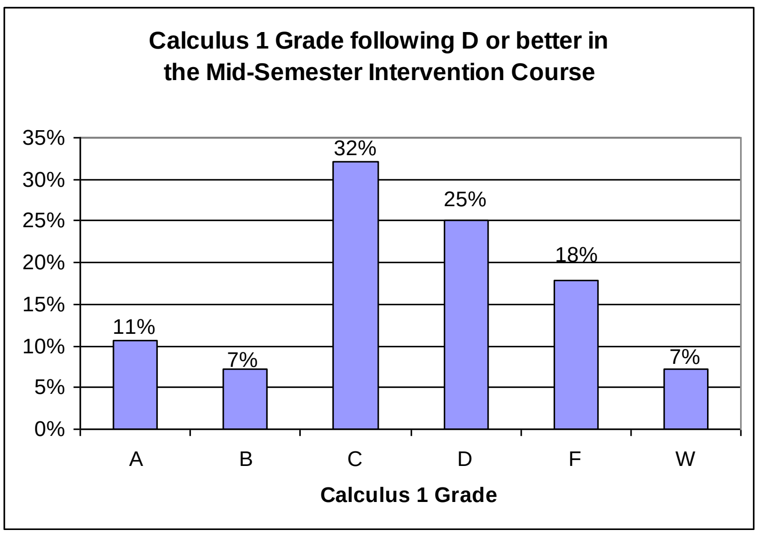


Figure 8: Calculus 1 Grades For Students Who Successfully Completed The Mid-Term "Engineering Math" Course, Then Re-Took Calculus 1 The Next Semester (Fall, 2008)

Note that all of these students had previously dropped Calculus 1 because they were in danger of failing or had failed Calculus 1 previously. However, 50% of the students who repeated Calculus 1 following earning a D or better in the mid-term Math Review course earned a C or better in Calculus 1. This result is significant since only 39% of all Calculus 1 repeaters at WVU earned a C or better during the same semesters.

The third measure of effectiveness, the retention rates of engineering students who successfully completed the mid-term Math Review course are presented in Figure 9.

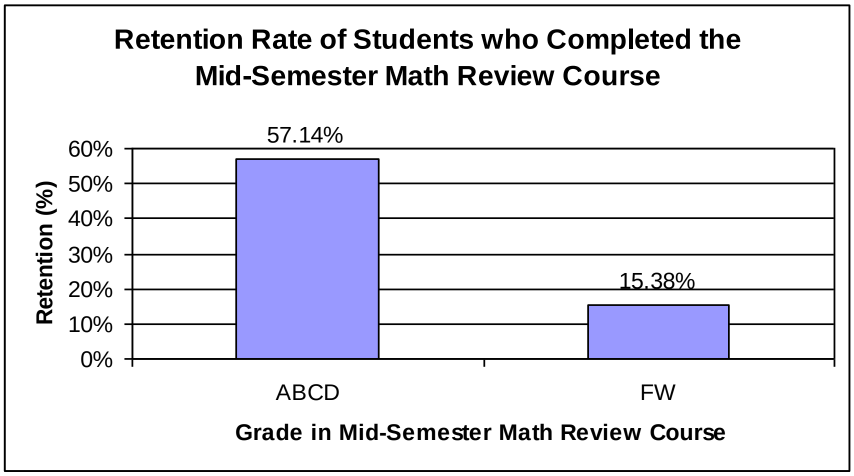


Figure 9: Retention Of Engineering Students Who Completed The Mid-Term Math Review Course

The fourth measure, shown in Figure 10, indicates that 64% of the students who took the mid-term Math Review course and repeated Calculus 1 the following semester, earning a C or better in Calculus 1, stayed in Engineering. During the period of our NSF project, students in the mid-term Math Review course improved their GPA by approximately 0.50, most likely the result of not earning an F in first-Calculus (because they dropped it), and earning an A, B or C grade in the 1-credit intervention course.

