AC 2010-123: IMPACTING STUDENTS' INTEREST IN STEM FIELDS: AN ELECTRONIC COMMUNICATION COURSE FOR K-12 UNDERREPRESENTED STUDENTS

Aurenice Oliveira, Michigan Technological University

Dr. Aurenice Oliveira is an Assistant Professor in the Electrical Engineering Technology program at Michigan Technological University, Houghton, MI, since 2007. She received the B.Sc. degree in Electrical Engineering from the Federal University of Bahia (UFBA), Salvador, Brazil, in 1995, the M.Sc. degree in Electrical Engineering from the State University of Campinas (UNICAMP), Campinas, Brazil, in 1998, and the Ph.D. degree in Electrical Engineering from the University of Maryland, Baltimore County, USA, in 2005. Dr. Oliveira has taught several classes in Electrical Engineering and Mathematics Departments at Michigan Tech, North Dakota State University, and at Minnesota State University, Moorhead. Dr. Oliveira current research interests include optical fiber communication systems, Monte Carlo simulations, digital signal processing, wireless communications, and engineering education. She has authored or co-authored 13 archival journal publications and 32 conference contributions. From 2007-2011 Dr. Oliveira is serving as the Michigan Tech project director of the U.S.-Brazil Engineering Education Consortium on Renewable Energy that is funded by FIPSE from the U.S. Department of Education. Dr. Oliveira is an ABET evaluator, and serve as panelist for NSF projects. Dr. Oliveira has also been contributing to several STEM K-12 outreach initiatives, and to the NSF-ADVANCE initiative at Michigan Technological University. Dr. Oliveira is a member of the IEEE Photonics Society, the IEEE Women in Engineering Society, and the American Society of Engineering Education (ASEE).

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Abstract

A growing demand for technological advances means more jobs for science, technology, engineering and mathematics (STEM) workers. The need for technical workers in STEM fields continues to grow as technology moves forward. The U.S. Bureau of Labor Statistics projects job growth of 22% for STEM occupations as a whole by 2014. Preparation for success in STEM areas should begin in middle and high school, through rigorous college preparatory coursework and extracurricular activities. Students participating in extra-curricular STEM activities during the academic year and in summer camps increase their interest in college education, explore career options, and are better prepared to pursue and successfully graduate in STEM majors, especially engineering.

Workers in STEM occupations use science and math to solve problems. However, the traditional method for teaching science and mathematics has been rote memorization of facts quantified by student achievement based on multiple choice or fill-in-the blank tests. Science and mathematics were not integrated but, rather have been taught as separate subjects. Current research suggests that science and mathematics be taught together to students prior to college[1]. An effective strategy for the integration of science and mathematics is the incorporation into the instructional strategies of topics that directly apply both disciplines, such as engineering and technology topics. Although students are taught about mathematics and science, most students are relatively uninformed about technology and the field of engineering. These topics assists in making thinking more visible to a student which leads to a greater likelihood of discussion and increased understanding[2], especially if students learn about technologies present in the daily lives.

This paper presents an Electronic Communication course that is part of an out of school time educational program targeting urban African American and Hispanic American students in high school to make STEM disciplines more culturally relevant for these underrepresented youths. The goal of this week-long summer day course is to impact students' interest in STEM fields, especially increasing awareness toward engineering and what engineers do, and to effectively contribute to the transition of high school into college. Students learn Electronic Communication Technologies through an intense load of hands-on activities closely coordinated with theoretical classroom discussion focusing on exciting real-world engineering applications of a variety of communication systems. The course attendees responded an end of course survey to assess the success of the course in achieving its goal in terms of impacting students' knowledge on engineering and on the specific subject, and attitude towards college education and STEM areas. The survey results revealed, among other findings, that students' interest in college education further increased. These results will assist us to refine our goals, and on the development of other similar programs.

