AC 2007-1064: A NEW MULTIDISCIPLINARY ENGINEERING EDUCATION INITIATIVE

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A New Multidisciplinary Engineering Education Initiative at Philadelphia University

Abstract

Philadelphia University is developing a new engineering school based on a strategic decision made three years ago to re-engineer its School of Textiles and Materials Technology and expand undergraduate educational offerings beyond its legacy B.S. textile engineering program. Today, the school has re-emerged as the School of Engineering and Textiles, currently offering baccalaureate degrees in Industrial and Systems Engineering, Mechanical Engineering, and General Engineering with a choice of minor concentration tracks in Industrial, Mechanical, Environmental, Textile, or Architectural Engineering. Furthermore, two new programs, Architectural Engineering and a dual degree program in Environmental Engineering/B.S. Chemistry (environmental science) will be offered beginning fall 2007.

To accomplish the above the School of Engineering and Textiles developed a five-year strategic plan around three major initiatives: 1) Recruitment and retention strategies oriented to attract, recruit and retain ultimately a diverse student body of 300 engineering students, 2) an integrated first two year engineering curriculum that emphasizes unity of knowledge across disciplines and promotes engineering as both a profession and service to humanity, and 3) preparing students to be life-long learners by developing student-centered learning communities enhanced by a state-of-the-art engineering classroom that integrates theory with experiential learning.

Even though it is premature to assess the effectiveness of School of Engineering strategic plan, preliminary results are encouraging. The first class (2005) consisted of 12 students, the second class (2006) of 21 students, and the freshman retention rate for the first class is 83.3%. The statistics with respect to diversity is also encouraging with 29% of the student body being female, and 16% of the students belonging to minority groups.

I. Introduction

Philadelphia University is developing a new engineering school based on a strategic decision made three years ago to re-engineer its School of Textiles and Materials Technology and expand undergraduate educational offerings beyond its legacy B.S. textile engineering program. The first program, B.S. Industrial and Systems Engineering that started in Fall 2005, is a result of an extensive review of the nationwide educational inventory of engineering programs and a needs analysis for the greater Philadelphia region. Today, the school has re-emerged as the School of Engineering and Textiles, currently offering baccalaureate degrees in Industrial and Systems Engineering, Mechanical Engineering, and General Engineering with a choice of minor concentration tracks in Industrial, Mechanical, Environmental, Textile, or Architectural Engineering. Furthermore, two new programs, Architectural Engineering and a dual degree program in Environmental Engineering/B.S. Chemistry (environmental science) will be offered beginning fall 2007.

To accomplish the above the School of Engineering developed a five-year strategic plan around three major initiatives: 1) Recruitment and retention strategies oriented to attract, recruit and retain ultimately a diverse student body of 300 engineering students, 2) an integrated first two year engineering curriculum that emphasizes unity of knowledge across disciplines and promotes
engineering as both a profession and service to humanity, and 3) preparing students to be life-
long learners by developing student-centered learning communities enhanced by a state-of-the-
art engineering classroom that integrates theory with experiential learning. The quantitative
goals, as well as the performance indicators established in the strategic plan for the period 2005-2010 are presented in Table 1.

Table 1. Strategic Plan Quantitative Goals 2005-2010

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Data Collection Method</th>
<th>Performance Indicator</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recruiting</td>
<td>Enrollment</td>
<td>Number of incoming freshman</td>
<td>12</td>
<td>20</td>
<td>25</td>
<td>35</td>
<td>45</td>
<td>60</td>
</tr>
<tr>
<td>Women in Engineering</td>
<td>Enrollment</td>
<td>% freshman females</td>
<td>17%</td>
<td>17%</td>
<td>18%</td>
<td>20%</td>
<td>22%</td>
<td>25%</td>
</tr>
<tr>
<td>Attrition rate</td>
<td># of non returning students</td>
<td>% attrition</td>
<td>NA</td>
<td>15%</td>
<td>17%</td>
<td>19%</td>
<td>19%</td>
<td>18%</td>
</tr>
</tbody>
</table>

Nationwide recruiting and retention have become a critical issue in engineering education, and
the subject of several research studies. Over the last three decades the attrition rate have
increased considerably. In 1975 attrition among freshman engineers was 12% and by 1990 it was
over 24%.¹ A more recent longitudinal study conducted from 1992 to 1998 surveyed 119
colleges and university and report that about 25% of entering first-year freshman declared
intention to study science and engineering degrees, and that by the second year 25% of these
students have dropped out or changed their major.² Undergraduate engineering enrollment has
also been a major concern in engineering education. Enrollment dropped from a peak of 441,205
(11.5% out of total undergraduate enrollment) entering students in 1985 to a low of 366,991
(8.5%) in 1999, and has increased again to 421,791 (9.1%). Even though, the increase is an
important sign that this trend has changed, it needs to be analyzed in terms of the percentage
since the overall enrollment to universities have increased by 7% in the past two decades. Thus
while other fields have experienced an increase in enrollment, the engineering enrollment has
decreased.³

