Improving the Freshman Engineering Experience

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Introduction

The University of Maryland Baltimore County has undertaken four initiatives to improve engineering education and awareness. The **first** initiative was to revamp the Introduction to Engineering Course (ENES 101) from a traditional lecture and design-on-paper course, to an active learning lecture and hands-on engineering design course. The revised ENES 101 course was presented and discussed during a three-day summer workshop to introduce high school teachers and counselors to the field of engineering. This workshop lead to the faculty at Eastern Technical High School's request for the development of a formal partnership with UMBC to teach the equivalent of the ENES 101 course in the high school environment. It is not the intent of the partnership to be a recruiting tool for UMBC, but rather to expose high school students to a college level introductory engineering course. This partnership and its expansion to other high schools is the **second** initiative. The **third** initiative is the establishment of a new variation (ENES 101Y) of the Introduction to Engineering course which is committed to helping new UMBC engineering students understand the academic expectations at a research university, develop their individual success strategies, and connect with the many resources that are available to help ensure success. The **fourth** initiative was a summer bridge program that was taught in the summer 2003 for new incoming students that are part of our STEP (Science Technology Engineering and Mathematics Talent Expansion Program NSF DUE - 0230148) and CSEMS (Computer Science Engineering and Mathematics Scholarship NSF DUE - 0220628) projects.

Background

The high school level Introduction to Engineering course was developed based on the interest and ideas that emerged from a workshop conducted at UMBC in July 2001. The objective of the workshop was to better equip high school teachers and counselors to identify, guide, and prepare prospective students at each of their schools for a career in engineering. The three-day workshop was developed and presented by UMBC faculty from the College of Engineering and was modeled after work done by Raymond Landis[1], former Dean of Engineering and Technology at

California State University, Los Angeles. Invitations to the workshop with a brochure and application form were sent to area high schools in Maryland. Each participant received a $150 stipend, meals, and Maryland State Department of Education (MSDE) continuing education credits. The workshop was sponsored by a grant from the University System of Maryland through their K-16 Disciplinary Alliance and matching funds from UMBC's College of Engineering (COE).

Twenty-eight mathematics, technology, and science high school teachers and counselors attended and explored the spectrum and reach of engineering in society. The following topics were covered during the workshop:

- An introduction to the broad field of engineering
- Student panel discussion on what it takes to be an engineering student
- Overview of the freshman Introduction to Engineering course at UMBC
- High school preparation for an engineering career, including math and science
- Future Scientists and Engineers of America (FSEA) program overview and competition
- Tour of local engineering facilities at Northrop Grumman
- Engineering faculty panel discussion on various engineering disciplines
- Opportunities and rewards of an engineering career
- Use of the Internet to learn about engineering
- 'Hands-on' projects to help introduce high school students to engineering
- Engineering alumni panel discussion on the future needs of industry
- Engineering research projects
- Success strategies students might use in pursuit of an engineering career
- Overview of engineering education, including curriculum, facilities, resources and opportunities for students

The approach taken in presenting many of the topics was to provide fun 'hands on' activities, during which the participants competed for a variety of 'prizes,' including UMBC t-shirts, key chains, and gift certificates. Pre- and post-surveys were conducted to assess the knowledge, abilities, and understanding of engineering, career opportunities, high school preparation, success strategies, incorporating projects to introduce high school students to engineering and advising students for an engineering career. Results[2] of these surveys and more details of the summer workshop were presented last year at ASEE.

Another measure of the success of this workshop was the interest it generated in follow-up collaborations between UMBC and local high schools. A few examples include:

- Invitations for UMBC to make several high school career day presentations.
- Numerous high school class visits and tours of UMBC's College of Engineering.
- UMBC's participation in the establishment of a High School Engineering Academy.
- New partnerships forming the basis of grant proposals to NSF in Engineering Education Program and the Maryland High Education Commission (MHEC).
- The formation of a high school level Introduction to Engineering course and the subsequent pilot field introduction of this course in a partnership between UMBC and Eastern Technical High School.
- Expansion of the high school partnership with additional high schools.