1. Introduction

For more than a decade, teachers, administrators, and other leaders in education have agreed that a solid background in science, mathematics, engineering and technology is critical for students preparing to enter the 21st Century workforce. However, there remains much to be done. The U.S. educational system is not currently developing the excellent grounding in science that is needed in the United States to remain competitive in this global economy. In international comparison exams, American students have long lagged behind those in much of Asia and Europe. The gap between engineers needed annually and the number of graduates available to fill positions is wide. Some experts place the need as high as 117,000 a year, while U.S. colleges produce about 65,000 to 70,000 engineering graduates[3]. This is in agreement with U.S. Bureau of Labor Statistics, which projects job average growth of 13% to all engineering disciplines[4]. In recognition of this need, several programs have continuously worked to build and reinforce a solid education foundation in science, technology, engineering and mathematics (STEM) through high-quality programming. More recently, the White House launched the "Educate to Innovate" campaign with the goal of encouraging students, especially in middle and high school, to pursue science, technology, engineering and math.

A change in motivation is perhaps the key factor in students' decision to earn an engineering degree. Positive experiences and preparation for success in STEM areas should begin in middle and high school, through rigorous college preparatory coursework and extracurricular activities. Students participating in extra-curricular STEM activities during the academic year and in summer camps increase their interest in college education, explore career options, and are better prepared to pursue and successfully graduate in STEM majors, especially engineering[5]. Thus, a challenge for teachers, administrators, and other leaders in education collectively is to find ways to build on these positive experiences and enable students to acquire some knowledge in STEM related areas.

In this paper, the author describes an Electronic Communication course that is part of an out of school time educational program targeting urban African American and Hispanic American students in middle and high school to make STEM disciplines more culturally relevant for these underrepresented youths. The goal of this week-long summer day course is to impact students' interest in STEM fields, especially increasing awareness toward engineering and what engineers do, and to effectively contribute to the transition of high school into college. Students learn Electronic Communication Technologies through an intense load of hands-on activities closely coordinated with theoretical classroom discussion focusing on exciting real-world engineering applications of a variety of communication systems.

The course gives to students their first and, for some students, their last formal exposure to some understanding of engineering. With the strong emphasis on applications, this course helps build a better understanding of the inter-relationships between each of the STEM disciplines. The author suggests topics that can help instructors to engage the students in a number of ways. The suggestions provided in this paper, while confirming principles and practices described in the literature, provides new insights and ideas. So far, the course can be considered successful due to the positive and encouraging feedback provided by the students. The course attendees responded an end of course survey to assess the success of the course in achieving its goal in terms of impacting students' knowledge on engineering and on the specific subject, and attitude towards college education and STEM areas. In addition to the surveys, students also took pre- and post-test to directly assess their knowledge and understanding of electronic communication main concepts.

2. Course Description:

Electrical engineering is one of the largest and most rapidly developing technical fields. It concerns developing, manufacturing, and maintaining electrical, electronic, and computer equipment and its applications in a wide variety of systems, such as communications and process control. Can you imagine your life without a cell phone, a TV, or a computer? How about making the technologies behind those devices even better? Electrical engineers and technologists spend most of their time learning how these technologies work and developing new ways to improve them.

This course emphasizes practical, hands-on laboratory work that is closely coordinated with theoretical classroom discussion. The course focuses on both standard and wireless communication systems.

Course Learning Outcomes

- Understand basic concepts of Electronics and circuit design;
- Understand how electronic communication systems work and their application to daily life;
- Understand concepts of radio frequency (RF) propagation, including AM/FM modulation;
- Understand the different types of transmitting media;
- Understand the architecture of a wireless cellular network;
- Use of simulation tools to design and test basic communication systems;
- Understand how technology relates to environmental issues, including energy efficient devices, and environmentally safe disposal of cell phones, batteries, and other electrical/Electronic devices.

Course Educational Objectives

- Student participation in this course will generate a positive recognition of the various facets of STEM;
- Recognition will result in increased interest among prospective STEM students;
- Open the college "door" to underrepresented students, especially in STEM areas;
- Increasing students interest, hence a greater enrollment in STEM disciplines at the college level;
- Retaining post-graduate interest in STEM area disciplines;
- Contributions of the course to the STEM-learning knowledge base.

