Promoting Engineering Education Among High School and Middle School Students

Rohitha Goonatilake and Rafic A. Bachnak
Texas A&M International University

Abstract

Recent decline of students pursuing engineering degree programs is a great concern for many higher education authorities including Federal and State governments (Kuenzi, 2008). Existing programs in high schools have not yet produced the desired results. Consequently, a number of initiatives to remedy this situation have been proposed and implemented. One such initiative is a funding opportunity by the Texas Higher Education Coordinating Board (THECB) to conduct summer engineering workshops to provide high school and middle school students with the opportunity to learn about the engineering profession. This includes information about engineering disciplines and careers, the basics of engineering education, and details about becoming a professional engineer, in addition to some subject-related materials being taught. This paper describes a one-week summer program, funded by THECB, that was held at Texas A&M International University, Laredo, Texas, in Summer 2010. This program provides not only adequate information about the benefits for choosing engineering disciplines, but also extends student's knowledge of the required skills and the career opportunities awaiting them.

Keywords: Hispanics, pre-engineering, workshop, engineering program, industry visit, THECB, and TAMIU

Introduction

The 2010 TAMIU Engineering Summer Program (TAMIU ESP) provided high school and middle school students the opportunity to participate in a one-week workshop on the campus of Texas A&M International University (TAMIU). The goals of this program were to enhance student interest in engineering as a potential career, to develop students' analytical skills, and to help students prepare for college-level courses. TAMIU is the only four-year institution within a 130-mile radius of Laredo, Texas. The University serves a predominantly 90% Hispanic and academically disadvantaged population along the Texas-Mexico border. Students in the service region are vastly underrepresented in STEM programs and lack adequate preparation. The mean ACT composite score of TAMIU first-time degree seeking students in 2010 was 17.94, compared to an average national average score of 21. The data suggest that there is a need for a stronger focus on science, mathematics, and engineering career interests and interventions to strengthen students' academic preparation to succeed in STEM disciplines. Students who participated in the program received instruction in mathematics, science, and engineering concepts. Student admission to the program was selective and participation must reflect the demographic diversity of the state. Underrepresented students in engineering programs include minorities and females. This program was conducted by experienced TAMIU faculty and experienced teachers in the area's high schools who were specially selected to serve the needs of this student population.

The focus in this one-week program was to elevate engineering education among high school and middle school students. Other aspects have been given much discussions and focus in the past. It is also important to point out that engineering professionals should adapt to the learning styles of the students to maximize the output and quality of engineering schools to prepare them for the needs of the 21st century workforce (Felder & Silverman, 1988). Besides the technical foundations of engineering, engineering professionals must impart their students with the necessary strategies to foster creative thinking, successful problem-solving skills, and the imperative to become cultured to meet these demands (Felder, Woods, Stice, & Rugarcia, 2000). In order to guarantee that students will have the critical-thinking skills to succeed as professionals and responsible members of society, we must identify the skills that we wish for our students to develop and communicate their importance to the students; additional suggestions have also been given that apply specifically to the development of problem-solving, writing, teamwork, self-assessment, lifelong learning, and change-management skills (Woods, Felder, Rugarcia, & Stice, 2000). In recent times, and through much turmoil, a consensus was reached among engineering educators as to what engineering education should encompass at the moment. The purpose of this focus is to achieve the changes necessary to bring this curriculum into effect nationally (Ernst & Peden, 1998). Three instructional approaches—active learning, cooperative learning, and problem-based learning—have been shown to achieve some successes in the training of future engineers (Felder & Brent, 2004). There were other programs conducted by TAMIU with this intention in mind. The STEM-RRG PE Cohort was such a program, in which a group of about 24 students was selected and given a year round advising, mentoring, and familiarity with the engineering programs and careers. A feature of the program is that this group of students is sent to Texas A&M University (TAMU), College Station, Texas, the largest engineering school in the country, to accomplish the task of benefitting students seeking programs in engineering (Bachnak, Goonatilake, Jin, & Belkhouche, 2010).