It is the last of these activities, the high school level Introduction to Engineering course, that became the second initiative for improving the Freshman Engineering Experience at UMBC.

The First Initiative – Revision of the Introduction to Engineering Course at UMBC

The Introduction to Engineering course (ENES 101) at UMBC was revamped in 2000 and has its origins in work done by Dally and Zhang[3], and in work the author did while teaching in the Freshman Engineering ECSEL[4] program at the University of Maryland, College Park. ENES 101 includes an overview of engineering and an introduction to various topics within engineering. The emphasis of the revision of the course was to make it a project based inquiry experience. The students must work in interdisciplinary teams to design, build, evaluate, test, report (both a formal written report and oral presentation) and develop a mathematical model for a specified product. ENES 101 is a three-credit freshman engineering course which consists of two fifty-minute class sessions and a two-hour discussion session each week over a 16 week semester. The current enrollment in this course is approximately 150 students in the fall semester and 120 students in the spring semester. The discussion sessions are limited to 30 students. The course has three primary components: engineering topics, design tools, and the design project. A new variation of this course was added in the fall 2003, as part of the First-Year Success Courses initiative at UMBC, and is the third initiative (and will be discussed below).

Since the majority of the students in the course are incoming freshman, the first few classes are devoted to educating students on how they can be successful[5-7] in studying engineering, discussing the engineering profession, providing academic strategies for success, and showing students how they can broaden their education. Also as part of the course each student is required to participate in at least one function sponsored by a student professional engineering society (AIChE, ASME, IEEE, SAE, etc.). This is a chance for the students to make connections with upperclassmen in their major and become acquainted with the various opportunities available through professional engineering societies. A variety of engineering topics are covered during class including unit conversion and dimensional consistency, data analysis and representation, strength of materials, introduction to statics, introduction to fluid mechanics, introduction to heat transfer, and computer programming. Depending on the design project topic, some of the topics are studied in more depth. A workbook, written by the first author of this paper, is given to each student and covers the course topics complete with example problems. These example problems supplement problems covered during class.

The students are instructed in the use of various design tools during the weekly two-hour discussion sessions. Most of the sessions are held in the dedicated COE freshman computer lab. Undergraduate Teaching Fellows[8], who are senior-level engineering students, lead the discussion sessions. The Fellows are recruited by the instructor and have demonstrated their ability to work well with students due to their previous experience in taking ENES 101 at UMBC and have demonstrated both collaboration and leadership in the classroom. The design tools include Microsoft Word, Microsoft Excel, computer aided design (CAD), computer programming, and Microsoft PowerPoint. *ESource The Prentice Hall Engineering Source* series of textbooks is

used for the discussion session exercises and homework assignments. The Teaching Fellows are responsible for grading the weekly homework assignments (prepared by the instructor), which includes material covering both the design tools and class topics. Student teams meet during discussion sessions as well as outside of class to work on their design projects.

Each year a different design project is selected and the students must research, design, construct, and develop an analytical model and then test, evaluate, and report on the product. The goal is to select a product that is fun[9], inexpensive to construct, simple, and yet requires fundamental engineering principles. Safety is the primary concern, and the design specifications are structured to include safety precautions. The projects are also structured to have "bragging rights" associated with the product performance. This has resulted in friendly competition among the teams. Successful projects have included: human powered pumps for pumping water up a vertical height of 10 feet, catapults or trebuchets used to launch water balloons for distance and accuracy at a target (which included the first author of this paper), hot air balloons[10] that were required to carry a minimum payload and stay aloft a minimum time period and a wooden block transport device[11]. The projects are introduced during class by having the students take apart simple soap dispensers or toy catapults to see how they work[12]. The homework assignments have problems that lead the students in the right direction for the modeling and product performance calculations that are required. It has been rewarding to see the creative designs[13], as well as the interest the teams have taken in the projects. Many teams have created videos they made during the construction and testing of their projects. UMBC's Office of Information Technology has also filmed the design process over the course of the semester and has produced a video ("Video: Teamwork, Design, and Making Things Work! Undergraduate Design Class" produced by Bob Kuhlmann and Damion Wilson of UMBC's New Media Studio http://www.umbc.edu/engineering/cbe/). Local interest in the design projects has also occurred with local television coverage and articles in local newspapers ('In experiment, it's ready, aim, inspire' by Alec Mac Gillis in *The Baltimore Sun*, May 8, 2002). This publicity has resulted in numerous contacts from area high schools that are interested in partnering with UMBC, as well as calls from prospective students and parents.

