1997

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AAPT PHYSICS EDUCATION | AMERICAN JOURNAL of PHYSICS

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Citation: Am. J. Phys. **65**, 1057 (1997); doi: 10.1119/1.18720
View online: http://dx.doi.org/10.1119/1.18720
View Table of Contents: http://ajp.aapt.org/resource/1/AJPIAS/v65/i11
Published by the American Association of Physics Teachers

Preparing physics majors for secondary-level teaching: The education concentration in the Haverford College physics program

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(Received 11 June 1997; accepted 29 June 1997)

It is easy to document both the strong demand for physics teachers at the secondary level and the fact that not all individuals currently in those positions are well qualified. Many undergraduate physics majors who might otherwise be interested do not pursue careers in teaching high school physics because the requirements for certification are quite strenuous in many states. We have accordingly developed at Haverford College a *concentration* in education for physics majors which provides experiential preparation for teaching physics but requires fewer courses beyond the standard physics major than does the typical curriculum leading to certification. We describe this concentration, the two key courses on which it is based, the career options it affords the B.S. physics major, and the experience of our recent graduates entering the high school teaching profession.

There has been much discussion in the physics community recently concerning career options for physics B.S. graduates. It can be readily documented that training in physics is useful in many careers,[1] and it seems obvious that that would be particularly the case for a career in teaching physics at the secondary level. One finds, however, according to ''The Condition of Education 1996'' report issued by the National Center for Education Statistics,[2] that only 48% of physics instructors in large public schools and 42% in private schools either majored or minored in physics in college. (The comparable percentages for biology, for example, are 77% and 81% and those numbers are typical of most other disciplines.)

We have found that our physics majors are at least open to the possibility of high school teaching and quite a number of them express some interest during the advising process. Doubtless this interest is encouraged by the fact that the demand for physics teachers has historically been and remains currently, quite strong. The 1996 report on ''Teacher Supply and Demand in the United States'' [3] indicates that the demand for physics teachers, as assessed by employers, is higher than for any other academic area. (A few special education areas have higher demand, but physics leads all traditional academic fields.) Also, according to the same report, the demand, if anything, appears to be increasing gradually with time and is relatively uniform across geographical regions throughout the U.S. Despite their openness and interest, very few of our majors[4] wind up pursuing certification in secondary physics education, although this option is available at Haverford College. The principal reason for this is that the requirements for certification in secondary education are relatively onerous, including practice teaching (by itself a full-time, semester-long activity), and a daunting number of education courses added to the physics major or minor.

In order to lower the barrier for physics majors to enter the field of secondary education, our physics department recently put in place a *Concentration in Education*. A concentration in the Haverford curriculum is a course of study taken in conjunction with a major in a related discipline. It consists of a total of six courses and so is comparable in weight to the *minor* found at many institutions, but differs in being closely tied to a particular major by design. At least two of the courses in the concentration and no more than three overlap with major requirements.[5] The education concentration creates two new lower barrier pathways into teaching positions for our physics majors. One is to continue on to a Masters program in teaching, thus earning simultaneously certification and the highly valued (by school districts) MAT degree. Such a program can be completed in a little over a year in most cases, and leads to a very advantageous situation career-wise for the student. The second pathway is to move immediately into a position in a private school setting, where certification is typically not mandatory at the starting level.[6] The education concentration improves the qualification of the student for such positions and (according to reports from our students) prepares him or her reasonably well for the difficult first year of full-time teaching. If certification is an eventual goal it can be obtained via continuing part-time study, or in some states simply by applying for it after obtaining a couple of years of teaching experience.

The Education Concentration course requirements for physics majors are as follows:

(1) EDUC 200 Critical Issues in Education;
(2) PSYC 203 Educational Psychology;
(3) EDUC 201 Literacies and Education; or EDUC 301 Curriculum and Methods;
(4) PHYS 459 Teaching Laboratory Physics–practical experience in laboratory instruction including assisting in the 1st-year lab course, development and evaluation of a new experiment, and investigation of resources available for laboratory instruction;
(5) PHYS 460 Association in Teaching Basic Physics—practical experience in physics classroom instruction via participation in the teaching of the first-year course at Haverford. Activities include preparation, practice, and delivery of a lecture including a new demonstration, staffing the clinic supporting the course, and preparation and evaluation of examination problems;
(6) EDUC 480 Independent Study—a field placement (8 h/week).

The first three courses listed in the concentration requirements are typical of education department offerings at most institutions and provide a nucleus of experience with the vocabulary and structure of education as an academic discipline. Physics 459 and 460 are the courses contributed by our

physics department and serve to introduce laboratory and classroom teaching in hands-on style. They are available only to upper-level undergraduate physics majors. Education 480, by placing the student in a real high school teaching setting (but with a lesser time commitment than a full-fledged practice teaching experience), rounds out the student's experience. The four nonphysics courses, or their equivalents, will be available at most institutions. Physics 459 and 460 are more novel and so are described in the following.