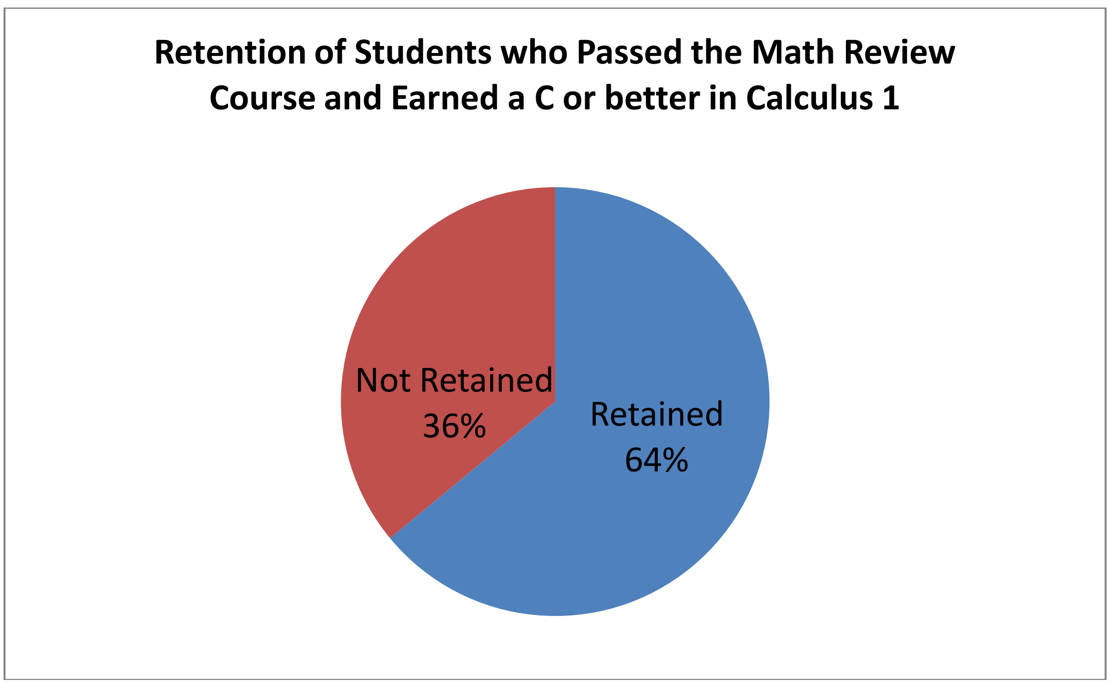
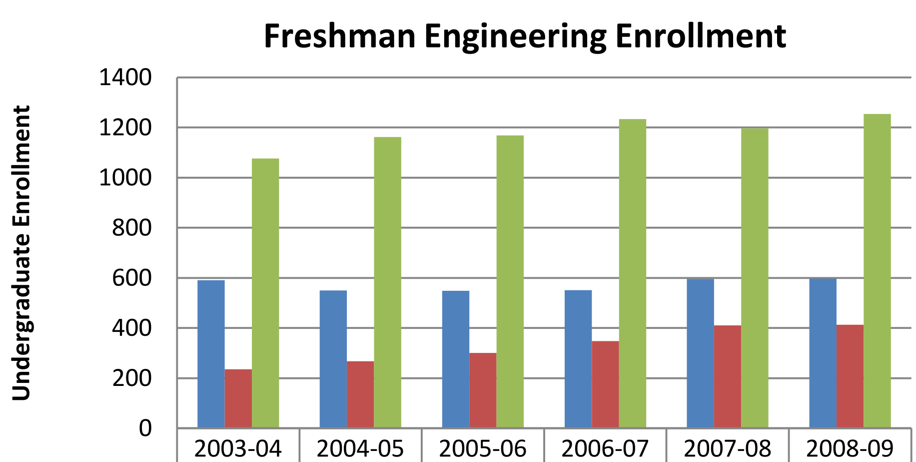


Figure 10: Retention Of Students Who Passed The Mid-Semester Math Review Course And Earned A C Or Better In The Subsequent Calculus 1 Course

By each of these four measures, the mid-semester Math Review course has been successful in preparing students to be successful in their next attempt at passing Calculus 1 and in retaining them in engineering.