Many of the research that study the low level of attraction and engagement in technical (STEM)
disciplines at higher education points to the following root causes: 1) Lack of widespread
understanding of these disciplines among the general public⁴, 2) dry, abstract, and non-related to
real world approaches to teaching math, science and engineering courses, 3) low level of
proficiency in mathematics and science for the freshman⁵, 4) high attrition rate due to poor
performance during the freshman year⁶, which creates a negative influence in the average high
school student.

In recognition of the need to reverse this trend, and even more to transform engineering
education according to the economical, technological and societal challenges of the 21st century,
engineering educators have initiated and documented several initiatives. Collaborative learning
and building learning communities have been encouraged by the NSF and required in 2000
ABET Criteria⁷-⁸. Pedagogical studies show that students learn more if they are actively involved
in the learning process and interacting among themselves⁹. In addition, the 2000 ABET Criteria
(I.C.3) also require that “the program must not only meet the specified minimum content but
must also show evidence of being an integrated experience aimed at preparing the graduate to
function as an engineer.” Traditionally, engineering programs offer one senior capstone design course, where the students bring together unconnected pieces that they have learned in separate courses. However, many institutions have moved to integrate design courses through the four-year curriculum as an integrator not only for the engineering courses but through the entire curriculum.  

Engineering educators in the 21st century are challenged to restructure higher education creatively to continue producing well-educated graduates and to maintain the leadership in cutting-edge research. To accomplish it, we need to work in interdisciplinary research teams inside and outside the university, including industry, government, K-12, and other countries. To do that, we need to integrate research and teaching, summer workshops with high school teachers and students, design and develop facilities to integrate teaching and hands-on experiments, increase STEM literacy through K-16, increase collaboration with STEM partners, and focus on student learning. Students’ learning may include a variety of initiatives that have been proved effective, such as first-year design courses, upper-level interdisciplinary courses, technology-enhanced classrooms that allow integrating lecture with experimental learning, through hands-on, team-oriented, and discovery learning projects.

This paper describes how Philadelphia University has developed and implemented three new engineering programs -and two new engineering programs will start in fall 2007-, focusing on the need of re-engineering the engineering education for the 21st century. Section 2 describes recruiting and retention initiatives, section 3 describes the first two-year integrated curriculum as a building block that will allow us to integrate learning communities and emphasize in unity of knowledge across disciplines, and finally in section 4 we describe how we integrate theory and practice in a state-of-the-art engineering classroom, where students attend to learn the theory, and to apply it working with the experimental work-stations within multidisciplinary teams on hands-on projects.

II. Recruiting and retention

The recruitment and retention initiatives involve collaboration with educational institutions as well as industry partners, and consist of a series of interrelated activities that includes engaging and exposing high school students and counselors to the engineering disciplines towards retention of recruited engineering students. In order to achieve the maximum outreach of these activities, we recognized the necessity to establish connections among business, economic development and education, and to work together to design programs and activities in support of increased enrollment in STEM education. Thus, in collaboration with Delaware Valley Industrial Resource Center (an economic development organization), High School Districts, Engineering Week Council, and the Institute of Industrial Engineering South Jersey Professional Chapter we have organized the following engagement and outreach activities:

- Creation and delivery of high school engagement and outreach materials which are used to create alignment among high school faculty and post-secondary professors in their communications about the opportunities inherent in applied engineering fields offered at Philadelphia University
- Design, development, and delivery of Student Career and Educational Awareness Conferences established to support increasing the participation of Philadelphia high school students in STEM education in general and Applied Engineering in particular
• The Establishment of two successful Engineering Summer Camp at Philadelphia University, which has provided a college-level, scientific educational experience for Greater Philadelphia High School Students
• Participation in regional industry/educational partnership advisory boards to conduct joint planning and development
• Organization of the 2007 Math and Science Workshop for High School Teachers

These activities are interrelated and sequenced in a one-year cycle that starts with dissemination of knowledge and understanding about the engineering programs at Philadelphia University among high school students, and ends with a one-week engineering summer camp for selected high school students. The outreach statistics of these set of activities are presented in Table 2. Note that we refer as an entity a high school institution, a high school student or a high school teacher.

