# Interdisciplinary Engineering via Engineering Physics: The Best of Both Worlds

**Stephen H. Cobb and James W. Rogers**
**Department of Physics and Engineering**
**Murray State University, Murray, Kentucky, USA 42071**

## Introduction

In recent years the engineering education community has focused attention on the need for engineers who can work across traditional disciplinary boundaries. Engineering has long recognized the importance of curricula that connect elements of engineering, mathematics, and the basic sciences. But as advances accelerate in the fields of biology, chemistry, and physics, engineers are increasingly called upon to integrate this new knowledge into the solution of practical problems. Many of these advances do not fall neatly into a single category, but rather occur at the boundaries of two or more traditional disciplines.

It would seem then that an engineering degree program recognizing and emphasizing an inter- or multi-disciplinary focus would be appropriate. Indeed, this approach has its proponents. In her study of the engineering profession as part of the Pedagogies for Professions series, Sheri Sheppard[1] chose to select schools that "ensure attention to issues that are critically important to engineering education….", looking at "programs that are highly interdisciplinary" and allowing "maximum flexibility of curricular choice." Likewise, the U.S. National Academy of Engineering has published a forward-thinking study[2] setting forth the desired attributes of engineering graduates in the year 2020. Their statements include the following:

> *"Since the late 19th century, when the major subdisciplines of engineering began to emerge, engineers have been aware that solutions to many societal problems lie at the interstices of subdisciplines."*
>
> *"…the National Science Foundation…created engineering research centers…in recognition of the value of providing an environment where engineers and scientists of different backgrounds could join together to solve interdisciplinary problems."*
>
> *"Contemporary challenges…increasingly require a systems perspective."*

Their study culminates with a vision statement,

> *"We aspire to an engineering profession that will rapidly embrace the potentialities offered by…cross disciplinary fertilization to create and*

*accommodate new fields of endeavor, including those that require openness to interdisciplinary efforts with nonengineering disciplines such as science…."*

It seems that there is support for engineering education of an interdisciplinary nature. The paradox is that as the technical knowledge base expands, engineering programs have tended toward increased specialization and disciplinary focus. Newberry and Farison[3] published a thorough study of ABET-accredited programs carrying the title General Engineering (or Engineering) and Engineering Science. These would be recognized as two of the more interdisciplinary program categories. Their conclusions were that Engineering Science programs as a discipline were dying, and that the majority of General Engineering programs were incubation efforts for institutions desiring to start an engineering degree offering.

In their study, programs carrying the title Engineering Physics were omitted from consideration. In this paper, we have solicited information from several engineering physics programs in the US and abroad in an effort to determine the health and scope of the Engineering Physics degree program, which by its very nature is an interdisciplinary approach to engineering.

Engineering Physics Programs in the US

A small but active group of engineering programs in the US carries the title Engineering Physics (EP). Engineering Physics, as the name implies, is an engineering curriculum based on a broad but traditional physical science stem. There are presently 17 such programs accredited by ABET[4] (see Appendix), and an internet search returned more than 50 programs that are not accredited. Taken in total, they are illustrative of recent emphases on engineering programs that are inter- or multi-disciplinary. It is difficult to find an exact enrollment for these EP programs, as the data is often combined with figures from Engineering Science (ES) programs. In 2002, EP and ES undergraduate enrollment made up approximately 1.4% of the total engineering enrollment in the US[5]. If we assume that Engineering Science comprises 0.4% of the undergraduate engineering enrollment (the figure reported for 2001 graduates by Newberry and Farison[3]), then EP enrollments would account for about 1% of the total number of students studying engineering. While this number is small (data for 2003 list EP/ES enrollments nationally at 4,414)[6], it is interesting to note that the EP/ES major is now one of the top ten engineering "disciplines", ahead of the more familiar petroleum, environmental, agricultural, mining, and nuclear engineering fields.

A questionnaire was sent to 66 EP programs in the US. Six of the seventeen accredited programs responded (35%), along with 11 unaccredited programs of 49 solicitations (22%), for a total return of 26%. The following observations and generalizations are noted in the responses:

- Of those programs responding, two originated in the 1940's and three have been initiated in the last three years. The returns reflect a good cross section of established and newer programs, as shown in Figure 1. There was no correlation between program enrollments and the length of time that the program had been in existence. However, the accredited programs had generally been established for a longer period of time, as might be expected.

