

Swimming Upstream: Recruiting Majors in a Shrinking Market

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Introduction

The social and economic impact of physics developments in the past few decades, both in fundamental discovery and in application, are more pronounced than ever, yet physics education is facing a recession of sorts. According to the AIP Enrollments and Degree Report (AIP R-151.36, March 2000), physics degrees are down 20% in just the last five years. In response to this decline the AIP, APS, and AAPT have formed a Task Force on Undergraduate Education to study the problem. The news of declining enrollments came as something of a surprise for us at the Colorado School of Mines (CSM) where we have seen modest growth in our undergraduate physics program over the same period. With an undergraduate student body of around 2500 we are averaging about 20 physics graduates per year, similar to numbers from much larger institutions. In October of last year Task Force members Robert Hilborn (Amherst), Ken Krane (Oregon), and Carl Weiman (Colorado) visited our department. In the process of preparing for this visit and through their observations and insights, we learned something about ourselves which will help us improve our program and could be useful to others. While there are other successful programs with their own stories to tell, we have been asked to describe briefly our program and experiences as well as the primary programmatic features and values which contribute to our enrollments.

Institutional and Departmental Profile

Whatever success we enjoy derives principally from the alignment of the department's mission with the fundamental role and mission of the institution. CSM is a small, state-supported, technical research university whose mission is focused in energy, materials, and resources. The school has about 290 teaching faculty and conducts about \$24M in sponsored research annually. While the school has a viable research/graduate program, the principal focus is on the undergraduate component. Of the 11 undergraduate degrees 8 are in ABET-accredited engineering disciplines, including our Engineering Physics program. CSM was founded in 1874 to serve the mining industry of the Colorado Rocky Mountain region. While still focused in its energy/materials/resource mission, CSM today has a diverse set of engineering and applied science programs of considerable breadth. We are proud of our tradition as reflected in our name although today the Mining Engineer major is selected by a small fraction of our undergraduates. For us the name embodies the ethics of hard work, technical proficiency, and self-reliance.

We are a state institution; drawing roughly 70% of the student body from in-state with an average SAT around 1250. However, for the purposes of this report, the most important student characteristic is their predisposition toward engineering and science. With this narrow focus the common core for every CSM student includes Physics 100 (Mechanics)

and Physics 200 (Electricity and Magnetism). We use this opportunity to recruit promising students. We put our best teachers in these classes and devote considerable attention to improving the introductory courses while maintaining their rigor. We have an opportunity to influence student decisions because the common core accounts for a significant fraction of the total program credit hours allowing students to make decisions about their majors fairly late, typically in the second semester of the sophomore year. In a survey of student interests we found that roughly half of our students were inclined to a different major when they started.

To align with the school's narrow mission as well as to provide some breadth in subject areas some years ago the department decided to focus in three research areas with faculty positions distributed as follows: condensed matter (~50%), applied optics (~25%), and applied nuclear (~25%). Our three degree programs are: B.S. in Engineering Physics, M.S. and Ph.D. in Applied Physics. The department has 15 full time faculty, 22 graduate students, and 125 undergraduate physics majors. With the emphasis in applications the department also enjoys close relationships with the engineering programs and conducts interdisciplinary research through the Materials Science program and two research centers, the Center for Electronic and Solar Materials and the Center for the Commercial Applications of Combustion in Space. The department also has close working relationships with nearby research institutions such as the National Renewable Energy Laboratory, the National Institutes of Standards and Technology, and our big sister, the University of Colorado at Boulder. The department maintains contacts with industry through its External Visiting Committee.

Curricular Features

The B.S. Engineering Physics degree is accredited by the Accreditation Board of Engineering and Technology (ABET). A year ago we underwent our 6-year general review under the new Engineering Criteria 2000. These new criteria address academic management as much as credit hour allocations used in prior years. For example, under EC2000 accredited programs must identify their constituents and implement a process for developing a broad set of program goals and objectives, as well as a delivery plan that makes extensive use of assessment and feedback to demonstrate continuous improvement. With the undergraduate focus of the institution and the department already a part of our academic culture, the faculty readily adopted this outcome-based approach resulting in a successful site visit.

Using elective options, we have designed the B.S. degree program with enough flexibility to allow career path alternatives to the physics graduate school one. We accommodate students who intend to go directly to industry as well as those seeking to go to engineering graduate school. We promote the physics degree as the "O-negative blood type", the universal donor, able to feed many different technical graduate programs. The fundamental knowledge and problem-solving skills of physics graduates ensure their success in a broad variety of technical careers. To take advantage of this locally, we have coordinated three 5-year ("4+1") programs with graduate engineering programs at CSM. In these programs capable and motivated students can earn a B.S. in Engineering Physics in 4 years, then, with adequate grades, gain automatic admission to one of three graduate

engineering programs and earn an M.S. (nonthesis) degree in just one additional year. The three 5-year tracks are engineering systems (electrical or mechanical specialty) and materials science (microelectronic processing and materials specialty). These applied tracks have proved very popular with our students, attracting almost half of our majors.