The first homework assignment consists of a team application form for each student to complete. Information regarding the students' major, high school attended, GPA, SAT scores, and access to a car are requested. The students are also required to identify their skills in writing, graphics, leadership, teamwork, analysis, drafting, planning and research/library, as well as their strengths and weaknesses. This information is then used to assign the teams[14], which consist of 4-6 team members. Teams are balanced using the following criteria: major[15], background, academic performance, gender and ethnicity[16], and access to transportation off campus to purchase materials for the construction of the project. The team application also requires the students to write about themselves: how they became interested in their major, what their long-term career goals are, and what they did over the last summer or winter break. This information is used solely by the instructor to get to know the students on a more personal level since the class sizes are large. After the team assignments are made, (by the end of the second week of the semester), class time is then spent learning to effectively build and work in a team[17, 18].

Communication skills are stressed as part of the design project experience. Each team must complete a logbook[19] over the course of the semester; the first team assignment is to have each team member interview one another and log the interviews. The remainder of the entries serves as documentation of team meetings, evolution of design, modeling, evaluation approaches, and actual performance. Each team must also submit a final written report summarizing their efforts. Guidelines for the report, as well as a detailed grading rubric[20] are handed out and discussed during class. The teams are encouraged to turn in a preliminary draft of their report for comments prior to submitting their final report. UMBC also has a Writing Center located in the Learning Resource Center on campus that provides assistance to the students in the preparation of their reports[21]. Each team is also required to make a formal oral presentation using PowerPoint at which each team member is required to present. Specific guidelines for the presentation are discussed in class and the students are given a grading rubric for the presentation. Each team member must also complete a peer evaluation on themselves and each team member, which is part of the students' grade for the course.

The Second Initiative - The High School Introduction to Engineering Course

The high school course is essentially the same as UMBC's ENES 101 course. The same workbook, *ESource The Prentice Hall Engineering Source* series of textbooks , homework assignments, quizzes and exams are given, as well as the same design project and evaluation criteria. The differences between the two experiences are that the high school course is taught over a full school year, versus a semester; therefore, the students have more class time to work on their design projects and assignments. The high school teams usually have time to complete two different design projects (the current UMBC project and a previous project). In addition, the high school teams are composed of only two or three students since it has been the experience of the high school teachers that groups of more students are less effective in the high school setting.

As part of a field trip, the high school students are required to attend one of the design project testing days during the fall semester at UMBC. This gives them the opportunity to experience the climate and culture of a college campus as well as meet and talk with some of the college students and learn from their designs. The high school students also attend a UMBC visit day where they attend engineering classes, a COE discipline overview, a student panel discussion, and a campus tour. Interested students also attend the COE open house during Engineers Week. Also as part of this exchange, the first author of this paper travels to the high school for the design project testing and the oral presentations.

The High School Sites – Eastern Technical High School and Dulaney High School

At the conclusion of the three day summer workshop, Eastern Technical High School requested UMBC to partner with them in the fall of 2001 to assist them in teaching their senior level engineering course, which is part of their Engineering Careers program. Eastern Tech serves students primarily from northern and eastern Baltimore County, Maryland. Eastern Tech has been named a New American High School National Showcase Site by the U.S. Department of Education and the National Association of Secondary School Principles, as well as a Maryland Blue Ribbon School of Excellence by the Maryland State Department of Education. With an

enrollment of 1330, Eastern Tech offers a comprehensive academic and technical education to students who successfully complete eighth grade and fulfill its highly competitive application process. Eastern Tech is the technology magnet school for eastern Baltimore County and offers advanced placement, gifted and talented, and honors level courses in English, mathematics, science and social studies. Eastern Tech emphasizes state of the art technology and offers ten career majors including the Engineering Career major.