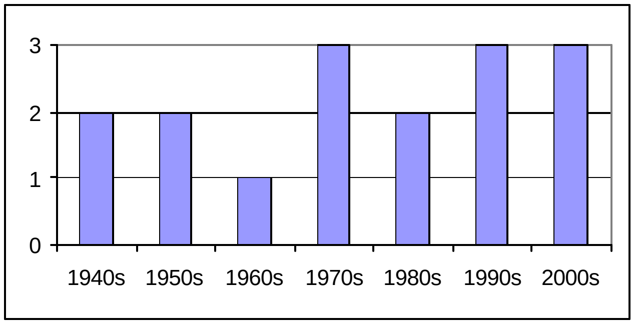


Figure 1. Number of Responding EP Programs by Decade of Origin

- The overwhelming majority (81%) of programs responding report a close curricular connection with electrical engineering. Mechanical engineering was second, with 69% reporting a curricular track associated with that field. Other traditional engineering emphases cited less often included nuclear, computer, and materials engineering. Greater than 60% of those programs responding report an affiliation with the engineering school at their institution, even if the program is administered by a physics department.

- Program enrollments ranged from a high of 240 to a low of 5 students. The mean of all programs reporting was 40 students. This figure is skewed by the large enrollment at one institution. The second-highest enrollment was 100 students. If the largest enrollment is neglected, the mean student population in these EP programs drops to 26. Accredited programs tended to have a larger student population, with numbers ranging from 35 to 240 students. The average non-accredited program in the survey had 15 students.

- The typical respondent program had a male/female student ratio of approximately 85:15.

- Only four respondents reported a majority of program graduates going directly to graduate schools. Preparation for graduate work was reported in physics, electrical engineering, mechanical engineering, nuclear physics/engineering, materials engineering, computer science, aeronautical engineering, biological engineering, acoustics, civil/architectural engineering.

- 70% of the programs tended to send a majority of graduates to industry upon graduation. Industries cited include defense and aerospace, semiconductors and microelectronics, computing and software development, heavy equipment, optics, biotechnology, laboratories and instrumentation, and automotive.

- Accredited programs tended to have a minimum of seven full-time equivalent faculty participating in the delivery of the EP program. Unaccredited programs tended to have fewer faculty involved, typically 4-6. Many institutions noted that that these were faculty already in place in either the physics or engineering units, and thus represented no additional staffing requirements to offer the degree.

- 55% of the unaccredited programs intend to seek accreditation within the next ten years, and an additional 18% are open to the possibility of accreditation were they to be convinced of potential benefits to their students. Interestingly, one of the accredited programs reported that they had dropped the accreditation six years ago, but is still listed on the ABET website, and another has indicated its intention to forego accreditation in the next cycle. Neither institution indicated an intention to drop the EP program offering.

- 63% of the responses indicated at least slow to moderate program growth in recent years. The remaining respondents reported enrollments maintaining a steady level. No respondents categorized the EP program enrollment as declining.

It is interesting to note the broad range of industrial and graduate opportunities represented in these responses. Prof. J.A. McNeil of the Colorado School of Mines refers to their EP program as the "Universal Donor Degree"[7], and the questionnaire results seem to bear out versatility as one of the attractive aspects of the EP degree. This breadth and versatility was consistently cited as one of the positive aspects of the EP curriculum. The sponsoring departments see value in providing students with a holistic, rigorous, science-based approach to engineering. Other benefits of the EP curriculum commonly cited were: (1) an enhanced student ability to work on and contribute to cross-disciplinary engineering teams; and (2) mentally agile students with an ability to adapt to problem-solving environments where "standard" engineering practice might be poorly defined or evolving rapidly. Respondents, however, also recognized that prospective employers were unfamiliar with the EP label, and often unappreciative of the strong problem-solving skills these students possess. Because of their hybrid nature, these EP programs often find themselves overlooked by both the professional physics and engineering communities. This public relations and marketing problem was the challenge most often cited as needing to be overcome by the survey respondents.