Building in this level of flexibility has not come without cost. To allow room in the curriculum for the variety of courses needed to meet the three career tracks, our students will typically take fewer specialized physics courses. For example our students need take only one semester of quantum mechanics and they are not required to take the standard variety of physics electives such as solid state or nuclear physics although many elect to do so. The career breakout for our graduates is as follows: 15% go to physics graduate programs, 35% go to engineering graduate programs, and 35% go directly to industry or government (the remainder did not respond to the survey).

There are two special features of the CSM Engineering Physics curriculum which are worthy of note. The first is the school-wide requirement of a summer "field session". Almost unique to CSM, this tradition dates back to the school's origins where mining engineers were literally taken to the field for on-the-job training. In the physics program we use this occasion to train our students in a wide set of technical skills: vacuum systems, thin films, machining, instrumentation and computers. Taken in the summer between the sophomore and junior years, this session runs eight hours per day, five days per week for six weeks. Once through this intensive training the students have the skills to be useful in research labs. One of the principal benefits of the field session is the high level of camaraderie and friendships which are formed among the students. After this intensive experience, the students have bonded into their cohort physics class.

The second curricular feature of note is the senior design capstone experience which is a requirement of our ABET accreditation. It is in the senior design experience the students apply their technical skills and broad physics background to open-ended problems often in the research groups. At the start of the senior year each student meets with individual faculty members to select a senior design advisor and define a project. The topics range widely and often involve industrial problems. Recent example projects include fabrication and characterization of back contacts for photovoltaic cells, design and fabrication of special components for a vacuum system to study quantum dot nucleation, designing a sulfur lamp system for pumping a laser, and designing and fabricating a novel high flux alpha detector. A few of the better projects are reported at APS meetings and some find their way into publications. Students participating in one of the 5-year programs usually conduct their senior design work in the engineering department in which they expect to earn their MS degree with the senior design project growing into an engineering report.

The facilities available to the department are old but functional. The Physics department is the sole occupant of Meyer Hall (40,000 sq. ft.) which was constructed in 1964 and has not undergone significant renovation other than part of one floor which houses the new microelectronic processing laboratory. Most classrooms and teaching labs do not yet have air conditioning which is occasionally a hardship. The space within the building has

undergone reallocation many times over the years such that today faculty offices are next to teaching labs which are next to the computer room and so forth. The Task Force site visit team pointed out that this worked to our advantage as students and faculty are forced to cross paths constantly in the normal daily operations which facilitates a high level of student-faculty interactions.

The Social Component

Perhaps the most important feature of our program is the commitment of the faculty and staff to serve the interests of the students. In senior exit interviews the department secretary is universally praised as being friendly and helpful. The faculty are recognized as personable and caring by the students who cited this as very important to their decision to become physics majors. This did not happen by accident. The institutional and departmental emphasis on the undergraduate teaching mission has meant that considerable attention is paid to the teaching potential of new hires, to the development of these teachers, and to the evaluation and continuous improvement of teaching practices. Teaching is a significant component of faculty effort (3 courses per year) and the evaluation and promotion process. Each faculty member is evaluated annually in this regard by the department head. The institution and department financially support and reward teaching innovation. The department nominates each of its new faculty to participate in the NSF/AAPT-sponsored new faculty workshops. These new faculty often end up teaching the older faculty a few new teaching tricks upon their return, thus multiplying the benefit.

The department works to integrate the students socially into the department's life. Physics students are entrusted with keys to the physics building including access to the computer room and library. In senior exit interviews this act of trust and inclusion is praised. CSM physics students form strong social bonds starting with the intensive 6-week summer field session following their sophomore year and building through the academically challenging junior year where homework help groups are routine and culminating in senior design teams. The CSM chapter of the SPS is strong and thriving having won several outstanding chapter awards.

Summary

In reviewing the institutional and programmatic features which influence our physics enrollments we have identified the following as the most important:

1. Alignment of institutional and departmental missions. This is fundamental for institutional support as well as attracting the input pool of students with an aptitude for science and engineering.
2. Active recruitment in the introductory physics sequence. The fact that the common core exposes all students to physics is a significant recruiting opportunity.
3. Institutional and departmental value in teaching and student development. CSM insists on high quality undergraduate teaching; the department recruits, develops, and rewards quality teachers. We can recruit students effectively because the word is out that

the physics faculty care about students, but we recognize that this trust must be won daily.

4. Strong sense of community. Starting with the summer field session, students bond with each other and the physics community. This sense of community is enhanced by entrusting the students with access to department resources.
5. A curriculum with an applied emphasis and flexibility for alternative career paths (e.g. 5-year programs). Since not all students with aptitude in physics wish to go to on for a Ph.D. in physics, it is important that the curriculum allow a spectrum of alternatives.
6. Strong leadership and an outcome-based approach to continuous improvement. Creating the conditions for a successful program requires vision and leadership. The CSM physics department has been blessed with strong leadership. The previous two Vice Presidents for Academic Affairs were former physics department heads, and one of these, John Trefny, is the current President of CSM.

While we have enjoyed some success in attracting students to our programs, we recognize that there are still many areas for improvements to our program and practices. This recognition is fundamental to an outcome-based approach to managing our academic enterprise. Further, while we note that in many respects the experience of the CSM Physics program is unique to our circumstances, it is our hope that some aspects of that experience will be helpful to others in attracting more students to the discipline we love and serve.