Program Synopsis

TAMIU ESP included many features to achieve the objectives of the program, such as student team competitions; project presentations; field trips; industry site visits; panel discussions with professional engineers and scientists; parent/guardian information that covers the Texas university application process,

financial aid system, and scholarship opportunities; and other program contents. Participants who completed the entire week-long program by earning 36 hours of summer engineering experience received a $400 scholarship. Program sessions and activities were scheduled from Monday through Friday, July 19–23, 2010 from 8:00 am to 5:00 pm, as summarized in Table 1. Registration and welcome started at 8:00 am on Monday. A pretest was administered on the first day of the program and the same test was administered at the end of the last day of the program as a posttest. This test consisted of 45 questions that examine students' knowledge in the areas of mathematics, physics, and engineering. The test included multiple choice, matching, and open-ended questions.

Throughout this week-long program, the participants prepared for the final project to be presented on its last day, Friday, July 23, 2010. There were sessions on the "role of mathematics in engineering education" and the "role of physics in engineering education" by two experts in the respective disciplines. These two sessions focused on introducing concepts and solving problems that demonstrate the importance of mathematics and physics to engineering education. We are aware some students think that the university application process is somewhat tedious and cumbersome. To address this issue and to get them familiarized with the process, a session was held to introduce the Texas university application process, financial aid system, and scholarship opportunities. The participants' parents and guardians were invited to participate in this session presented by the representatives from the Office of Admissions and the Office of Financial Aid at TAMIU. A session that drew much attention and was considered highly important was the panel discussion on "What engineers do" by a group of prominent engineering professors and area engineering professionals. They were able to answer the participants' questions and contribute to the theme of the program. Stories that panel members shared with the students were especially well-received. As for the subject matters in the profession, two carefully-tailored sessions accomplished this portion of the program. One was on "Engineering design projects using AutoCAD" and other was "Lego robot session" followed by a Lego robot competition for the participants. Winners of this competition were recognized by awarding certificates. In addition, all participants were given a certificate of completion indicating that they had completed 36 hours of summer engineering enrichment experiences. Work on engineering design projects by the participants was concluded midday on Friday in preparation for the conclusion session in the afternoon that comprised the posttest, project presentations by participants individually and in groups, awarding of certificates, and completing a feedback form.

	9:00 am – 12:30 pm	1:30 pm – 5:00 pm
Monday 7/19/10	Role of mathematics in engineering education Dr. Firooz Khosraviyani	Role of physics in engineering education Dr. Juan H. Hinojosa
Tuesday 7/20/10	Foundations of engineering Dr. Young-Man Kim	1:30 am – 3:30 pm: Texas university application process, financial aid system, and scholarship opportunities. Parents/guardians are invited to participate. (Representatives from the Office of Admissions and the Office of Financial Aid) 3:30 pm – 5:00 pm: Panel discussion: What engineers do Dr. Rafic A. Bachnak
Wednesday 7/21/10	Engineering design projects using AutoCAD Mr. Gerardo J. Pinzon	Industry site visit Mr. Gerardo J. Pinzon
Thursday 7/22/10	Lego robot session Dr. Young-Man Kim	Lego robot competition Dr. Young-Man Kim
Friday 7/23/10	Work on engineering design project Mr. Gerardo J. Pinzon	Conclusion: • Posttest • Project presentations • Award of certificates • Completing feedback form

Table 1: Program Schedule for the 2010 TAMIU Engineering Summer Program (TAMIU ESP)

A planned industry site visit to a local water treatment plant showed what awaited students as they embarked upon completion of the program. This is one of the exciting activities that occurred during the TAMIU ESP. The water treatment plant is located in the west end of Jefferson Street in Laredo, Texas, and is owned and operated by the City of Laredo Water Utilities Department. The facility is a 45 MGD (million gallon per day) plant that is currently undergoing a renovation and up-grade, which will bring the capacity level to 65 MGD. The participants were met by the plant's superintendent and then taken over to the construction site, where they met with the contractor and inspectors to get an overview of the plant's construction. Afterwards, the participants were given a walking tour of the facility so they would be able to appreciate the plant's capability of providing their own drinking water. The participants learned about not only the process and the equipment and materials used for the treatment, but also about the federal laws and requirements to which the plant is expected to adhere in order to produce good quality drinking water. For example, the plant employs a system that combines sensors, seals, and motion-detection to protect water from contamination.