Table 2. Outreach Programs Statistics

<table>
<thead>
<tr>
<th>Activity</th>
<th>Audience</th>
<th>Exposure (# of entities)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High School Presentation</td>
<td>High Schools</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>High School Students</td>
<td>720</td>
</tr>
<tr>
<td>Student Career and Educational Awareness</td>
<td>High School Students</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>Math and Science HS Teachers</td>
<td>20</td>
</tr>
<tr>
<td>2007 Math and Science Workshop</td>
<td>High School Math and Science Teachers</td>
<td>75</td>
</tr>
<tr>
<td>Engineering Summer Camps</td>
<td>Selected High School Students</td>
<td>40</td>
</tr>
</tbody>
</table>

The rationale of including the activities oriented to high school teachers, such as the Math and Science Workshop, is that we have found that without the collaboration of high school teachers and counselors, the outreach of the recruiting activities would be very limited. Thus, we have included two conferences/workshops specifically oriented to the them:

1) the Student Career and Educational Awareness Conference, where students and their teachers are exposed to the different engineering programs, and the multiple opportunities that exist in the job market for engineering professional. We invite a diverse forum of industry speakers to talk and interact with the students. Some of the sessions that the students attended included Women in Engineering, Starting Your Own Business, and How to Get Hired.

2) the 2007 Math and Science Workshop, which is offered to high school teachers to earn 3 hours of ACT 48 credit, and whose objectives are to provide the teachers with a view regarding technical education in an increasing complex society, as well as to provide teachers and counselors with information which will help students to choose STEM majors.

The engagement-outreach cycle is completed with the engineering summer camp, which is conducted by engineering faculty members in collaboration with industry partners, to expose high school students to the fields of engineering. We have developed two engineering summer camps, where the students worked in teams to solve real engineering problems using the
Fundamentals of Engineering Lab, which consists of integrated technical learning systems from Amatrol®, Lego® and Fishertechnick®. The summer program consists of two sessions, one is oriented for entering sophomore and junior students, and the second is oriented for entering senior students. The objective of the sophomore-junior session is that the students explore engineering while having fun solving real problems in a college atmosphere. The students design and build a prototype of an automated material handling solution using robots, sensors, conveyor belts, and indexed lines. Simultaneously, the students receive orientation to plan their high school courses in order to succeed in college, understand the type of jobs existing in the engineering fields. The senior camp is oriented for those high school students that have some interest in engineering and science but want to know more about engineering, or those students that are good in math and science but are undecided to pursue an engineering career. The students work within cross-discipline teams on hands-on project using simulation, automated material handling systems, a Pegasus robot, a CNC mill, and RF wireless communications. The camp is complemented with a career orientation seminar, a college and financial aid application seminar, talks by professional engineering speakers, and a final project presentation.

At the end of the summer camp program the students fill a questionnaire that help us to assess the effectiveness of the program (Table 3)

Table 3. Summer Camp Students Evaluations

<table>
<thead>
<tr>
<th>Question</th>
<th>Percentage of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Were you interested in pursuing an engineering degree before attending the camp?</td>
<td>0% 45% 18% 18% 18%</td>
</tr>
<tr>
<td>2. Are you interested in pursuing an engineering degree after attending the summer camp?</td>
<td>9% 9% 18% 27% 36%</td>
</tr>
<tr>
<td>3. Would you considering applying to Philadelphia University to an engineering program?</td>
<td>9% 0% 27% 18% 45%</td>
</tr>
<tr>
<td>4. Would you recommend other students to participate in the Philadelphia University Engineering Summer Camp?</td>
<td>0% 0% 0% 9% 91%</td>
</tr>
<tr>
<td>5. Did you find the summer camp helpful to you?</td>
<td>0% 0% 0% 55% 45%</td>
</tr>
<tr>
<td>6. Did you find the professors and the graduate students guided you appropriately?</td>
<td>0% 0% 0% 36% 64%</td>
</tr>
<tr>
<td>7. How do you rate the overall summer camp?</td>
<td>0% 0% 0% 9% 91%</td>
</tr>
</tbody>
</table>

We have established articulation programs with several area community colleges that enable students with an associate degree in engineering science and a GPA of 3.0 or better to complete an engineering degree at Philadelphia University. We also have a 3+2 articulation program with West Chester University that offers students an educational program in liberal arts and sciences and engineering. Students will spend three years at West Chester University studying liberal arts, science, and pre-engineering courses and then will enter Philadelphia University and complete in two years the requirements for a baccalaureate engineering degree.