The Engineering Careers program is designed for highly motivated high school students who intend to enter a college engineering program. The program emphasizes the preparation of each student for the rigorous natural science, mathematics, and computer programming courses required for the mastery of an engineering curriculum. In addition, the Engineering Careers program exposes students to the different disciplines of the profession. The program culminates in the senior level engineering course, which is the equivalent of UMBC's ENES 101 course. The students that complete this high school course (in addition to the required computer aided drafting and design and computer programming courses) are eligible to receive credit for ENES 101 if they elect to attend UMBC.

The senior level high school engineering course (enrollment is 25-30 students) is taught by Mr. James Matalavage, who worked as an engineer for seven years prior to becoming a high school engineering teacher 11 years ago. He also serves on the Industrial Advisory Board of UMBC's COE.

Dulaney High School is a comprehensive public high school situated on a 45-acre campus in the Timonium area. The school serves a large suburban residential community of middle to high socio-economic level, and currently has an enrollment of 1853 students and has a 20% minority population with 4% of its students on the free-lunch/reduced lunch program. Dulaney is fully accredited by the Middle States Association of Colleges and Secondary Schools and by the Maryland State Department of Education, and is a member of the National Association of College Admission Counselors. Dulaney High School complies with the NACAC Statement of Principles of Good Practice.

The numerous programs offered at Dulaney are designed to meet the educational and career needs of all students. These include a full range of academic, vocational, and work-experience programs. In addition, concurrent college enrollment programs are available to a qualified senior, which includes ENES 101 with UMBC.

The Third Initiative - First-Year Success Course ENES 101Y

In August 2001, the University of Maryland Baltimore County began the planning process for the development of a Student Success Course model in order to strengthen the First-Year Experience for students. Both a steering committee and working group were established and developed the student success course topics and anticipated outcomes for the First-Year Success Course, as outlined below:

Course Goals:

- Clarify academic expectations and develop in students the essential academic skills for UMBC study
- Facilitate students' involvement as active members of the UMBC community
- Maximize students' personal development and self-awareness

Course Outcomes:

Upon the completion of this course, students will…..

- Liberal Arts Education
    - understand the value and importance of a broad-based educational experience, having been exposed to the major areas of current knowledge
    - understand what is required of them to achieve success in negotiation the university environment, what faculty expectations are for university students, and what specific intellectual skills will be necessary to meet these expectations
    - appreciate more fully cultural diversity and understand how such an appreciation can be of benefit in developing and strengthening ties with new communities
- Academic Integrity
    - understand the virtue and value of 'integrity' for their personal and professional lives and why academic integrity is an important value at UMBC
    - know the procedures UMBC has for upholding the university's high standards for academic integrity and the possible consequences that can result form academic misconduct
- Time Management
    - be able to set personal and academic goals and plan weekly and semester schedules
- Academic Expectations/Skills
    - know how to examine and develop their academic skills, including reading, listening, writing, speaking and problem-solving
- Communications
    - understand the value and importance of speaking and writing skills to their academic and personal success and the methods of (and resources for) developing these skills
    - know how to use the computer and internet responsibly
    - appreciate the value of lining and working in a diverse community
    - understand the importance and ethics of collaborative learning and collective work
- Library Skills
    - have been oriented to UMBC's AO Kuhn Library and understand how to use its resources
    - understand the nature of library research
- Major/Career Decision Making
    - have examined personal and academic goals and values in terms of how they relate to their chosen major and to the world of work

    - have experience in utilizing identified career exploration tools which they then will relate to themselves through a project or assignment
- Life-long Learning
    - understand theories of learning styles and life-long learning concepts
    - understand, as the result of self-assessment, their preferred learning styles
    - be able to identify behaviors, motivators, and barriers that limit successful learning – and resources for successful learning
    - have a framework for making wise choices

Due to the comprehensive coverage of the above topics (as compared to what is covered in the first few classes of the ENES 101 course), a new section, ENES 101Y, was offered in the fall 2003 semester. Students enrolled in this section attended the same ENES 101 lectures and discussion sessions, but they also attended one extra fifty minute class each week to cover the 'student success course' and received 4 credits for ENES 101Y (versus 3 credits for ENES 101). There were 22 students enrolled in ENES 101Y during the fall 2003 semester.