Data and Analyses

Analyses have been conducted using the data from participants' applications and responses received to the questionnaires in the feedback form. They have been summarized as reflected in Tables 2 and 3 and in Figures 1, 2, and 3.

In addition, and most importantly, pretest and posttest analysis determined the success of the program. Analyses were two-fold. One part was a comparison of descriptive statistics, and the other was a compression of individual test scores received by all 23 participants using line graphs.

The main descriptive measures—such as mean, median, and mode—have increased as a result of the work of this program. The variability of test scores in terms of standard error, standard deviation, sample variance, range, and confidence level (@ 95.0%) have diminished, demonstrating that this program was able to narrow the educational and knowledge gaps among the participants. These measurements and other descriptive measures are listed in Table 2.

The scatter diagram and trend lines obtained for pretest and posttest scores are presented in Figure 1 and showed that participants performed remarkably well on their posttests as compared to their pretests. About 92% of participants were able to achieve higher scores in their posttests. While we do not have a good answer as to why two students' performance on the posttest was lower than that of the pretest, it is possible that students did not take these tests seriously since they did not affect their completion of the program in any way.

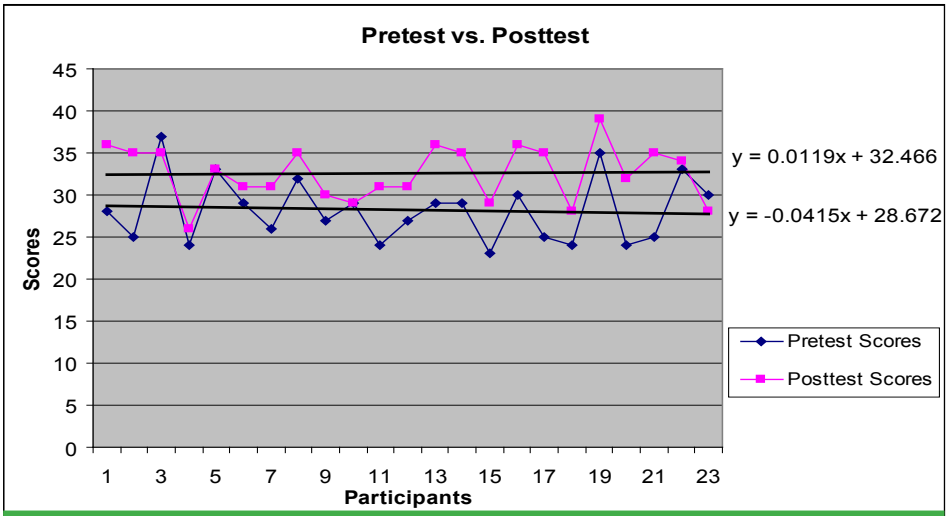

Figure 1: Pretest and Posttest Comparison using Line Graphs

The end-of-summer program survey comprised two parts, I and II. Part I invited responses to a set of questionnaires about the program's successes, intended for participants who completed the entire program. Part II was about their preparation for engineering education in terms of family background, awareness

Descriptive Statistics	Pretest (of 45 points)	Posttest (of 45 points)
Mean	28.17391	32.6087
Standard Error	0.806721	0.690818
Median	28	33
Mode	24	35
Standard Deviation	3.868899	3.313048
Sample Variance	14.96838	10.97628
Kurtosis	-0.30443	-0.73608
Skewness	0.655115	-0.20555
Range	14	13
Minimum	23	26
Maximum	37	39
Sum	648	750
Count	23	23
Confidence Level (@ 95.0%)	1.673037	1.432669