The final recruiting activity that we have implemented is a bridge activity between recruiting and retention, an engineering open house co-organized with the current engineering students. We invite all the accepted high school students to the engineering programs and their families to
participate in the engineering open-house. Current engineering students, prospective engineering students, their families and faculty members interact with invited experts in engineering professions to learn about their career paths, job market, and how their engineering education helped them to succeed in industry. This activity is oriented to recruit the accepted students, as well as to motivate the current engineering students by exposing them to engineering personnel from the industry.

Most of the retention initiatives that we have implemented are closely related with the integrated curriculum and life-long learners initiatives that will be described in the next two sections. However, we include in this section those activities whose principal objective is retention, and are oriented to integrate a learning community and to help the students to deal with the stress and academic challenges during the freshman year.

- Facilitate and motivate the students to form a learning community. We have created two student chapters, the IIE Philadelphia University Student Chapter, and the ASME Philadelphia University Student Chapter, and through these student chapter we motivate the students to organize multiple activities that will integrate them, such as plant tours, participation in conference-dinners with IIE South Jersey Professional Chapter, participation in regional student conferences, and student mentoring in math and science courses.

- The freshman engineering courses; Introduction to Engineering, Introduction to Computing and Engineering Drawing, are taught around the fundamentals of engineering lab where students learn by discovery learning, working within multidiscipline teams, and with hands-on projects.

- Participation of the students in a research retention project. A common final project is jointly assigned to the Introduction to Engineering (freshman) and Engineering Statistics (sophomore) students. The instructor, Dr. F. Tovia, organize them in teams from both courses to design a questionnaire about which factors do the students consider important in retention. Then, the students perform a random survey among freshman and sophomore university students \( n \approx 350 \), and perform a statistical analysis to determine which factors by school are significant in retention. The findings of this study will be presented at the 2007 International Engineering Education Conference.

III. Integrated first two years engineering curriculum

The first two years of our engineering programs have common courses which allow students to choose their major at the end of the fourth semester. All engineering students participate in learning communities where the engineering courses are taught in the state-of-the-art fundamentals of engineering experiential learning center equipped with engineering lab modules, a classroom, team working stations, and teaching computers for students.

It is interesting to note that engineering fields can be divided into four general categories: the mechanical arts, electrical arts, chemical arts and interdisciplinary arts. The discipline specific fields under the mechanical arts category are: mechanical, architectural, industrial, structural, textile, civil, and aerospace engineering. A strategic decision was made by Philadelphia University to offer engineering degrees which are in the mechanical arts category: the discipline specific degrees in Industrial and Systems, and Mechanical Engineering, as well as the BS
Engineering degree with minor in Industrial and Systems, Textile, Architectural, Environmental, and Mechanical Engineering.

In view of the Philadelphia University’s mission to offer a blend of liberal arts and science with professional studies, the commonality of courses in the mechanical arts enables the University to offer engineering programs that consist of an interconnected combination of courses in basic science and mathematics, humanities, business, general engineering courses, and specific discipline engineering courses. Table 4 presents a breakdown of the courses by area in the three engineering degrees. As we can see, 50.8% of the curriculums are common courses, and among them 21.9% are in general engineering, 21.1% are in math & science, and 7.8% are in the liberal arts fields. The commonality of these courses allows us to have an integrated curriculum and contribute to build learning communities among the engineering students.

Table 4. Course Breakdown by Area of Study

<table>
<thead>
<tr>
<th>Area of Study</th>
<th>BSE</th>
<th>BSISE</th>
<th>BSME</th>
<th>% of Total Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering Common</td>
<td>28</td>
<td>28</td>
<td>28</td>
<td>21.9%</td>
</tr>
<tr>
<td>Engineering Specific</td>
<td>28</td>
<td>34</td>
<td>37</td>
<td>21.9%</td>
</tr>
<tr>
<td>Math &amp; Science Common</td>
<td>27</td>
<td>27</td>
<td>27</td>
<td>21.1%</td>
</tr>
<tr>
<td>Math Specific</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Common Liberal Arts</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>7.8%</td>
</tr>
<tr>
<td>Liberal Arts</td>
<td>26</td>
<td>26</td>
<td>26</td>
<td>20.3%</td>
</tr>
<tr>
<td>Business &amp; Electives</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>7.0%</td>
</tr>
<tr>
<td>Total</td>
<td>128</td>
<td>128</td>
<td>128</td>
<td></td>
</tr>
</tbody>
</table>

It is important to note that the liberal arts courses count for 28% of the curriculum, which is aligned with the recommendation of the National Engineering Academy committee that prepared “The Engineer of 2020”. The committee suggests preparing engineers for the 2020 well-grounded in the basics of mathematics and science but expanding their vision of engineering design through a solid grounding in the humanities, social sciences, and economics. Solutions of societal problems require applying new technologies in innovative ways with consideration of cultural differences, historical perspectives, and legal and economic constraints, among other issues. Thus, we integrate the liberal art courses into the engineering curriculum and to the Engineering Senior Design courses. The Liberal Arts courses culminate with a capstone course (Contemporary Perspectives) where the students explore major economic, political thrusts, and connect world affairs and the global economy with issues in their engineering major.

