Building a physics degree for high school teachers

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Abstract

Designing a program for prospective physics teachers involves many compromises. In this paper we report on the development of a bachelor's degree we have created in the Department of Physics at California State University, Chico. Our experience with our unique collection of choices and limitations may serve as a guide for others building similar programs.

Introduction

In 1998, Robert Ehrlich cited some very disturbing statistics[1]:

- The number of physics bachelor's degrees is at a 38 year low.
- The percentage of physics degrees to all degrees has declined by 75% since 1960.
- The percentage of physics degrees to all degrees has declined by 28% between 1986-96 while the number of students taking physics in high school has increased from 13.9 to 21.5%.
- The US Dept. of Labor projects only 500 openings per year for physicists and astronomers through 2005 while we produce two to three times that many each year.

According to the 2001 AIP Enrollment and Degrees Report, the situation has only gotten worse. The number of physics bachelor's degrees is now at a 40 year low[2]. There is certainly trouble brewing if small physics departments continue solely in their traditional (albeit highly effective) role of preparing student solely for graduate study in physics.

Ehrlich statistics show a glimmer of hope and a bit of guidance. More students are taking physics in high school. Yet, only 33% of their teachers majored in physics or physics education while an additional 12% minored in physics or physics education[3]. This is an area where there is job growth for our profession and an opportunity for us to reverse the long downward trend in our enrollments. At the same time, we can take a stronger hand in developing a greater interest in our field among a broader population.

This paper describes the implementation of our "General Physics" degree designed specifically for students interested in becoming high school physics teachers. Since teacher certification processes vary from state to state, the first section contains some background information on the teacher credentialing process in California. The next section discusses some constraints in the design of the degree. The details of the degree program will then be presented and contrasted with our traditional degree. Next, we address the issues and concerns our faculty expressed as we developed and implemented General Physics. The last section contains a preliminary report of the effectiveness of the program.

The Credentialing Process in California

The State of California requires that students wishing to become high school teachers have "Subject Matter Competency" (SMC) before they enter a professional training program that is usually under the auspices of a university Department of Education. The professional training program at California State University Chico has several formats. The traditional program is one-year long and includes full-time study and student teaching. In the internship program graduates begin teaching directly after completing their SMC program, completing their coursework on nights, weekends and during the summer. In addition, there is a "flex" program for people currently employed outside the teaching profession. They complete their professional coursework at the same times as internship candidates.

SMC can be achieved one of three ways; completing a program of study in the subject that has been approved by the California Commission on Teacher Credentialing (CCTC), passing a prescribed exam on the subject matter, or through a waiver process. So, it became our goal to design a bachelor's degree in physics that would provide SMC in physics and be approved by the CCTC. In addition to the CCTC requirements, there are many other pre-requisite courses demanded by our Department of Education for their professional training programs such as courses in adolescent health, linguistics, language and public speaking. There is also a requirement for 45 hours of volunteer time spent in a public school. Some, but not all of these requirements can be included as part of the general education requirements of the university.

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Design Constraints on General Physics

CSU Chico is on the semester system. The university's general education requirements total 60 units[4]. Our traditional physics degree requires 70 additional units as shown in table 1. The central administration of the California State University system has mandated a maximum of 120 units for any degree. Our traditional degree can reach this limit because 4 units of math and 4 units of physics double count for general education. Our first constraint for General Physics was to avoid adding to the total number of units.

The second constraint was strictly financial. If any new courses are to be added to our offerings, they must be "cheap to teach." Physics departments always have financial issues in this regard because our total number of majors is small compared to other sciences. Adding a new collection of low-enrollment classes to the schedule was simply out of the question.

The third issue was the CCTC requirement for one year of biology and one year of geosciences for all secondary science teachers, which adds at least 14 units to our already full program.

Tugging at us also was the view of experts in the area of Physics Education Research (PER) that physics is far ahead of the other sciences in understanding how students learn. We felt that we should attempt to provide some experience where the students focused on educational methodologies in physics. As mentioned previously, the credential program requires 45 hours of volunteer time in a public school. This would be most beneficial to our students if this time were spent in a physics classroom. On the issue of PER, it might be noted that the insights of PER are beginning to change the way that many of our faculty members teach. Some of us use instruments such as the FCI and FMCE. Others use some of the techniques of peer instruction, active learning and JiTT. Our newest faculty member earned her PhD in PER. As a result, our students in both our traditional program and General Physics see a variety of pedagogical methods inspired by the results of PER.

Yet another issue stems from the fact that only 19% of high school physics teachers just teach physics[5]. The CCTC requires a total of 20 units in a second science to earn a supplementary authorization to teach the second science. In most cases, this would add 12 units to our program. Considering the fact that a substantial fraction of new teachers opt out of the profession, the need for a broad set of knowledge and skills was clear. As you will see below, in many ways General Physics can be thought of as an interdisciplinary physics degree.