In part to address this lack of recognition, the ASEE has recently established the Multidisciplinary Engineering Constituent Committee (MECC). The MECC supports non-traditional engineering programs including engineering physics, engineering science, and general engineering programs, and is set up to assist in promoting and developing curricula, publicity, and accreditation assistance in these areas.[8] ASEE is now the lead society for ABET accreditation of these non-traditional programs. Thus, this agency will now be tasked with setting up policies and criteria for accreditation of EP programs. Many EP programs hope that this increased visibility for non-traditional programs within ASEE and ABET will lead to a greater familiarity with the strengths of the EP degree.

## Engineering Physics Programs Abroad

Engineering Physics programs are not unique to the US. In fact, EP programs are common in Australia, Canada, Great Britain, and other countries. An examination of the curricula in these programs shows a variation in physics content and engineering roots that is similar to their American counterparts. As a result, a case may be made that EP programs are particularly well suited to globalization efforts and international study abroad experiences, since the broad curriculum provides a flexible platform compatible with many international programs.

An email questionnaire similar to that distributed to EP programs in the US was sent to seven universities in Canada, two in Australia, and one in England. Responses were received from five of these ten programs. Engineering Physics programs have a long history in Canada, with the program at the Queens University dating back to 1917. They are known to have rigorous admission standards and attract a high caliber student. Those universities that reported enrollments indicate that their EP offerings may be expected to have a higher enrollment than in the US at about 60-75 students in established programs. However, responses on relationships to traditional engineering disciplines, perceived views on advantages and challenges facing EP, student recruitment and retention, EP employment outlook, and graduate school preparation closely mirrors the input from US institutions. It was noted that in some of the institutions, the name Engineering Physics reflected more on the location of the course of study within the faculty structure rather than the curricular content. In some of these programs, EP would closely resemble an applied physics program in the US. One Australian institution is phasing the program out, reporting that students preferred an available dual degree (BE/BS) route rather than the EP degree plan. These students, while successful in finding acceptance in graduate programs or industry via EP, chose an available alternative that left the EP less unique and attractive.

## Outreach Efforts in Engineering Physics

While EP programs often resemble electrical, mechanical, nuclear, and other traditional engineering curricula, their strong foundation in physics make them good candidates for integration into the K-12 curriculum via modular teaching units and outreach activities. In the US, it is rare to find engineering topics integrated into the curriculum, and technology is often limited to computers and information systems or topics in audio/visual areas. (This is changing, but the progress lags). But physics and physical science is a staple of the K-12 curriculum. This physics stem in EP facilitates the incorporation of engineering topics in a seamless transition that teachers can accommodate, and that students tend to enjoy.

There are many examples of engineering applications in the physics and physical science curricula. These include robotics, telecommunications, rocketry, and structural design. Universities offering EP programs can easily contribute to outreach activities in the public schools by partnering with teachers in these standard physical science courses delivered in every school. The authors' wish to highlight two outreach activities that have proven particularly successful in increasing the profile of engineering in general, and EP in particular, in regional public schools.

Engineering Survivor

We have developed an outreach activity that takes advantage of National Engineering Week's emphasis on introducing females to engineering. Our Girls in Engineering activity copies the theme of the popular TV show "Survivor" to create an "Engineering Survivor" scenario for 6th grade girls. The girls are asked to construct a PVC pipeline from an oasis to their remote camps, and must plumb their pipeline over, under, and around obstacles. The event is mentored entirely by female faculty and college students, and allows girls to work in teams while using their creativity to solve a practical engineering problem. No boys were allowed to participate in this activity, to the delight of many of the girls!

In the event last year, more than 175 girls at two local middle schools participated in the activity that lasted for approximately 90 minutes. Each team of 5 girls was assigned a mentor who explained the premise of the challenge. The girls had to make measurements of their pipeline path, decide on appropriate lengths of PVC pipe and fittings, and purchase these items using a currency of candy. The emphasis on engineering economy quickly became obvious to the participants, who understood that the most economical solution to the challenge meant there would be more candy left over for them to divide at the end of the game. The event was not a race, but rather a chance for the girls to use their ingenuity to solve an entertaining problem. Figures 2 and 3 show examples of girls participating in the Engineering Survivor activity at their schools.