The course objectives of Physics 459 are to give the student experience in laboratory instruction, to enable the student to assess the effectiveness of laboratory experiments and to develop new ones, and to acquaint the student with the array of resources available to support laboratory instruction. The course is typically taken in the spring semester of the junior year and we involve the 459 student in teaching the laboratory of the second semester of our introductory sequence for nonmajors (course Physics 102 at Haverford). The Physics 459 content and requirements are as follows:

(1) During each 102 laboratory session the 459 student interacts with students taking the lab, circulating through the lab while the experiment is in progress, responding to questions, and stopping at each group from time to time to check on progress. A faculty member is always present.

(2) The 459 student prepares and delivers the prelaboratory lecture in the 102 lab for one experiment early in the semester. The lecture is practiced in advance with the instructor responsible for the 102 laboratory.

(3) For the same experiment the student evaluates the work of the students under the supervision of the instructor. (The 459 student grades only this lab; he or she is not responsible for the grading for the rest of the course.)

(4) After this evaluation the student analyzes the extent to which the experiment accomplished its curricular objective and then critiques the existing experiment and writeup.

(5) The student chooses, designs, and builds a prototype of an experiment appropriate to the level and content of Physics 102. The choice is discussed in advance with the instructor and the approval of the department for any necessary equipment purchases will be sought. (The Department expects to be able to support purchases up to about $500 for this purpose.) The student also prepares the accompanying writeup for the guidance of students performing the experiment. The writeup is expected to include prelab questions and to conform in other ways to the format used for other experiments in the 102 laboratory.

(6) The student carries out the experiment as designed, and arranges for other students to perform it as well (on a not-for-credit basis). He or she then analyzes and critiques the laboratory on bases similar to those in requirement (4). The analysis is part of the final paper for the course.

(7) The student writes a paper including the analysis of the experiment he or she designed and an analysis of the success of the entire Physics 102 laboratory in accomplishing its curricular objectives.

Physics 459 amounts to a demanding course, requiring about the same level of effort as any other upper-level physics course. Course grading takes into account all the above requirements.

Physics 460 is a study of the principles and practice of physics instruction via involvement in the classroom portion of the first semester of our sequence for nonmajors, Physics 101. The student attends and critiques lectures given by the 101 instructor; prepares, practices, and delivers a lecture; develops a lecture demonstration to be used in his or her lecture; participates in the preparation of examination problems and their evaluation; addresses student questions in the physics clinic; and writes an evaluative final paper.

Physics 460 is typically taken by first-semester seniors. A more detailed description of content and requirements is as follows:

(1) CLASS SESSION—for a topic chosen in consultation with the 101 course instructor the student:

-prepares and delivers to the Instructors of Physics 101 a practice lecture on the topic. If after improvements in response to a critique the session is judged to be effective, the 460 student conducts it in Physics 101 at its proper place in the sequence of the material. The presentation is expected to conform in design to those given by the 101 instructors, who use an adaptation of the techniques of peer instruction introduced by Eric Mazur.[7]

-designs and develops with the assistance of the Physics Instructional Laboratory Assistant a new demonstration to be used in the classroom session he or she conducts. This demo is subsequently added to the department inventory.

(2) EXAMS—for each of the 101 exams, the 460 student is responsible for proposing one test problem. The problem is evaluated by the 101 instructors and the 460 student edits it in response to their critique. If it is subsequently selected for inclusion, the 460 student grades that problem on the 101 exam.

(3) CLINIC—throughout the semester the 460 student is involved in assisting the students in their work on the (weekly) assigned exercises in the physics clinic. This involves 2 h of contact time in the clinic on Thursday evenings. The 460 student works out all solutions in advance to prepare for the students' questions. He or she is prepared to expect pressure from the students to simply do the problems for them, and writes out in advance for selected problems his or her first response to a student who says something like, ''I don't understand problem 2.48.'' The 101 instructor monitors the work of the 460 student in the clinic (by attending the clinic occasionally throughout the semester) to ensure that student questions in the clinic are being addressed with attention to pedagogical effectiveness.

(4) FINAL PAPER ON PHYSICS PEDAGOGY—the 460 student prepares a paper in lieu of a final examination analyzing and evaluating his or her experience in teaching in Physics 101. This paper must be informed by a detailed study of the extensive and growing literature in physics pedagogy.

Like Physics 459, this lecture association takes about the same level of effort as any other upper-level physics course.