3. Appropriate pedagogy

The traditional order to teach electrical engineering is that one must learn about semiconductor junctions before common emitter amplifiers. Wolaver et al. [6], defend the thesis that electrical engineering instruction can be greatly improved by taking up many topics in reverse of the usual order. Instruction should follow an order that starts with the broad uses and system components and only then delves further down into such details as transistors and solid state. This methodology is known as "outside-in" or "top-down" approach and is widely applicable and is practiced in many fields, especially by engineers. The advantages of the outside-in approach, includes the motivation to students. Another advantage of the outside-in order of study is that, the study can logically stop at whatever level of detail satisfies the need at the moment. The author has follow an approach consistent to the top-down approach, where the application is briefly discussed first and the teaching of the basic principles follows. In addition, the author often makes a mapping between a typical application (physical world) and its representation in circuit analysis domain (electrical schematic).

The author also makes use of technology such as PowerPoint® presentations, simulation software such as Multisim®, and basic software such as Excel®, and Word®. For class presentation, the author applies a balanced combination of PowerPoint presentations, and traditional lecture on the whiteboard, in which the author often demonstrates how to use the theory to solve practical problems to help the student develop problem solving skills.

It is also important to discuss real-world applications that are straightforward extensions of fundamental ideas. Emphasize "transferable skills" and their relevance to future careers in STEM areas such as: robotics, information system management, telecommunications, etc. The use of examples relating electronics to specific fields, for instance, a mapping correlating the electrical circuit of an automobile and an electrical circuit diagram helps students to make a connection between the classroom and the mechanical engineering field, or the need for electrical cables with different proprieties to carry out binary data at different data rates for computer networks.

4. Encourage discussions

The author encourages students to positively interact with those around them, especially during the laboratory experiments. When time permits, students are asked to form small groups of 2 or 3 to solve a particular problem, and they should spend a few minutes discussing about the appropriate answer. Through this engagement, students appear to feel more confident about the material. The author also actively pursues the engagement of the students in the classroom by frequently asking them questions and stimulating them to ask questions to the instructor. Moreover, the instructor also stimulates students to do work on their own, reducing the attitude that everything must come from the instructor, in other words, an instructor should be a facilitator of students success.

5. Lab Experiments and simple simulations

It is a common understanding that the laboratory must serve as a learning resource center in which the students not only perform formal lab assignments, but also have the opportunity to use the equipment and computers to strengthen their understanding of the concepts presented in the lecture section[7]. We can't stress enough the value of hands-on learning. The laboratory adds realism and solidity to the topics covered course. Students usually enjoy laboratory work, especially as it can be related to some of their own major interests. Therefore, it is imperative to choose experiments that provide students with real life applications that are challenging but achievable, and most importantly that the lab experiments are tightly couple with lecture. Students' data should be checked before they leave the lab to make sure that the data is at least acceptable to complete the lab assignment, this policy is particularly important for pre-college students taking possibly their only laboratory session.

It is also of great use to have a computer on each bench that can be used for instrument control and data acquisition, data processing and plotting, and circuit simulation. The author encourages students to simulate simple circuits using software such as Electronic Workbench Multisim® by assigning them simple simulated lab homework prior to the hand-on lab experiment. The simulations provide a link between the theory learned in class and the actual lab experiment. Computer-based lab experiments speed up student progress in hands-on experiments and make the learning experience in the lab more efficient. However, careful attention should be paid to avoid the use of simulation as a substitute for thinking, as can be the case for some students. Students have reported in their end of course surveys that the laboratory experiments were valuable elements of their learning process, through meaningful hands-on experience gained in the laboratory.

List of lab experiments includes:

Lab 1: Basic electronics laws

Concepts: DC Voltage, DC Current, Resistance, and Ohm's Law, KCL, KVL, and DC multimeter measurements.