Table 2: Descriptive Statistics Comparison for Pretest and Posttest

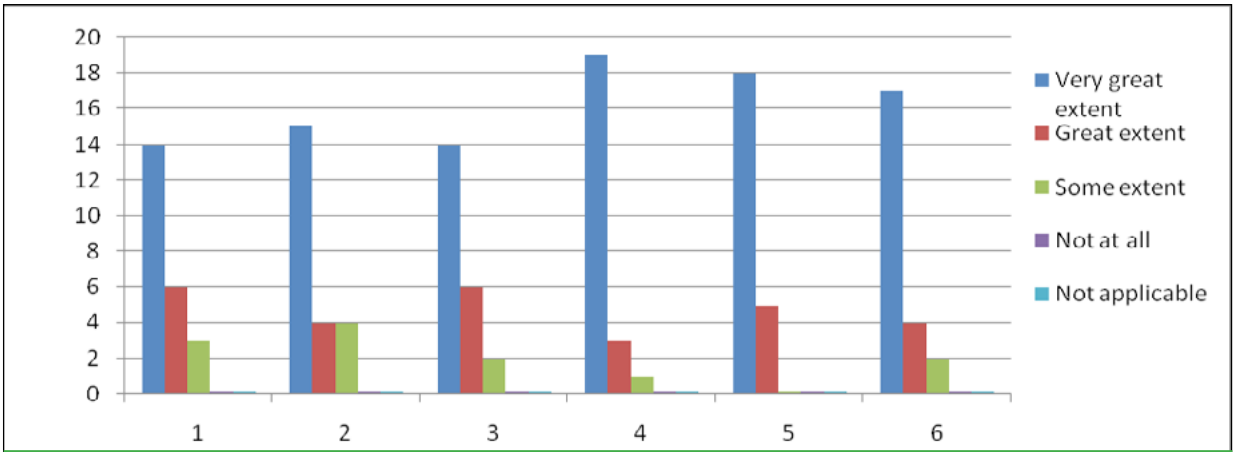

Figure 2: End-of-Summer Program Survey using Responses in Part I

[1: To what extent were you satisfied with this Engineering Recruitment Summer Program? 2: The student team competitions helped me to understand more about what it is like to be an engineer. 3: Working on a project presentation helped me to understand more about what it is like to be an engineer. 4: The field trips helped me to understand more about what it is like to be an engineer. 5: The industry site visits helped me to understand more about what it is like to be an engineer. 6: The discussions with professional engineers and scientists helped me to understand more about what it is like to be an engineer.]