Although the concentration in education has only been fully in place for one year at the time of this writing, the courses 459 and 460 have existed in other forms for more than a decade, and so it is already possible to gauge their effectiveness. In terms of sheer numbers, about a third of our majors have been going on to secondary teaching positions over the last several years, 11 since 1993. Only one of these 11 obtained certification as an undergraduate at Haverford, as already exclaimed upon in Ref. 4. Two others went on to obtain Masters degrees with certification before beginning to teach. (The experience of one of them is described more fully below.) The remaining 8 proceeded directly to teaching positions. Most, but not all, of these students had participated

in the association courses, and several have reported back that the courses were extremely helpful to them. The actual hands-on participation in instruction plays a crucial role, of course. Furthermore, they acquired unusual pedagogical sophistication via their exposure to the literature on misconceptions and the efficacy of peer-instruction and experiential techniques. Finally, in terms of basic teaching skills, they learned how to write clear and fair exam problems at the correct level of difficulty, the importance of being realistic about the level of effort required to develop successful laboratory experiments, sound techniques for assisting individual students with problem solving, and other practical skills. Not all of our graduates that embark on a teaching career continue in the profession—this is another reason why it is advantageous to reduce the initial effort—but of those that do, most eventually obtain certification either via graduate study, or experience-based application.

We conclude by describing the experience one of our graduates who has achieved considerable success. Josh Bridger, class of '94, continued on to Duke U. obtaining his MAT in physics and mathematics. He started teaching in Bethesda Chevy Chase High School in the suburban Washington, DC area in the fall of 1995 and teaches all the physics courses offered there. In his first year at BCC Josh was named ''outstanding first year teacher in Montgomery county'' and was entered by the State of Maryland for a national award. Josh has a web-site (http://www.mcps.k12.md.us/schools/bcchs/apphys.html) describing his novel AP course which incorporates use of the Web and integration of lecture and laboratory work. In the semester just concluded his AP students built electric guitars, including the pickup coils, from scratch, thus investigating E&M, magnetic induction, Ohm's law, and other aspects of low frequency circuitry, tension, and shearing, waves on a string, amplification, and sound. This project and Josh's AP class was recently featured on a national broadcast of ABC News.

Departments considering the development of a program like our concentration in education will have various questions. The answers no doubt will be institutionally specific so we simply report our experience.

What about the reaction from the Education Department? The Education Program at Haverford and Bryn Mawr College has been extremely supportive of our program. It adds useful courses from their point of view and does not compete directly with their certification program.

How can courses like 459 and 460 be efficiently staffed? We add the duty of supervising the 1–3 students per offering in these courses to that of teaching the 102 lab and the 101 lecture, respectively. This does not add much net work to those activities, since the assistance of the student(s) is helpful to the success of the course, and it makes the course a little more interesting as a teaching responsibility. When I personally teach 101 or 102 with 459 or 460 participants I notice that I do a better job, for reasons that are best left unspecified.

Do the 459/460 students do a good job in teaching the 101/102 students? Yes, assuming reasonable supervision, of course. Also, we have found that good relationships develop in the context of the clinic between the 101 and 460 students. This results in a friendly and supportive atmosphere for the 460 students when they conduct their classroom session.

It is a pleasure to conclude by acknowledging Jerry Gollub, Suzanne Amador, Adam Landsberg, Walter Smith, Bruce Partridge, and Steve Boughn, my colleagues at Haverford, all of whom have contributed importantly to the development of this program. More information about this program and our department can be obtained by visiting our Web Site at http://www.haverford.edu/physics-astro/pahome.html.

[1]Werner P. Wolf, Phys. Today (October 1994), p. 48. (See especially the table on p. 51.) See also CareerPlus, Supplement to APS News of June, 1996, which is also available on the web from the APS at http://www.aps.org under the Careers/Employment button.

[2]See web-site http://www.ed.gov/NCES

[3]Published by the American Association for Employment in Education, 820 Davis St., Suite 222, Evanston, IL 60201-4445.

[4]One in the past decade!

[5]Other concentrations available to physics majors include Computer Science and Biophysics/Biochemistry, but a physics majors could not enroll in the Comparative Literature Concentration, for example. That is available only to English and modern language majors.

[6]This option might not be restricted to the private setting in the future. Our state (Pennsylvania) has recently enacted a ''Charter School'' initiative. This law permits individual public schools to withdraw from their school districts and operate under alternative charters. Allowed charter revisions would include relaxing certication requirements for teachers. At this writing 18 other states have passed similar legislation.

[7]Eric Mazur, *Peer Instruction: A User's Manual* (Prentice-Hall, Upper Saddle River, NJ, 1997).

LAZINESS AND STUPIDITY

For this problem [of laziness or stupidity] I see no solution except the radical one of declaring such numskulls to be unfit for education in book-work, and devising trade-schools, outdoor schools like the CCC camps, and domestic schools, to occupy their strong hands until they grow up. (Montaigne, who was a mild enough man and devoted to kindness as an educational ideal, had no solution either. He said that if a boy refused to learn or proved quite incapable of it, ''his tutor should strangle him, if there are no witnesses, or else he should be apprenticed to a pastry-cook in some good town.'')

Gilbert Highet, *The Art of Teaching* (Vintage Books, New York, 1989; originally published by Alfred A. Knopf, 1950), pp. 117–118.