Programs to Increase STEM Graduates: An Evaluation of the Engineers of Tomorrow Project

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This study is an external evaluation of the 'Engineers of Tomorrow' project. This multi-faceted intervention program was designed and implemented to increase the number of students graduating from STEM programs at West Virginia University over a five year period. These interventions were begun with high school students exploring course offerings and career choices and then identifying those interested in pursuing a STEM related career. Once recruited and enrolled at WVU, the students were provided support services and mentoring to maximize success in curricula, retention, and graduation rates. The project has had some success in introducing students, especially minority and female students to the skills and knowledge necessary to succeed in STEM careers. The project has also demonstrated success in retaining and graduating students in STEM programs.

Keywords: STEM, Project evaluation, Careers

Introduction

In the past few years deep concerns have been expressed regarding the critical need to invest in mathematics and science education in the United States. The lack of students enrolled and graduating from universities with STEM majors (National Academies of Science, 2005) has also been a cause for concern. The failure of mathematics and science education in the U.S. and paucity of engineers being produced have been identified as reasons why in the coming years "China will rule tech" (Thibodeau, 2010).

Although the representation of U.S. women and girls in STEM fields has risen in recent decades they tend to be limited to certain disciplines and subfields (National Science Foundation, 2006). In the U.S., gender inequities have been observed in computer use, skills and interests (AAUW, 2000; Margolis & Fisher, 2002), and since the mid-1980s the proportion of women pursuing computer science degrees has declined (Spertus, 2004). Further, across all STEM fields the proportion of women belonging to minority groups represents a very small fraction and these numbers decrease as we look at advanced degrees (National Science Foundation, 2007). Reports from other countries also suggest gender differences in STEM. In Italy, the advancement of female researchers in national labs is half the rate of their male counterparts (DeWandre, 2002). In the U.K. in the last 30 years, women have accounted for 50% of all the biology graduates but hold fewer than 10% of full professorships (DeWandre, 2002).

Concerns regarding the lack of enrolment and degree completion in STEM majors were the impetus for the project reported in this paper. In 2005, West Virginia University (WVU), a research institution located in Morgantown, West Virginia (WV), was awarded a five year grant from the National Science Foundation (Grant No. 0525484) for a project called *Engineers of Tomorrow*. The overall goal of the project was to increase the number of high school student selecting STEM careers, particularly women and underrepresented minority students.

Purpose of Paper

The focus of this paper is on the external evaluation of EoT. WVU is located in a state whose typical population has a high school education, high unemployment rates (McLaughlin, Lichter, & Matthews, 1999), lower median incomes than much of the rest of U.S. (Black, Mather, & Sanders, 2007) and few students traditionally selected career paths in STEM. The multi-pronged EoT interventions were begun with high school students exploring course offerings and career choices and then identifying those interested in pursuing a STEM related career. Once recruited and enrolled at WVU, the students were provided support services and mentoring to maximize success in curriculum, retention, and graduation rates. Formative external evaluations of the project goals were conducted annually by Educational Research and Evaluation Services, LLC (ERES). Assessment tools, protocols and collected data were reviewed in relation to the stated goals for each of the strategies.

The project, implemented in 2005-06, was completed in the 2010. The ERES team has conducted one site visit to WVU and in collaboration with the internal evaluation team, completed an annual evaluation for each year culminating in the final evaluation report.

Project Implementation and Evaluation

The specific goals and associated interventions are given below.

Goal 1

The *first goal* of the project was to improve math scores and encourage students in grades 9-12 to pursue a career in STEM fields. This goal included a number of activities for improving the preparation of high school students to enter STEM fields including training current and future high school teachers to better prepare their students in the science and math curriculum.