Objectives: Students are introduced to properties of resistors, resistor color code, and resistance measurement with the Fluke 8050A Digital Multimeter. Students also learn how to use multimeter for voltage and current measurement, and application of Ohm's law, KCL, and KVL.

Lab 2: Time-varying signals

Concepts: Time-varying signals, amplitude, period, frequency.

Objectives: Students are introduced to the tools used to generate and measure signals that vary with time, such as: function generator and oscilloscope. In addition, students learn the main characteristics of time-varying signals.

Lab 3: Hearing Test: Frequency response plot

Concepts: Input and output voltage measurements, frequency response.

Objectives: Students learn how to use basic electronic equipment to determine their own hearing response, learn how to make dB calculations, use of Excel to plot results, use of multimeter, function generator, resistors.

Lab 4: Battery level indicator
Concepts: Circuit implementation in bread board, voltage measurements, use of op-amps, LEDs, and resistors.
Objectives: Students learn how to construct a 1.5 V battery level indicator using LM324 quad op-amp integrated circuit, resistors, and LEDs.

Lab 5: Alarm system
Concepts: Soldering techniques and safety issues.
Objectives: Students learn soldering techniques, become familiar with a variety of electronic components, and learn low to appropriately assemble a circuit board.

Lab 6: Wireless FM broadcast band receiver
Concepts: Radio Frequency (RF), basic modulation theory, receiver characteristics, soldering techniques, application of basic electronic components.
Objectives: Students learn how to construct a wireless FM broadcast receiver, learn the different circuitry compositing a FM receiver, and how different components are placed together to receive and "display" a FM signal.

Lab 7: Wireless FM microphone
Concepts: Radio Frequency (RF), basic modulation theory, transmitter characteristics, soldering techniques, application of basic electronic components.
Objectives: Students learn how to construct a wireless FM broadcast transmitter, and learn the different circuitry compositing a FM transmitter. Students also learn the relationship between power and distance covered by the transmitter.

Lab 8: Transmission line measurements
Concepts: Line capacitance and inductance measurements, velocity of propagation, frequency dependent attenuation, power calculation.
Objectives: Students learn how to use the LCR bridge to measure the inductance and capacitance of a RG-58/U cable sample, and how to calculate velocity of propagation. Students also measure input and output voltage used to calculate input and output power, and power loss or attenuation.

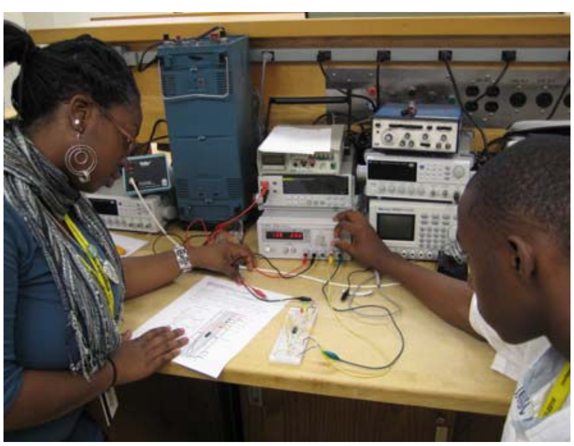


Figure 1. Lab activities providing hands-on experience.

6. Assessment

Assessment is vital and should reflect to what extent the course meet the learning objectives; direct and indirect assessment measurements were developed to measure the effectiveness of the course and whether goals are met.

Participating student knowledge and understanding of subject material were directly evaluated through quizzes and pre-test and post-test that measures competence of the course components. Results of the exams were analyzed to determine specific areas of cognizance of the subject matter, interest in subject matter, areas of non-interest, and areas not addressed. In addition to pre-test and post-test, the course attendees responded an end of course survey to assess the success of the course in achieving its goal in terms of impacting students' knowledge on engineering and on the specific subject, and attitude towards college education and STEM areas. The survey results revealed, among other findings, that students' interest in college education further increased. These results will assist us to refine our goals, and on the development of other similar programs.