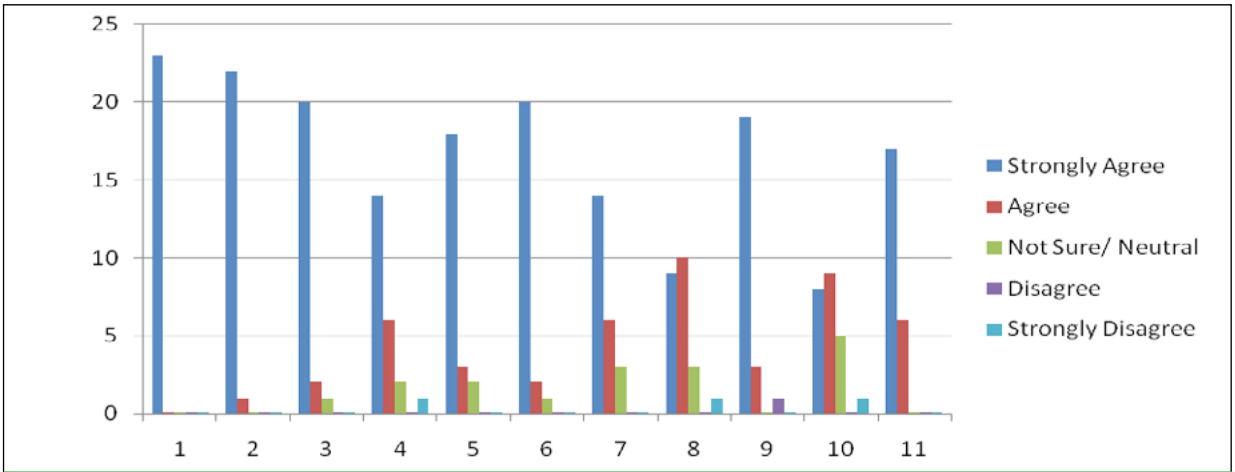

Figure 3: End-of-Summer Program Survey using Responses in Part II

[1: I plan to go to college when I finish high school. 2: My parents/guardians are encouraging me to go to college. 3: My friends plan on going to college. 4: I enjoy school. 5: My teacher(s)/counselor(s) care if I go to college. 6: I am interested in a specific college(s). 7: I have a specific career goal(s). 8: I am interested in a career in engineering. 9: Participating in the Engineering Recruitment Summer Program has encouraged me to go to college. 10: Participating in the Engineering Recruitment Summer Program has encouraged me become an engineer. 11: I would recommend the Engineering Recruitment Summer Program to my friends.]

of programs, and support systems in place. Figures 2 and 3 depict summaries of their responses for questionnaires in parts I and II, respectively, as assembled by THECB. Questionnaires which appear in these sections are listed in the bottom of each figure.

A demographics criterion was established to reflect that of the current demographics composition of the state of Texas when selecting participants for the program. Figures 4 and 5 indicate that the participants of this program meet this demographic breakdown that deserves intervention, and also were in need of the program's activities designed to help their high school plans for timely graduation either in distinguished or recommended levels.

Conclusions

During the program's week of activities, the participants expressed their excitement about the program and their appreciation for the or-