The primary intervention to achieve this goal was the development of Tools for Integrating Math and Engineering (TIME) Kits. These kits were developed by certified mathematics and science teachers to expose high schools students to engineering concepts related to careers in science and technology. Online lesson plans provided ideas for practical learning experiences for students, and provided teachers new formats for assisting students in understanding math and science concepts. The content was aligned with state and discipline standards. To assess changes in student knowledge each TIME Kit included pre and post assessments for students. A 5th year evaluation plan provided causal-comparative data to gauge the impact of the intervention on student learning outcomes and attitudes.

Specific activities to achieve the objectives of Goal 1 included summer workshops for teachers to develop TIME Kits and train them in their use. Teachers then implemented the Kits and were expected to administer pre and post assessments to students. The development and implementation of the Time Kits has progressed and expanded through the grant period. Forty kits have been developed, with 60 teachers already trained and approximately 1000 students exposed to the kits. The kits are posted on-line and are integrated into WV teaching standards. WVU also offers post secondary certification for teachers trained in the use of the TIME Kits.

For the preliminary causal-comparative study three participating teachers used TIME Kit materials and served as their own controls. In one class they used TIME Kits and in the other class they used traditional materials. A larger study is currently underway. In addition to pre-tests and post tests administered to students in the TIME Kit and Traditional instruction classrooms, teachers in the TIME Kit instruction group were observed while using the instructional materials and interviewed after the instruction was completed. Students in the TIME Kit classrooms were also interviewed regarding their experience of the instruction.

Student performance summaries on the pre-test and post-test in both instructional conditions is shown in Table 1. It is apparent that the pre-test mean scores in the TIME Kit classrooms are similar to the scores in the matched classrooms. However, the standard deviations indicate differences in variability in Classroom 1 for the two conditions. The pre-test and post-test means for all the classrooms is plotted in Figure 1.

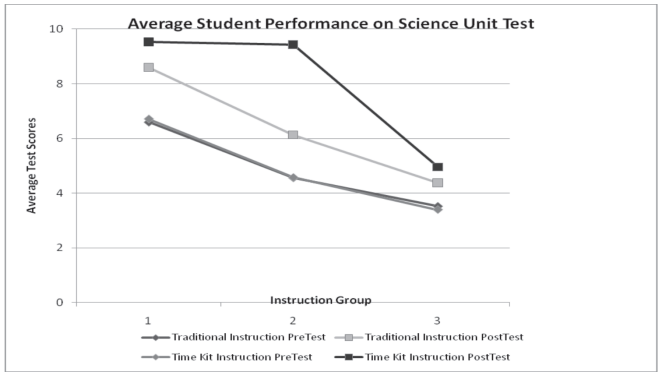


Figure 1: Pre-test and post-test means for intervention and comparison classrooms

			Pre Total		Post Total	
Group	**Classroom/Teacher**	**N**	**Mean**	**Std. Deviation**	**Mean**	**Std. Deviation**
Traditional Instruction	1	20	6.6	1.5	8.6	1.2
	2	23	4.6	1.7	6.1	1.8
	3	21	3.5	1.6	4.4	2.0
Time Kit Instruction	1	21	6.7	2.4	9.5	0.7
	2	21	4.6	1.7	9.4	1.3
	3	23	3.4	1.7	5.0	1.9

Table 1: Summer camp participant demographics

Attitudinal data collected from the students who were exposed to TIME Kit units is presented in Figure 2. Nearly half the responding students reported having a better understanding of the kind of problems engineers solve. Nearly two-thirds of the respondents reported that exposure to the TIME Kit unit led to a better understanding of "what it might be like to be an engineer". The agreement levels dropped considerably on feeling better prepared to do the kinds of mathematics engineers do and increase in the likelihood of majoring in engineering.