The Fourth Initiative - The Summer Bridge Program

UMBC has received NSF funding for our STEP (Science Technology Engineering and Mathematics (STEM) Talent Expansion Program NSF DUE - 0230148) and CSEMS (Computer Science Engineering and Mathematics Scholarship NSF DUE - 0220628) projects. The *STEP* project identifies the relative effectiveness of a two-week summer bridge program, a minimal stipend, and an internship program on student enrollment and retention in STEM programs. This program, developed in partnership with Community College of Baltimore County (CCBC), seeks to increase the number of students, particularly those from underrepresented groups, receiving degrees in science, technology, engineering, and mathematics. Issues of articulation and increased cooperation between the two institutions will also be addressed. Seventeen faculty representing the two institutions support the project. In addition, UMBC's Shriver Center will help CCBC establish the first internship program at a community college in the state. Finally, high school students will develop an interest in STEM fields through a pilot program in which 90 upper level UMBC mechanical and chemical engineering students, divided into teams, visit ten high schools per year to introduce high school students to physics, chemistry, biology, mathematics or technology concepts using engineering applications. The *CSEMS Scholarships* project provides scholarship money, a one-week summer bridge, and programming support throughout the year to low income, academically talented students majoring in computer science, engineering, and mathematics. Again, articulation of transfer students from CCBC is a part of this project.

One of the objectives for each of the program was to establish an academic bridge program for incoming freshmen. The summer bridge program was a non-residential, on-campus summer experience for the CSEMS and STEP students which lasted two weeks long for the STEP students and one week long for the CSEMS students. The following were the key elements of the summer bridge:

- Orient UMBC students to the university and acquaint students enrolled at a two-year college with the four-year college environment;

- Provide exposure for two-year and four-year students to the various professional societies (AIChE, ASME, IEE, SWE, ACS, Triangle Fraternity, etc.), recent graduates from CCBC and UMBC, and professionals from STEM-related professions, who discussed their job experiences.
- Highlight outstanding professors at UMBC and CCBC and have their undergraduate students provide presentations so that the bridge students are exposed to exciting new areas, as well as meet undergraduates who have had the opportunity to perform research.
- Provide instruction in academic survival skills (study skills, time management, preparing for tests and test-taking strategies, etc.).
- Provide two UMBC upper-class students to serve as tutors, mentors, and guides on campus during the two weeks and provide an electronic mentoring component throughout the year.
- Provide academic review and enrichment to insure college preparedness in STEM areas, such as mathematics, physics, chemistry, biology, computer science, engineering, etc.
- Create awareness of current research on the issues of women and minorities in STEM areas of study.
- Provide social activities to build a cohort of students by putting students in teams and playing various team-building games to strengthen their leadership skills and teach them how to work as a team.