Entering students are exposed to an Introduction to Engineering seminar so that they can explore the general field of engineering and become exposed to the areas of engineering associated with the different majors offered at Philadelphia University. Furthermore, this course is integrated with the freshman and sophomore engineering courses, since in this introductory course the students are introduced to topics such as engineering design, computational software, mechanical drives, CIM, structural systems, and statistical analysis, that are covered in depth in the subsequent courses such as Engineering Drawing, Introduction to Computing, Statics and Engineering Statistics. All of these freshman and sophomore courses require that the students
work in teams, have a capstone hands-on final project, and are offered at the student-centered, state-of-the-art engineering classroom (Figure 1).

Figure 1. Fundamentals of Engineering Lab/Classroom.

IV. Preparing the Students to be Life-Long Learners

Considering the pace at which technology change nowadays, it is essentially impossible to teach the students all they will need during their career span. However, enlightened engineering educators can teach them how to learn by themselves, and how to learn to use the multiple technological tools that are available. Technology will change, no doubt, but they will be able to learn as technology changes.

Engineers are no longer isolated individuals working by themselves; they are individuals working within a multidisciplinary team in a global context to solve or improve technological, societal and economical issues. Therefore, the learning process must change from a lecture-oriented with passive-student to a hands-on, discovery-learning process with active students interacting among them. They need to face from day one in their engineering education challenging problems that need to be solved through multidisciplinary teams with the tools and information that they have or is available. The instructor’s role must be an extra tool that the students can use as a mentor, guide, and/or a consultant, watching and evaluating closely the students’ performance; their responsibility is the same, but now the students are the main players of the learning process.

Having that in mind, we have implemented the fundamentals of engineering learning center, fully equipped with Amatrol® skill-based, integrated technical learning systems, consisting of real-world industrial replica quality hands-on training equipment workstations, coupled with comprehensive training solutions including interactive multimedia, simulation software, and print-based student learning materials and teacher’s guides. The computers in the learning center have the latest software available related to our engineering programs. As a result, the students
have available in the learning-center most of the tools that they need to solve their projects and assignments; on-line access to information and instructions, a space to work with their team-members, the equipment -hardware and software- required to experiment and implement their proposed solutions, and faculty members that consult and help them upon progress and request (Figure 2). The students are the ones that learn through a discovery, trial and error process, being active players of the learning process, which is similar to the situation that they will face in the short term as professionals, learning new technology, facing an international competition, and changing working teams continuously, all of it within a multicultural/multidisciplinary context.

![Figure 2. First year engineering students learning to program robotic material handling.](image)

The fundamental of engineering lab consists of the following workstations equipped with data acquisition systems:

- Computer Integrated Manufacturing
  - CNC Machine
  - Conveyor transfer system
  - Palletized system
  - Pegasus robot
  - Indexed machine, pneumatic center and 3-axis robot workstation
- Mechanical Drives
- Electrical Systems
- Materials Engineering
- Structural Systems
- Thermo and heat-transfer Systems
- 3-D printer

It is important to note that all the workstations have the simulation software installed in the computers located in the leaning center, such that the students can design and test their proposed solution before implementing it on the industrial replica workstations.
V. Conclusion

Even though it is premature to assess the effectiveness of the strategic plan of the School of Engineering, preliminary results are encouraging. The first class (2005) consisted of 12 students, the second class (2006) of 21 students, and the freshman retention rate for the first class is 83.3%. The statistics with respect to diversity are also encouraging with 29% of the student body being female, and 16% of the students belonging to minority groups. We have accepted and enrolled for the spring semester of 2007 four new transfer engineering students, and for 2007 we have accepted 88 students. The University Undergraduate education Committee has approved two new engineering programs, the BS Chemical/Environmental Engineering and the BS Architectural Engineering programs, which have been designed under the same philosophy of integrated curriculum build upon the synergies of our strengths.

We are, in all the categories, ahead of our goals. The feedback from our students, industry and educational partners are very pleasing, and we are willing to share and collaborate with the engineering community new ways to improve the engineering education for the 21st century.

Bibliography