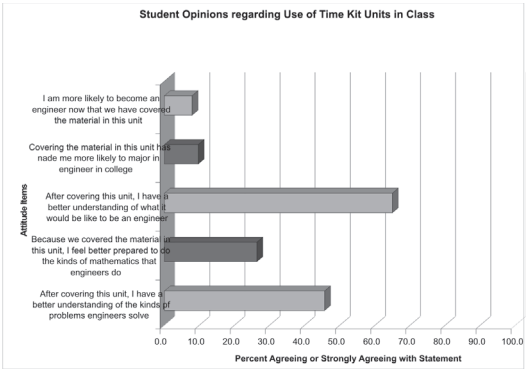


Figure 2: Students opinions regarding use of time kit units in class

Goal 2

The second primary goal of the project was to provide mentoring to women, minority, and Appalachian students to promote success in engineering career majors. The intervention, currently referred to as STEP-Up (Summer Transition to Engineering Program), includes week long summer experiences with engineering labs and college survival skills training. The goal is to increase enrolment and retention of underrepresented students at WVU. Mentors provided campers interaction with successful professionals in the engineering field.

A total of 58 students attended the camp which reflects a drop in participation rate compared to 2008 and 2007. There were also changes in the demographic characteristics of participants over the four year period. Changes in gender and diversity of participants for all four summers are presented in the Table 2.

Demographic Information of Participants	2006	2007	2008	2009
Percent Female	48.7	15.9	41.9	31.5
Percent White/ Caucasian	30.8	58	60.5	59.3
Percent African American	53.8	28.4	32.6	31.5

Table 2: Summer camp participant demographics

The percentage of females attending the camp dropped about 10% in 2009, while the percent of White/Caucasian students and African American students was about the same as 2008. In 2009, 39% of the females were White/Caucasian and 31% were African Americans. Survey data from the 2009 participants indicated that the summer camp was very successful in promoting an understanding of engineering career options, ACT/SAT tests, skill in using Excel, and general and mathematics study skills. These data are presented in the Figure 3.

In reviewing participant feedback from all four years of the summer camp it is clear that more than 75% of the students were in agreement that the camp activities increased their understanding of engineering career options and of the ACT/ SAT tests. The increase in general study skills and in the use of AutoCAD is reported by about 60% to 80% of the participants over the four years. A majority of the participants also agreed that camp activities enhanced their time management skills. In 2009, there was a much greater agreement among the participants in the area of EXCEL and mathematics study skills increase. These findings are presented in Figure 3.

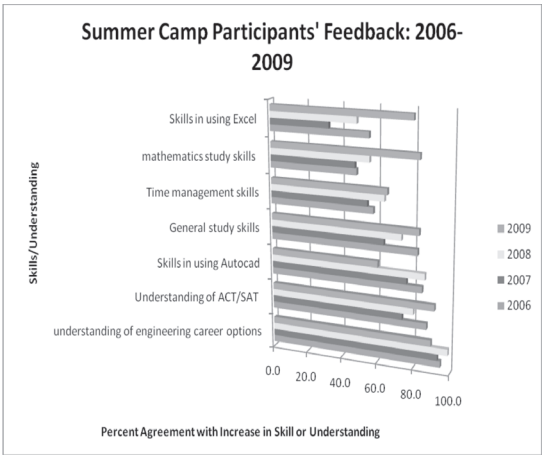


Figure 3: Summer camp participant feedback: A comparison of 2006-2009

Student Interviews: Previous Summer Camp Participants- Current WVU Students

Two current WVU students and former Summer Camp participants were interviewed to obtain retrospective feedback regarding the influence of camp activities and offerings on their academic choices. The voices of these students reinforce the feedback received from the summer camp participants over the years. One student, an engineering major at WVU, stated:

Before I came to the camp, I had no idea of what WVU engineering was about. I thought it was just another engineering program. I really did not know any college of engineering was about. So, once I came here, it gave me a better understanding and like it really let me know WVU is a serious school for engineering and that's something that I wanted to do in my whole life.