Moonbuggy Competition

The second outreach event recreates NASA's Great Moonbuggy Race competition for regional high schools. The NASA-Marshall Space Flight Center event is held annually in April at the US Space and Rocket Center in Huntsville, Alabama. Our department received NASA-MSFC support to host the first regional high school moonbuggy competition in March, 2005. Teams of students and teachers from local high schools designed and built human-powered vehicles that addressed a series of engineering problems similar to those faced by the original designers of the lunar rovers used on the Apollo missions. The culmination of the project was a grueling endurance race over terrain including craters, inclines, lava ridges, and loose soil in an obstacle course that runs through the heart of the university campus. Four high schools went on to compete in the national competition held in Huntsville. Figure 4 is a photo of a typical buggy in competition. For a complete description of this activity, the full paper is included elsewhere in these proceedings.[9]

Figure 2. Girls pipe water through the "Camel" obstacle in the Girls in Engineering "Engineering Survivor" event.

Figure 3. Girls make measurements on their water pipeline during the Girls in Engineering "Engineering Survivor" event.

Figure 4. Moonbuggy in the 2004 competition at the US Space and Rocket Center in Huntsville, AL.

## Conclusions

Understanding the nature and structure of interdisciplinary engineering programs like EP is important as the engineering education community seeks to respond to industry's desire for more broadly educated engineers. As engineering programs look to prepare students to function in complex, system-level environments, programs such as EP may serve as models for providing multidisciplinary and multinational contributions in communications, computing, defense, transportation, and energy applications. It is also significant that ASEE is now serving as the lead society for ABET accreditation of non-traditional engineering programs in the United States. This includes EP, as well as engineering science and general engineering programs. ASEE's Division of Physics and Engineering Physics and the new Multidisciplinary Engineering Constituent Committee are well-positioned to assist these non-traditional programs in the accreditation process.

Engineering Physics programs remain few in number, and are not necessary or practical for every institution. But for many universities desiring to offer a broad engineering degree program that prepares engineers to work in areas where traditional science and engineering disciplines overlap, it can be an appropriate and successful approach to engineering education.

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## Biographical Information


STEPHEN COBB is professor and chairman of the Department of Physics and Engineering at Murray State University, Murray, Kentucky. He received his Ph.D. in physics from Georgia Tech in 1988, and he holds registration as a Professional Engineer (Mechanical). His interests include issues in physics and engineering education, and he presently serves as an officer in the Physics & Engineering Physics Division of ASEE. He a curricular consultant for physics and engineering physics programs nationally and abroad.

JAMES ROGERS is an assistant professor in the Department of Physics and Engineering at Murray State University, Murray, Kentucky. He received his Ph.D. in mechanical engineering from the University of Illinois, Urbana-Champaign in 2002. His research interests include MEMS, microscale visualization techniques and engineering education including the use of technology in the classroom.

## APPENDIX

### ABET-Accredited Engineering Physics Programs

| University | Location | Original Date of Accreditation |
|---|---|---|
| Colorado School of Mines | Golden, CO | 1977 |
| Cornell University | Ithaca, NY | 1951 |
| Embry-Riddle Aeronautical University – Dayton Beach | Daytona Beach, FL | 1993 |
| Kansas, The University of | Lawrence, KS | 1949 |
| Maine, University of | Orono, ME | 1949 |
| Murray State University | Murray, KY | 1998 |
| Oklahoma, The University of | Norman, OK | 1953 |
| Pacific, University of the | Stockton, CA | 1986 |
| Pittsburgh, University of | Pittsburgh, PA | 1994 |
| Princeton University | Princeton, NJ | 1972 |
| Rensselaer Polytechnic Institute | Troy, NY | 1993 |
| Southeast Missouri State University | Cape Girardeau, MO | 2001 |
| Stevens Institute of Technology | Hoboken, NJ | 1986 |
| Texas Tech University | Lubbock, TX | 1965 |
| Tulsa, The University of | Tulsa, OK | 1971 |
| Wisconsin-Platteville, University of | Platteville, WI | 2001 |
| Wright State University | Dayton, OH | 1988 |