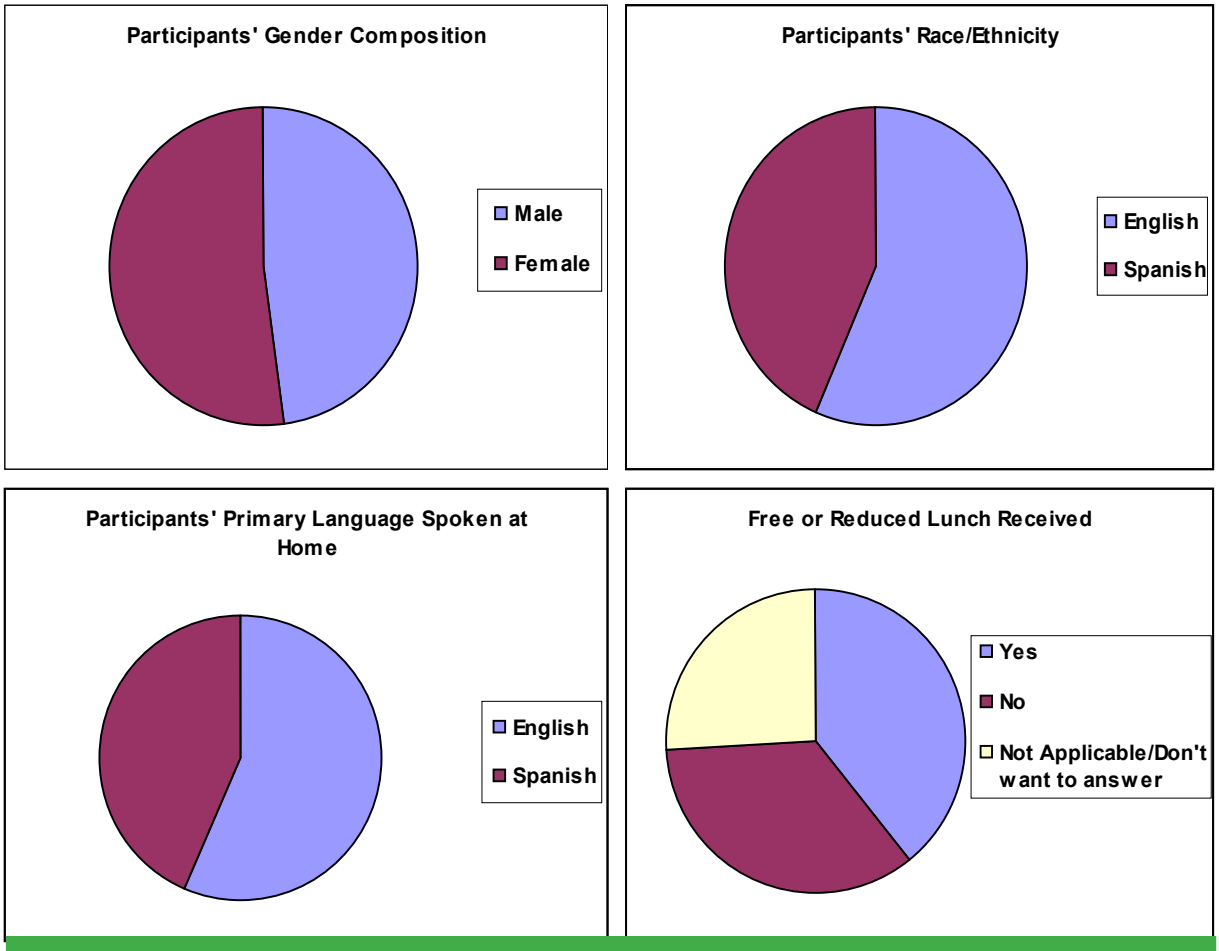

Figure 4: Demographics Composition of the Participants in terms of Gender, Race/Ethnicity, Language Spoken, and Federal Assistances

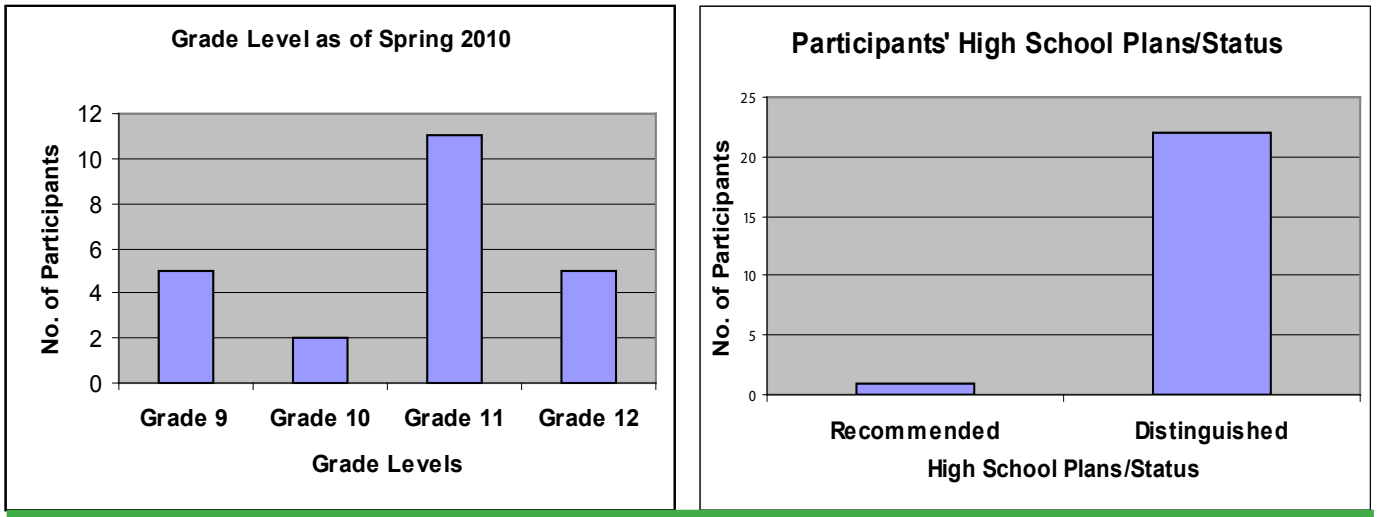

Figure 5: Participants' Preparations in terms of Grade Level as of Spring 2010 and their High School Status

ganizers. All indications are that the program objectives were achieved beyond expectations. Some participants have expressed that they will seek an engineering program, either at TAMIU or elsewhere. Some students planned to enroll in the courses in Fall 2010. Among the remaining participants, the majority expressed that they would seek admission to TAMIU's engineering programs at a later time.