Finally, we needed to be able to attract students. This could be a challenge considering the disparity in salary between most scientific and technical professionals and high school teachers. However, we had several assets. We have personal relationships with nearly all of the local high school physics teachers, our faculty value good teaching above other professional concerns and we have a large number of students in our service courses that haven't completely decided upon their career. We send emissaries out to local community colleges to make transfer students aware of our program. We shared our ideas at APT meetings and prominent author and physics educator Paul Hewitt established a scholarship for future high school physics teachers at our university.

The General Physics Degree

Our department has had a CCTC approved program for decades. Only one student had completed it in the previous two decades. This is because it was simply our traditional program with the additional requirements described above added on. The total number of units required was more than 160.

It was clear from the beginning that the only way to make an attractive and viable program was to design it train an effective future high school physics teacher not a future physics graduate student. We absolutely had to minimize the number of required units. It became evident rather quickly that these would have to come from upper division physics courses. We decided that the requirements for the traditional degree stated in table 1 as "core" were absolutely essential and we kept these same core courses for the General Physics Degree as shown in table 2.

Our Traditional Bachelor of Science In Physics

Lower-Division Core Requirements: 36 units	
General Chemistry	8 units
Analytic Geometry and Calculus	12 units
Elem Diff Equation/Vector Calc	4 units
Mechanics	4 units
Electricity and Magnetism	4 units
Heat/Wave Motion/Sound/Light	4 units

Upper Division Core Requirements: 10 units	
Modern Physics I	3 units
Modern Physics II	3 units
Advanced Laboratory	3 units
Physics Seminar	1 unit

Additional Requirements: 24 units	
Boundary Value/Partial Diff Eqs	3 units
Analytical Mechanics	6 units
Electricity and Magnetism	6 units
Thermal Physics	3 units
Quantum Mechanics	6 units

Table 1: The Traditional Physics Degree at CSU Chico. Note that the "additional requirements" are all upper division math and physics courses.

The courses we would have to live without are listed as the "additional requirements" in table 1 and they are also listed in table 3 for comparison with the additional requirements for General Physics. While upper division courses in mechanics, electricity and magnetism, thermal physics and quantum

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General Physics Bachelor of Science In Physics

Lower-Division Core Requirements: 36 units	
General Chemistry	8 units
Analytic Geometry and Calculus	12 units
Elem Diff Equation/Vector Calc	4 units
Mechanics	4 units
Electricity and Magnetism	4 units
Heat/Wave Motion/Sound/Light	4 units
Upper Division Core Requirements: 10 units	
Modern Physics I	3 units
Modern Physics II	3 units
Advanced Laboratory	3 units
Physics Seminar	1 unit
Additional Requirements: 35 units	
Upper Division Physics Electives	6 units
Earth Science/Geology	6 units
Biological Principles	8 units
Second Science Breadth Courses	12 units
Internship in Physics Teaching	3 units

Table 2: The General Physics Degree at CSU Chico.

mechanics are certainly our pride and joy, we came to the difficult conclusion that high school physics teachers could become excellent teachers without taking all of them. However, we did feel that potential high school teachers had to see a bit more than ten upper-division physics units in the core. We compromised at sixteen by requiring six units of upper division physics electives be part of the additional requirements.

The additional requirements also include the geology and biology courses to meet CCTC standards. The second science breadth courses have also been added to the additional requirements. These courses not only make the prospective teachers eligible for a supplemental authorization in the second science, but they provide an opportunity to apply their physics knowledge to another area of science. In fact, General Physics can be viewed as an interdisciplinary physics degree and students have used it in this manner.

Finally, the additional requirements include an internship course that meets the CCTC forty-five hour requirement. Our department maintains regular contact with the local high school physics teachers. Someone from our department visits every high school physics class in the local area at least once a year. This relationship with the local teachers allows us to ask them to take our students into their classrooms for the mandated forty-five hours. This, in turn, helps us maintain close contact with these teachers. You might note that this constitutes the addition of a low enrollment course. We were allowed to add this course because it is extremely cheap. In fact, no faculty member actually gets paid for it and the local physics teachers have our students in their classroom out of the goodness of their hearts.

Issues Raised by Faculty

While it may seem trivial, naming the degree brought to the surface many relevant issues. The most obvious name, Physics Education, typically refers to a course of study centrally focused on pedagogical issues. Due to the fact that CCTC requires this to be a degree in the content area of physics (not pedagogy) coupled with the inability to add additional courses in pedagogy, it certainly is not a degree in physics education. Besides, anything with the word "education" in the title could cause friction with the university's education department. Since our graduates would be entering their certification program, maintaining good relations with them would be valuable.

Some faculty felt that having the word "physics" in the degree title would be a misnomer because of the limited amount of upper division coursework. One faculty member was particularly concerned that a student might graduate with this degree, get into a physics graduate school and wind up embarrassing us. We settled on General Physics because some faculty felt that since the one-year algebra based course often has the same name, it would convey a "lesser" physics degree; "physics-lite" as one faculty member quipped. Others felt that General Physics expressed the interdisciplinary character of the degree.