The most important measure of these integrated interventions is engineering freshman enrollment data as shown in Figure 11. The number of first-time, full-time CEMR students was at 591 in AY 2003-2004, but decreased approximately 7% the next year, and remained around the 550 level for three years. In the past 2 years, AY 2007-2008 and AY 2008-2009, the enrollment has increased to slightly above the AY 2003-2004 level. The number of students served by the *freshman engineering program (FEP)*, however, has grown significantly since AY 2003-2004. The FEP serves all First Time Full Time (FTFT) Engineering College students as well as the sophomore non-discipline majors (NDME). The 22% growth (from 826 to 1,010) in total non-discipline majors (both FTFT and Sophomore NDME) served by the FEP between AY 2003-2004 and AY 2008-2009 can be attributed to the 76% growth (235 to 413) in the sophomore NDME population. During the same time period, the FTFT General Engineering population grew only 15% from 256 in AY 2003-2004 to 294 in AY 2008-2009. Most of the growth in sophomore NDME students can be attributed to increased retention of engineering students who may have difficulty passing one or more "freshman engineering" courses during the first year. Whatever the reason, the freshman program is currently responsible for teaching, advising, and retaining 1,010, or 45%, of the 2264 total undergraduates in CEMR, a remarkable achievement.



	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09
FTFT	591	550	549	551	596	597
SophNDME	235	267	300	348	411	413
DME	1077	1162	1169	1234	1197	1254

Figure 11: Freshman Engineering Enrollment, AY 2003-2004 - AY 2008-2009

As can be seen in Figure 12, our NSF project has exceed its stated goal of a 4 per cent annual increase in STEM enrollment, including engineering. Minority and female enrollment has increased dramatically, but, to be fair, not as consistently as we had anticipated, and moreover, the numbers overall are still small. Female engineering enrollment in particular, while increased, still has significant and pressing cultural barriers to overcome.

Figure 12: Engineering And STEM Enrollment, 2003 – 2008*

WVU STEM Enrollment, 2003 – 2009*	2003	2004	2005	2006	2007	2008	03/04Δ	04/05Δ	05/06Δ	06/07Δ	07/08Δ	**03/08Δ**
Engineering Total	942	1007	999	1060	1016	1154	7%	-1%	6%	-4%	14%	**23%**
Engineering Female	91	84	88	86	95	126	-8%	5%	-2%	11%	33%	**38%**
Engineering Minority	70	96	83	96	99	158	37%	-14%	16%	3%	60%	**126%**
Total STEM	2351	2574	2934	3072	3144	3445	10%	14%	5%	2%	10%	**47%**
STEM Female	769	909	1080	1073	1187	1292	18%	19%	-1%	11%	9%	**68%**
STEM Minority	175	221	254	278	306	446	26%	15%	9%	10%	46%	**155%**

*Note: Each of the following column headings is the beginning of the academic year for which data apply (e.g., 2008 = Academic year 2008-2009 data, which was reported to NSF Fall 2009 during the final year of the Engineers of Tomorrow project).

CONCLUSIONS

Our integrated approach consisted of three main components: first, sensitizing teachers to engineering careers through web-based, standards-linked TIME kits; second, a model and data-driven recruitment effort featuring summer engineering camp operated by undergraduate engineering students; and, third, a multi-faceted and intensive retention effort for freshman engineering students. Together, these efforts have resulted in significant improvements in enrollment and retention of Appalachian freshman engineers.

We've learned that when teachers use realistic engineering design exercises to teach science, math, and engineering concepts, student learning improves and student interest in STEM fields increases. We also learned that Appalachian high school students strongly prefer to see recruiters in the form of undergraduate engineering students and participate in fast-paced design exercises with real social implications such as coal mine safety. Engineering summer camp is a good way to show high school students about engineering disciplines and at the same time begin to acquaint them with the stresses and time pressures of college life: who better to learn from than undergraduate engineers who have undergone the same stresses and pressures in the last year or so? Finally, we've learned that intensive retention efforts with real structure and consequences, coupled with math placement testing and mid-semester rescue options are necessary to maintain persistence levels as high as we have observed.