Although this summer engineering program alone will not solve all problems unique to this discipline, it provides a place where other educators, college administrators, and state legislators can think about restructuring, planning, and creating a practical approach to remedy the situation once and for all. It also provides a glimpse of the situation we are all experiencing as we promote engineering education to meet the increasing demands of today's society.

Acknowledgements

The 2010 Summer Engineering Program is partially supported by a project funded by the Texas Higher Education Coordinating Board, Texas. More information about this grant is found at http://www.tamiu.edu/~rbachnak/THECB-ESP/ESP.html. The authors would like to thank all session leaders, professionals who contributed to the delivery of the sessions and activities, and also our student assistants, Navil Lozano, Ramakanth Lambu, Sasha Obregon, Ravikiran Puchalapalli, David Gomez, Gabriel Trejo, Julio Talamantes, Jefferey Gonzalez, Marco Serna, Arnulfo Cazares, and William Hammers, who have tirelessly assisted in activities related to the workshop. Finally, Ms. Juliana Medrano, department secretary, helped in providing and purchasing items needed for successful completion of the workshop and arranging payment of expenses for the participants in the program. The comments received from two reviewers were very helpful in improving the article, and they are appreciated, as well.

References

Bachnak, R. A., Goonatilake, R., Jin, T., & Belkhouche, F. (2010). A Glimpse of an Effective Cohort Program for Undergraduate Students to Promote Engineering, The International Journal of Engineering Studies (IJES), 2(1), 59-66.

Ernst, E. W. & Peden, I. C. (1998). Realizing the New Paradigm for Engineering Education, Proceedings, June 3-6, 1998 Omni Inner Harbor Hotel Baltimore, Maryland, Engineering Foundation Conference, New York, NY 10016.

Felder, R. M. & Brent, R. (2004). The ABC's of Engineering Education: Abet, Bloom's Taxonomy, Cooperative Learning, and So On, Proceedings of the American Society for Engineering Education Annual Conference & Exposition, American Society for Engineering Education.

Felder, R. M. & Silverman, L. K. (1988). Learning and Teaching Styles in Engineering Education, Institute for the Study of Advanced Development, Engr. Education, 78(7), 674–681.

Felder, R. M., Woods, D. R., Stice, J. E., & Rugarcia, A. (2000). The Future of Engineering Education II: Teaching Methods That Work, Chem. Engr. Education, 34(1), 26–39.

Kuenzi, J. J. (2008, March, updated). Science, Technology, Engineering, and Mathematics (STEM) Education: Background, Federal Policy, and Legislative Action, Specialist in Education Policy, Domestic Social Policy Division, Science, Technology, Engineering, and Mathematics, (STEM) Education: Background, Federal Policy, and Legislative Action, (Order Code RL33434).

Woods, D. R., Felder, R. M., Rugarcia, A., & Stice, J. E. (2000). The Future of Engineering Education III: Developing Critical Skills, Chem. Engr. Education, 34(2), 108–117.

Rohitha Goonatilake received a Ph.D. in applied mathematics from Kent State University, Kent, Ohio in 1997 and is currently working as an associate professor of mathematics in the Department of Engineering, Mathematics, and Physics at Texas A&M International University. He was a Co-PI for a grant funded by the Texas Higher Education Coordinating Board for the 2010 Engineering Summer Program to provide enrichment for area middle and high school students to enter into careers in engineering. He is a member of American Mathematical Society, Mathematical Association of America, Institute of Mathematical Statistics, and The Honor Society of Phi Kappa Phi.

Rafic A. Bachnak received his B.S., M.S., and Ph.D. degrees in Electrical and Computer Engineering from Ohio University in 1983, 1984, and 1989, respectively. He is currently a Professor of Engineering at Texas A&M International University (TAMIU). Prior to joining TAMIU in 2007, Dr. Bachnak was on the faculty of Texas A&M University-Corpus Christi, Northwestern State University, and Franklin University. His experience includes several fellowships with NASA and the US Navy Laboratories and employment with Koch Industries. Dr. Bachnak is a registered Professional Engineer in the State of Texas, a senior member of IEEE and ISA, and a member of ASEE.