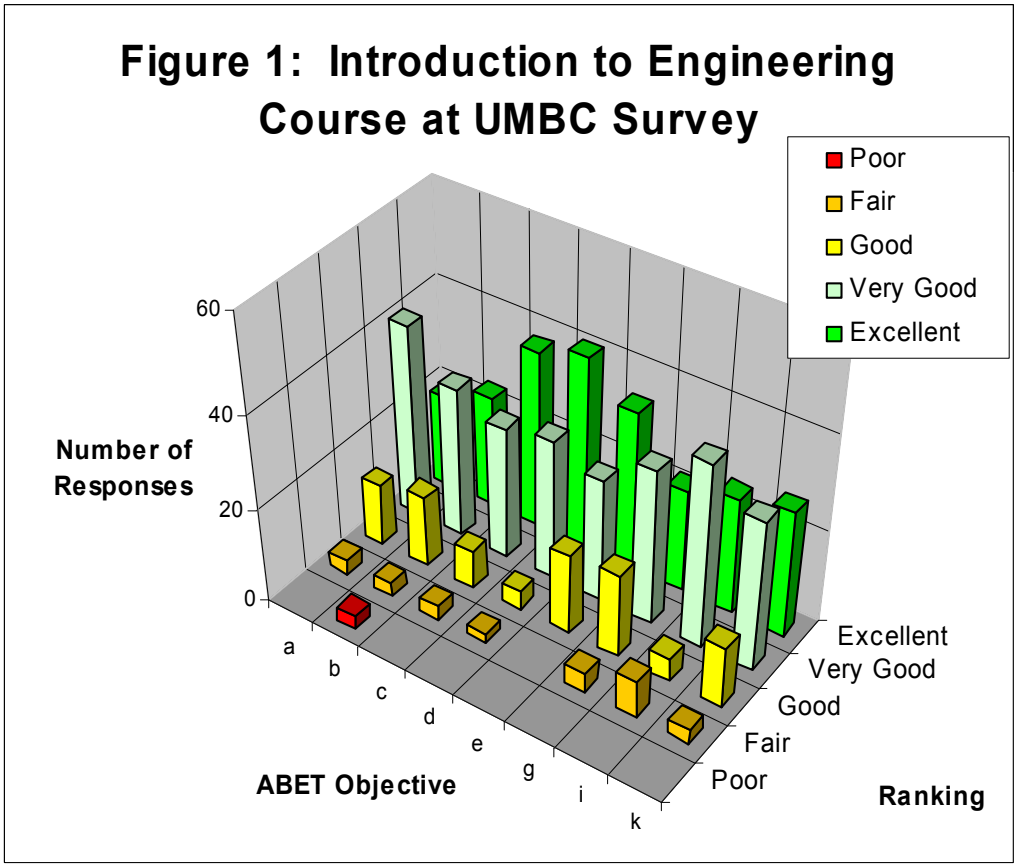
Discussion of Results

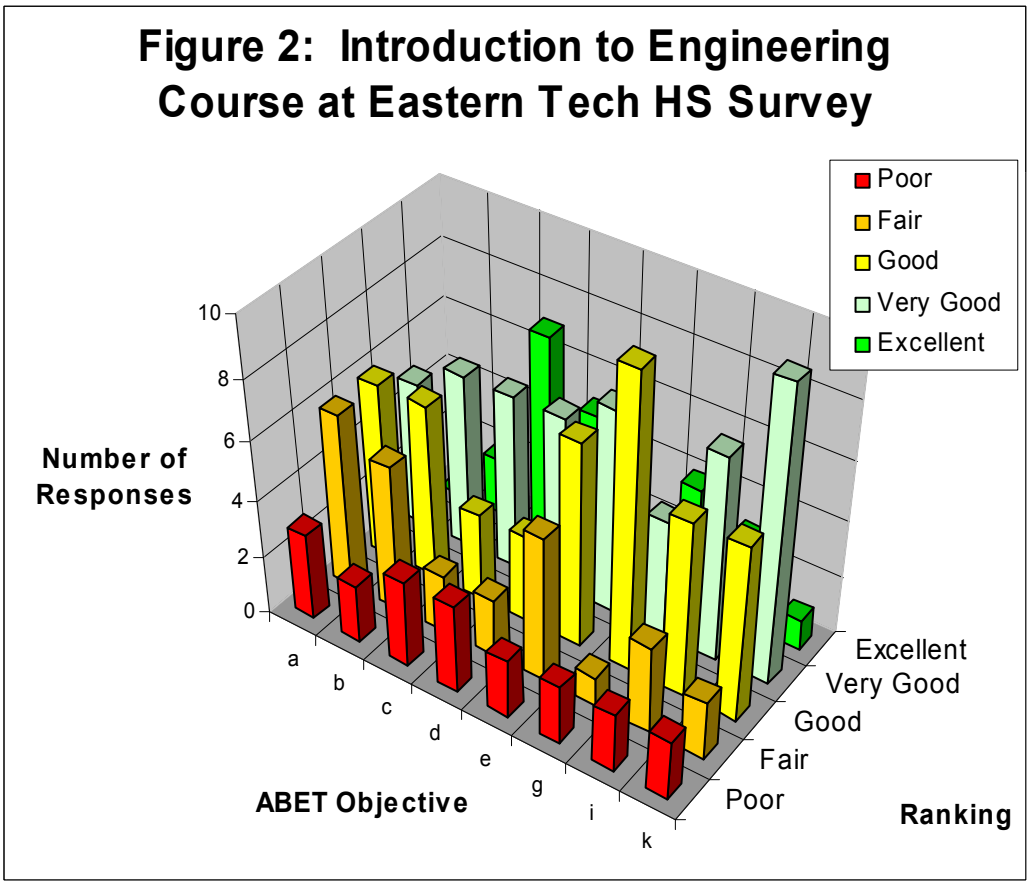
UMBC has revamped their introduction to engineering course to include a hands-on, project-based inquiry experience in the design of a specified product. The University also developed and taught a three day summer workshop to introduce the field of engineering to high school teachers and counselors. This has resulted in numerous follow-up collaborations between UMBC and local area high schools. One such collaboration was a partnership to teach the Introduction to Engineering course in the high school setting.