In summary, three distinct efforts were implemented to recruit and retain students into the STEM, and specifically engineering, career pipeline: (1) working with high school teachers to develop and implement realistic hands-on engineering design projects based on realistic societal problems (TIME Kits) to introduce STEM-related concepts and careers to high school students, (2) enhancing recruitment efforts by using a strong peer-mentoring approach and featuring a high-intensity summer engineering camp led by undergraduate engineering students, and (3) implementing an intensive first year retention effort. This three-pronged approach has been successful in increasing the engineering interest levels of high school teachers and students, increasing STEM enrollment, in general and engineering enrollment, in particular, at West Virginia University, increasing enrollment of underrepresented populations, and improved retention of students within the engineering program. Continuing recruitment and retention efforts, based on the "lessons learned" through this research, may result, someday, in the Appalachian "invisible minority" to become visible, and perhaps even notable, in contributing to the solutions of society's greatest challenges.

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AUTHOR INFORMATION

Gary L. Winn, Ph.D., is a Professor in Industrial and Management Systems Engineering, and Co-Investigator on the NSF STEP project discussed here. He also manages the summer engineering camp for the College of Engineering and Mineral resources at WVU. He is a professor in Industrial and Management Systems Engineering, and teaches freshman engineering, construction safety management, and safety management principles. His research interests are in construction, transportation and youth development. E-mail: Gary.Winn@mail.wvu.edu

Robin A. M. Hensel, Ed.D., is the Assistant Dean for Freshman Experience in the WVU College of Engineering and Mineral Resources. She directs all aspects of the WVU Freshman Engineering Program, including the academic courses, student support activities, and advising. In addition, she teaches freshman engineering courses, supports the outreach and recruiting activities of the College, and serves as the West Virginia *Project Lead The Way* Affiliate Director. Her research and outreach interests include: (1) High school to College transition, (2) retention of first year engineering students, (3) math education and student math achievement at a variety of academic levels, and (4) increasing high school and middle school student awareness of, and interest in, engineering and mathematics, particularly among women and underrepresented minorities. Dr. Hensel is a senior faculty on the NSF STEP project presented here. E-mail: Robin.Hensel@mail.wvu.edu

Reagan Curtis, Ph.D., is Associate Professor of Educational Psychology, Program Evaluation, and Research Methods at West Virginia University, and pursues a diverse research agenda including areas of interest in (a) the development of mathematical and scientific knowledge across the lifespan, (b) online delivery methods and pedagogical approaches to university instruction, and (c) research methodology, program evaluation, and data analysis (qualitative, quantitative, and mixed methodological) for studies in developmental, educational, and counseling contexts. E-mail: Reagan.Curtis@mail.wvu.edu

Lydotta Taylor is President of The EdVenture Group, a non-profit organization based in Morgantown, West Virginia whose purpose is to provide quality service through cutting-edge technology and teacher-training strategies. The EdVenture Group's projects have focused on providing K-12 technology integration and training to teachers, developing an online repository for teacher-created lesson plans (www.TheSolutionSite.com), and establishing community technology opportunity centers (TOCs) in schools throughout West Virginia. Mr. Taylor is contractor on the NSF project discussed here. E-mail: lmtaylor@edventuregroup.org

Gene Cilento, Ph.D., is Principal Investigator on the NSF project discussed here, and since 2001, he has been the Glen H. Hiner Dean of the WVU College of Engineering and Mineral Resources. He has taught and been an active researcher in both the chemical engineering and anatomy departments at WVU. As Dean, his key interests are to raise awareness of engineering and computer science fields of study among middle school and HS students among women and underrepresented minorities, which are especially underserved in Appalachia. E-mail: Gene.Cilento@mail.wvu.edu

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