This student also acknowledged that learning study skills at the camp had proved invaluable in maintaining focus during classroom lectures and also in his ability to juggle academics and socializing with friends. His overall experience of the summer camp was very positive, "*it's just an experience that any kid that wants to do engineering should have. They should come to WVU and experience the engineering camp because they can open up doors for you like it did for me."*

A second WVU student, a pre-business major, reporting on how the summer camp affected his choice of major stated:

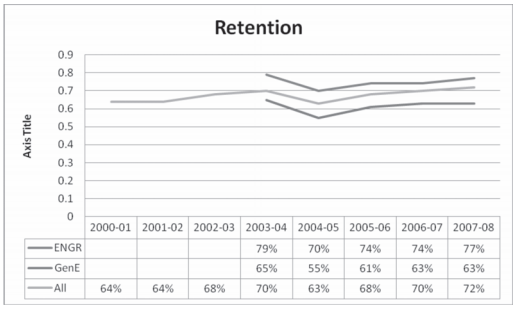
It had a little bit of effect because I was thinking about Engineering and actually decided to try it last semester. But I was sort of unsure but I think it's probably the program that pushed me to try it out." Regarding the help and support he received from the summer camp, the student indicated, "I got to meet some nice people, some of the upper classmen that were helping with it. I still talk to a couple of them and they help me out a little bit. So, if it is anything, the connections that I have made because of the program.

Goal 3

This goal was designed to encourage high school students to explore an online engineering curriculum. Engineering 100 was offered fall 2007 (4 sections with 204 students), spring, 2008 (1 section with 27 students), fall, 2008 (3 sections; 108 students) and spring, 2009 (2 sections; 72 students). The course has been approved with a permanent course number.

Goal 4

The recruitment and retention of STEM students at WVU in the target population was the final goal and the culmination of the previous goals. Enrolment data from the past years indicates that since 2003-2004 there has been a 30% increase in STEM enrolees as compared to a 15.5 % increase in the non-STEM. There was evidence of a 9% increase in retention of engineering students from 2004-2005 to 2006-2007. In 2006-2007, 74% of the students were still enrolled in the program as sophomores. In 2007-2008 the retention rate increased to 77%. This rate compares very favourably with the nationwide freshman retention rate of 50% for engineering majors (Figure 4).



	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08
ENGR				79%	70%	74%	74%	77%
GenE				65%	55%	61%	63%	63%
All	64%	64%	68%	70%	63%	68%	70%	72%

Figure 4: Retention rates for years 2000-01 through 2007-08

Summary, Conclusions and Recommendations

The Engineers of Tomorrow (EoT) has made excellent progress in working towards its stated goals. EoT has built on its strengths, sharpened its focus with each intervention and has been decisive regarding interventions with inadequate outcome data. Feedback from the camps was overwhelmingly positive along with suggestions for improvement. It is clearly evident that the project directors take this feedback very seriously and are very responsive.

In response to the funding agency's suggestion to provide on-going mentoring for summer camp participants, the project with support from a foundation developed a virtual community called MYnexthorizon.org. This virtual community is modelled after Facebook and was designed to attract and inform students regarding STEM related educational and career opportunities. This pilot project was evaluated and the findings were encouraging. The external evaluators recommend that the project continue with impact assessment of this virtual community in the coming year.

Progress on the collection of outcome data is evident for the TIME Kit intervention. Development of the fifth year plan for collection of detailed outcome data was noteworthy. The plan has now been implemented and as reported in the previous section, the preliminary data are encouraging.

To strengthen the connection between recruitment activities undertaken by the project and the attainment of project goals the external evaluators recommended the design of data collection plans of sufficient grain-size such that it included a basis for comparison. The project is working on a system that will sharpen its ability to track and connect field based information with information maintained in WVU system. Once this system is fully developed it will allow for the connection of recruitment effort data with enrolment data.

The project goals were ambitious and multi-faceted. The project personnel have demonstrated their commitment to fine-tuning the interventions in response to evaluation feedback. The presence of an internal evaluator who is an integral part of the project team developed, designed and carried out on-going outcomes assessment. The project in carrying out the interventions not only provides a model for successful recruitment and retention of STEM students but also highlights its adherence to an evidence-based model for assessing the efficacy of its interventions.

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