In Table 1, the author shows the survey questions and students' responses for the student rating of attitude towards college education and STEM areas for the class evaluation of Summer 2009. The survey questions shown in Table 1 are closely linked to the course educational objectives. Twenty-eight students responded the survey out of a total of 29 students taking the course in Summer 2009. The rating used for the questions in Table 1 was: (4) a great deal, (3) moderately, (2) slightly, (1) not at all.

My participation in this activity…	Rating (mean)
1) Helped me understand engineering better.	3.64 (91%)
2) Led me to a better understanding of my own career goals.	3.57 (89%)
3) Increased my interest in studying engineering in college.	3.21 (80%)
4) Made me think more about what I will do after graduating from high school.	3.71 (93%)
5) Made me decide to work harder in school.	3.43 (86%)
6) Made me to decide to take different classes in school (including college) than I had planned to.	2.85 (71%)
7) Made me more confident in my ability to succeed in engineering.	3.56 (84%)
8) Increased my confidence in my ability to participate in engineering projects or activities.	3.64 (91%)

(Table 1 – Attitude towards college education and STEM areas)

Also related to Table 1, students' comments to the question "What did you like best about this activity" were:

"*Building a FM receiver system*"
"*The hands-on learning was really encouraging*"
"*Building an alarm system*"
"*Enjoyed the College environment*"
"*Learning about different engineering fields*"
"*The information about College was immensely helpful*"
"*Enjoyed working with equipment that I never used before in my school*"

Despite of the fact that the time structure of the course was based on approximately 60% of hands-on and 40% of lectures to cover the basic principles used in the lab experiments, several students comment that they would prefer even more hands-on activities and even less lectures.

In Table 2, the author shows the survey questions and students' responses for the student rating of instruction for the class evaluation of Summer 2009. The rating used for the questions in table 2 was: (4) excellent, (3) good, (2) average, (1) poor.

Question	Rating (mean)
1) How well was your instructor prepared?	3.79 (95%)
2) How did your instructor encourage questions in class?	3.71 (93%)
3) How approachable and easy to talk was your instructor?	3.71 (93%)
4) How well did your instructor explain information clearly?	3.71 (93%)
5) How knowledgeable was your instructor about her subject?	3.93 (98%)
6) Did your instructor allow enough time for completion of tasks and have enough activities to keep you busy?	3.86 (96%)
7) Was your instructor creative and able to keep the class interesting?	3.36 (84%)

(Table 2 – Instruction evaluation)

In Table 3, the author shows the survey questions and students' responses for the student rating of statements describing work or jobs student might do in the future. The rating used for the questions in table 3 was: (4) very important, (3) somewhat important, (2) not important.

How important is it to you to do …	Rating (mean)
1) Work that makes me to think.	3.48 (87%)
2) Work that allows me to make lots of money.	3.92 (98%)
3) Work that allows me to use math, computer, engineering or science skills.	3.04 (76%)
4) Work that allows me to tell other people what to do.	2.88 (72%)
5) Work that allows me to help solve problems and create solutions.	3.52 (88%)
6) Work that is fun to do.	3.76 (94%)
7) Work that allows me to have time with family.	3.76 (94%)
8) Work that allows me to help my community and/or society.	3.52 (88%)
9) Work that makes people to think highly of me.	3.56 (89%)
10) Work that is satisfying to me.	4.00 (100%)

(Table 3 – Statements describing work or jobs student might do in the future.)

In Figs. 2 and 3, the author shows the results for pre-tests and post-tests used as a form of direct assessment for the participating students' knowledge and understanding of electronic communication main concepts, and whether or not the course learning outcomes were successfully achieved. The pre-tests were administered at the beginning of the first day of course before the students have been giving any class material. All 29 students participating in the program in weeks 1 and 2 answered an exam with 31 multiple choice problems. The same electronic communication course was presented to two different groups of students during Summer 2009, one group in week 1 (with 14 students), and another group in week 2 (with 15 students). The plots in Figs. 2 and 3 have the number of correct problems on the vertical axes and the student initials in the horizontal axes. The results reveal an impressive improvement of students' knowledge on main electronics and electronic communication principles, therefore clearly indicating that the course learning outcomes were achieved. Similar results were also obtained for 3 groups of students who took a similar course by the same author during Summer 2007. Some of the 31 multiple choice questions used in the pre- and post- tests presented in Figs. 2 and 3 were:

1. *The function of an electronic communication system is:*
2. *How do changes in frequency affect wavelength?*
3. *Modulation is:*
4. *The two ways a radio wave can be modulated are:*
5. *Why modulation is necessary is radio communication?*
6. *Examples of electric signal transmitting media are:*
7. *Which of the following devices is (are) wireless communication device (s)?*
8. *One way to increase the capacity of a cellular wireless network is by:*
9. *Frequencies above the range of hearing are called Radio Frequencies. This range is above:*
10. *The superheterodyne principle for FM reception is based on:*
11. *Global Positioning System (GPS) is:*

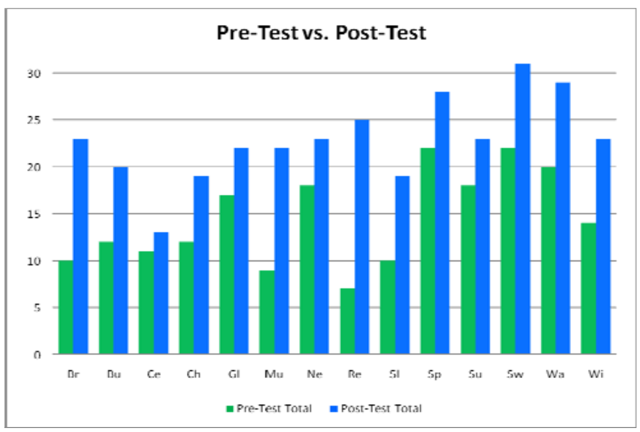

Fig. 2 - Pre-test results (green) and Post-test (blue) results for week 1 – Summer 2009. Vertical axis indicates number of correct problems per student, with maximum value equal to 31. Horizontal axis indicate the student ID name.

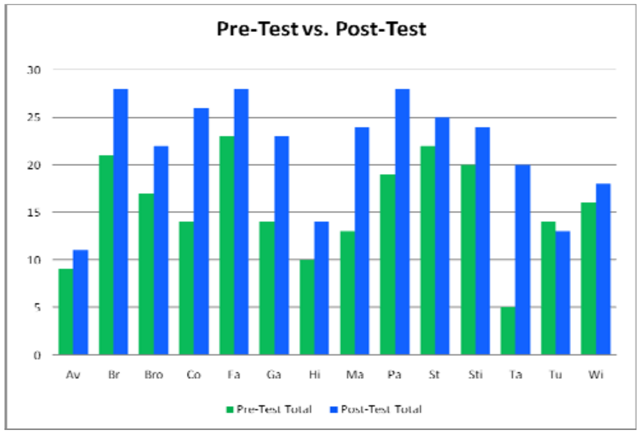

Fig. 2 - Pre-test results (green) and Post-test (blue) results for week 2 – Summer 2009. Vertical axis indicates number of correct problems per student, with maximum value equal to 31. Horizontal axis indicate the student ID name.

7. Conclusions

The electronic communication course presented in this paper was a pre-college preparation for underrepresented minorities in STEM disciplines. Overall, assessments data indicates that the combination of hands-on laboratory activities focusing on real-world engineering applications, classroom activities, and out-of-class fun activities all contributed to the positive experience the students reported. The surveys indicated an increase in students understanding of what engineer do, attitude towards college education and STEM areas. The summer program also helps students to experience and understand college life, to have dorms experiences, and to experience a supportive environment for advance their career goals. While the author feels that the suggestions presented in this paper show promise to a successful pre-college experience to make the idea of STEM more appealing to a wider, diverse group of students, each instructor must work within the context of his or her own institutions. Tailoring these course suggestions to our own institutions and to the particular group of students is a critical success factor and must be taking into consideration.

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