We generally agreed on one aspect of the debate regarding rigor or lack thereof. There was certainly not sufficient rigor in physics alone. However, a degree composed of 28 units of physics, 16 units of math and 20 units in a second (lesser?) science

ADDITIONAL REQUIREMENTS

Traditional Degree:	**24 units**
Boundary Value/Partial Diff Eqs	3 units
Analytical Mechanics	6 units
Electricity and Magnetism	6 units
Thermal Physics	3 units
Quantum Mechanics	6 units

General Physics:	**35 units**
Upper Division Physics Electives	6 units
Earth Science/Geology	6 units
Biological Principles	8 units
Second Science Breadth Courses	12 units
Internship in Physics Teaching	3 units

Table 3: A comparison of the additional requirements between the traditional degree and the General Physics degree.

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certainly didn't lack rigor in an overall sense. In addition, this degree has more required units than the great majority of other degrees on campus, even our traditional physics degree. It is important to realize that physics departments' inability to compromise on physics rigor has contributed to the lack of physics majors pursuing careers in high school teaching.

Faculty pointed out that General Physics might reduce the numbers of students in our traditional program or force us to reduce the rigor of our upper division core courses. In fact, the number of students in our traditional program has not changed. In addition, we agreed that core courses for both degrees must maintain high standards or we would not be providing the content component demanded by graduate programs or CCTC. In general we felt that our ability to add a teacher-training track was built upon the foundation of our strong traditional program. It is hard to imagine that the reverse could be accomplished. Building a strong traditional program out of a teacher-training department would be nearly impossible and definitely inconsistent with the intent of the CCTC.

A Preliminary Report

At this time we cannot report on the effectiveness of our program, as measured by the well-defined methods used in PER. Our program is new and our graduates are either just entering the teaching profession or have taught for a couple of years at most. However, we do believe our program is effective relative to the norm in California. Our program produces high school physics teachers who have had at least 28 units in calculus-based physics, and who have a genuine interest in and commitment to the discipline of physics, as evidenced by their choice of major. The typical California high school physics teacher has had at most 8 units of non-calculus physics, and who would rather, most probably, teach their discipline of choice, as evidenced by their choice of major (Biology). Departments that are considering the creation of a major designed for future high school teachers may find useful the following narrative detailing the career paths of some of our graduates.

Including 1998-99 through the 2002-03 school year we have had 20 graduates. Seven of them in General Physics. The thirteen graduates that earned the traditional degree is about the normal number for us, so the seven General Physics graduates are additional majors that have added to our total number of graduates.

The first graduate in General Physics completed her degree in 1999. She entered the traditional professional teacher-training program and a year later applied for nine jobs. She had nine interviews! She chose a job for geographical reasons and as a result had a rather unpleasant first year of teaching. Like a large fraction of new teachers, she left the profession[6]. She immediately became a county health inspector, a job she still enjoys. There are several lessons we learned from this tale. First, the demand for high school physics teachers is very real. Second, we need to take a stronger hand in guiding the job selection of first year teachers. Finally, the value of the interdisciplinary nature of General Physics is vital for our graduates wherever they end up.

Of our seven General Physics graduates, three have taken advantage of the interdisciplinary features of the degree. There is the former teacher turned health inspector, one is working for an environmental firm in the private sector and the third headed off to graduate school in theology. One of our graduates decided to put her career on hold and raise children. Another completed the traditional professional teacher-training program this year and already has a teaching job at a high school about fifty miles away. The two that graduated most recently (June 2003) immediately got jobs in northern California and will complete their professional teacher-training as interns. The fact that these three got teaching jobs for the 2003-04 academic year in the current fiscal climate of the state of California is another testament to the demand for qualified high school physics teachers.

Clearly from these anecdotal reports, it is still too early to completely assess our program. In future years we hope to be able to provide a more thorough analysis of the success or failure of General Physics.

References

1 R. Ehrlich, "Historical Trends in Physics Bachelor Degree Output," TPT Sept. 1998.

2 P. Mulvey and S. Nicholson,""Enrollment and Degrees Report," AIP Report R-151.37 (August 2001).

3 M.Neuschatz and M. McFarling,
" Maintaining Momentum: High School Physics for a New Millennium," AIP Report R-427 (August 1999).

4 Choosing classes that count in two categories can reduce this maximum number. The minimum number is approximately 48 units.

5 M.Neuschatz and M. McFarling,
" Maintaining Momentum: High School Physics for a New Millennium," AIP Report R-427 (August 1999).

6 According to a recently reported statistic, more than half the new teachers in Los Angeles, California, give up their profession within 3 years. A 1996 study in North Carolina found that 17 percent of the state's teachers leave the profession after the first year in the classroom, 30 percent by the end of 3 years and 36 percent by 5 years. Nationally, 22 percent of all new teachers leave the profession in the first 3 years. These statistics are from"A. DePaul, "The Survival Guide for New Teachers," U.S. Department of Education Pub. No. 065-000-01303-7 (May 2000), which can be found at http://www.ed.gov/pubs/survivalguide/message.html.

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