As a metric of the effectiveness of the course at the college and high school levels, some key criteria established by ABET for assessing engineering programs were used. In order to receive accreditation, ABET requires that engineering programs demonstrate that their graduates have:

(a) an ability to apply knowledge of mathematics, science and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(c) an ability to design a system, component, or process to meet desired needs
(d) an ability to function on multi-disciplinary teams
(e) an ability to identify, formulate and solve engineering problems
(g) an ability to communicate effectively
(i) a recognition of the need for, and an ability to engage in life-long learning
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Although it is unlikely that a single freshman engineering course can prepare students to satisfy the ABET criteria, it is a useful tool to gauge students' progress in their ability to utilize key engineering concepts and thought processes. To this end, students are asked to provide a self assessment, via a survey, of their progress in key ABET areas. Survey results from the Fall 2002 UMBC freshman course are presented below in Figure 1 and the corresponding High School course survey from June 2003 (academic school year 2002-3) can be found in Figure 2.





The survey measures the students' self-perceived attitudes and comfort level in key ABET areas. The proof of their progress can be readily seen in the working products they design and produce in each of the engineering challenges. Examples are given here (more can be found on the ENES 101 website: http://www.umbc.edu/engineering/101.html). In fall 2000 the teams had to design a human powered pump that had to pump water up a vertical height of 10 feet, and 4JDS Consulting Engineers are shown in Figure 3 and their pumping rate was 12.5 gallons per minute. Figure 4 depicts Team Pork and Beans from the fall 2001 semester. Their project was to build a trebuchet to launch water balloons. Their furthest water balloon launch was 124 feet, and their target accuracy was 60 %. Their most accurate launch resulted in drenching the instructor from a distance of 108 feet. In fall 2002 the project was to design, build and model a hot air balloon. Team Five Dollar Bet is shown in Figure 5 and their balloon carried a payload of 30 grams and stayed aloft for 113 seconds. And finally, the fall 2003 project was to design a wooden block transport device. Team High Fliers is shown in Figure 6 with their design of a floating arm trebuchet which successfully launched the wooden block 58 feet and their accuracy was 100 %.

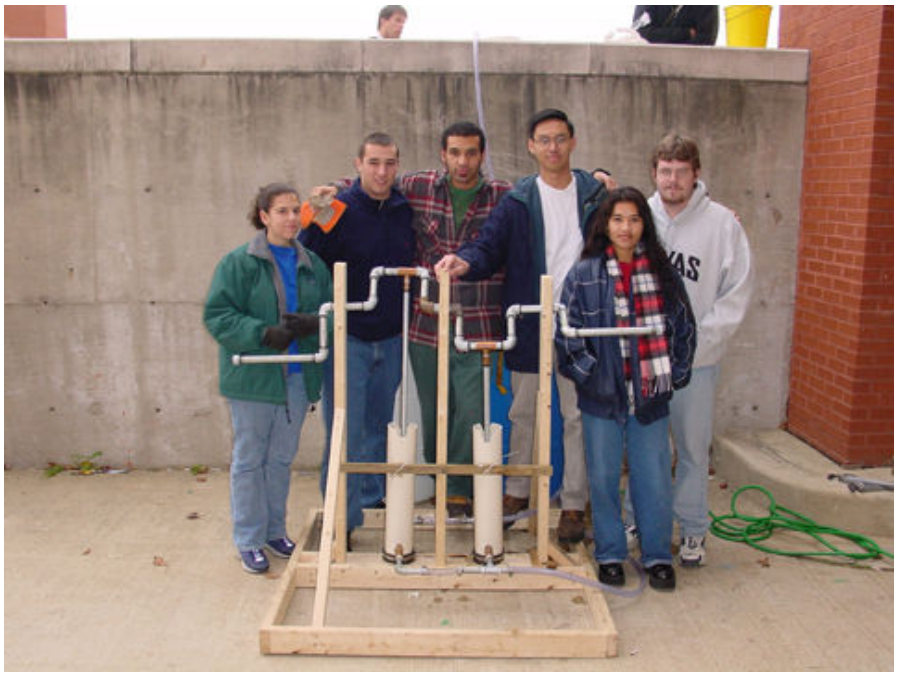


Figure 3: 4JDS Consulting Engineers; Jennifer Curcio, David Robbins, Jeff Coleman, John Robert Lim, Jennifer Sharma and Sean Kenny.

Figure 4: Pork and Beans; Drew Lenhart, Dustin Fickel, Samantha Silverston, Laura Sacker, Justin Garner, and Peggy Preston (not shown).

Figure 5: Team Five Dollar Bet; Ray Moore, Brendon Worst, Terri Hanks, Robin Babaris, Milton Jones and Michael Dennis.

Figure 6: Team High Fliers; Heon Ryou, Joseph Rybak, Joshua Herring, Matt Trendell, Matt Ontiveros and Tony Wong.

Over ninety percent of the students in the first two high school classes that took part in this partnership are currently majoring in engineering in college (24 % and 60 % at UMBC). The Eastern Tech high school students that enrolled at UMBC and met the eligibility requirements, have received credit for ENES 101. It is UMBC's intent to survey the high school students that completed the partnership program to determine if they felt the introduction to engineering course helped prepare them for college. At this time, results from the partnership with Dulaney High School are not available since this is the first year of the partnership. In addition, UMBC has assisted[22] the high school in teaching a summer workshop for middle school girls, establishing an 'Engineering Olympics' for their feeder middle schools and starting an FSEA after school club. The high school has also partnered with us in writing several engineering education grants to the NSF. Several other area high schools and school districts have approached UMBC to establish a similar partnership.

The Learning Resources Center at UMBC has a program in place through which they ask instructors of first semester freshmen to identify students that are in danger of failing at the mid point of the semester. Over one third of the students in the ENES 101Y section were identified at the end of October, as failing the course. However, by the end of the semester and with the assistance of the success strategies, less than ten percent of the students in ENES 101Y failed the course. The students in ENES 101Y completed surveys at the end of last semester. The results are still being compiled by the First-Year Success Course committee, but will be presented in June.

Eighty-six percent of the students attending the summer bridge rated it as 'very good' or 'excellent'. The most beneficial aspect of the bridge program was the UMBC student panel discussions, with 72.7% of students feeling they were beneficial "a lot" or "a great deal". Discussions with recent graduates (68.2%), exposure to STEM related professions (68.2%), and instruction in study skills (66.6%) were also rated as highly beneficial.

The implementation of these four initiatives to improve engineering education and awareness at UMBC has begun in the last two years. At this time, we have been unable to measure the direct effect of each initiative on recruitment, enrollment and retention. However, as these initiatives continue, it is anticipated that we will have a better understanding of how we can best use our scarce resources to address the needs of engineering students.

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