Foreign physics graduate students in the United States

Foreign citizens have become an integral part of the practice of physics in the United States, helping to staff research and teaching programs in universities and remaining after graduation to help avert shortages of research manpower.

Mark N. McDermott and Edward W. Thomas

The proportion of foreign citizens among first-year physics graduate students in the US has now reached 42%, up from 17% in 1971. This dramatic increase[1] has drawn attention to a wide range of issues, including the following:

- The very small number of US-born students who seek higher degrees in physics. Fewer than 800 US citizens a year, from a population of over 230 million, complete PhDs in physics.
- The balance between theorists and experimenters in physics. Half of the growing number of new foreign-student PhDs are theorists, yet for every physicist hired to do theoretical work, three are hired to do experimental work. What will happen when large numbers of theorists graduate in the next five years?
- The quality of undergraduate instruction by teaching assistants. Few schools train TAs of any citizenship in communication and instruction. This must change if we are to head off restrictive legislative measures that threaten our graduate programs.
- The dependence of US research institutions and industry on the continuing influx of foreign physics graduate students, half of whom remain in the United States after receiving their PhDs. Current trends point to a shortage of physicists within ten years, in spite of the influx.

In this article we look at these and other issues and find that it is very much in the interest of the physics community to acknowledge and defend the value of foreign students to research and teaching (see figure 1) and ultimately to the health of the profession. Our analysis indicates that the US physics community should direct its concern not at its attractiveness to foreign students, but rather at its lack of attractiveness to American students.

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A migration of manpower

Physics in the United States has always drawn heavily on the talents of foreign-born scientists. A review of Nobel Prizes awarded for physics since the onset of the Second World War shows that of the more than 40 recipients who resided in the US, over 25% were foreign born. Interestingly, Nobel Prizes in chemistry to US residents have been only half as frequent, and barely 15% of such recipients are of foreign origin. Any review of prominent personalities in the US physics community would show a significant proportion of foreign-born scientists. Many of these individuals received their full educations in their countries of birth and brought with them some of the best inspirations for research developed by scientific centers outside the United States.

By contrast, the overseas students who now populate our graduate programs in such large numbers are predominantly from developing nations with very limited scientific establishments. They arrive with only formal undergraduate training and negligible research experience. Thus they do not necessarily bring with them the new ideas that were such a valuable feature of past migrations of scientists. Today's scientific migration serves principally to meet this nation's manpower needs, both in the research and teaching activities of graduate schools and in the activities of the industrial and educational institutions where students find employment after graduation.

Figure 2 shows the history of the flow of US and foreign students into our graduate programs.[1] The number of foreign first-year graduate students in physics increased from 600 in 1971 to 1250 in the 1986 academic year. In this same period the number of US citizens entering physics graduate programs declined from 2900 to 1720, suggesting that the increased impact of foreign students on our programs is due as much to a decline of US-student interest in physics graduate work as it is to increased enrollment of foreign students. As the numbers of American students declined we were able to maintain the vitality of our graduate programs by accepting an increasing number of foreign students. Enrollment expanded in the 1980s as the number of US students leveled off and the foreign component increased rapidly. The situation is of course not unique to physics: In engineering the percentage of foreign students in all fields was[2] 38% in 1983, almost identical to that in physics, and foreign students now receive a majority of the engineering PhDs.

Foreign students also participate in educational programs at the undergraduate level. Some 6% of the physics-bachelor's-degree recipients in the class of 1984 were foreign citizens.[3] In this article we do not consider this relatively small source of foreign graduate students.

Figure 3 gives an estimate of the regional origins of the major groups of foreign physics graduate students. The predominant groups are Asian Orientals, Asian Indians, Arabs and foreign-citizen Hispanics; the approximately 25% of foreign students who do not identify themselves as belonging to any of these classifications come from European, African and non-Arab Middle Eastern countries. The most significant recent change in regional distribution is the rapid increase in Asian Oriental students, with most of the increase being from the People's Republic of China. Working toward the PhD is a long process, so it will be some

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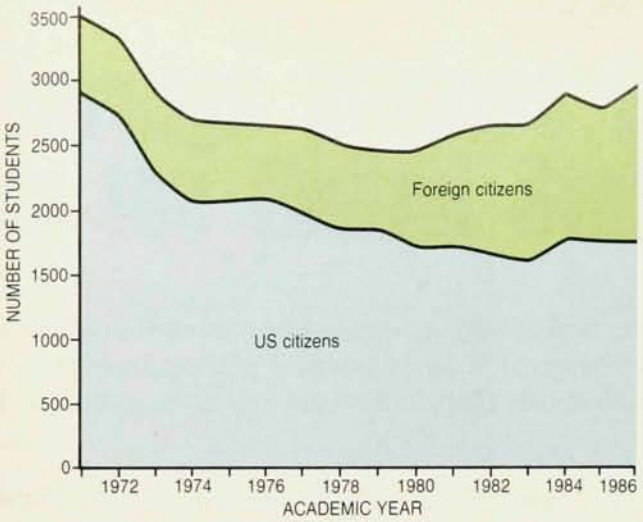
Graduate student Jinchu Huang of the People's Republic of China teaches an undergraduate physics lab at New York University in New York City. Figure 1



Enrollment of first-year physics graduate students, by citizenship, 1971–86. (Data from reference 1.) Figure 2

years before today's first-year enrollment will have an impact on graduation rates. Figure 4 shows graduation projections for various assumptions. The general trend of the projections is that by the end of the century about one-half of all graduating PhDs will be foreign citizens.

It is very difficult to project the future course of foreign enrollments and graduations because many of the contributing factors are not within our control and are currently undergoing significant changes. For example, the earliest students from the People's Republic of China were older and more advanced than typical first-year students or even the Chinese students who arrived this year. Many of this first group have recently received their PhDs, frequently after only three years of graduate work. In the past, only 43% of all first-year physics graduate students completed the PhD degree, and they required five to six years to do so. Thus this first group of Chinese students may have caused an increase in the PhD graduation rate that might not continue in future years. One should bear in mind that graduation and employment projections such as those given in figure 4 and in other parts of this article are based on data acquired before 1983 and cannot be reliably extrapolated while the composition of the entering foreign student group is undergoing significant changes. In examining the statistics, one should also keep in mind that some of the individuals classified as foreign students are immigrant Americans who have not yet become US citizens.

Selection of students

The excellent academic quality of foreign graduate students is a large part of their attraction for US universities. Selection is generally based on the same materials used to evaluate US students—GRE scores, academic transcripts, letters of recommendation and the reputations of their undergraduate schools. In some cases universities can supplement these measures with additional screening devices, which we will discuss below. The pool of foreign applicants is larger than that of US applicants, and the foreign student's level of preparation is often higher because of a more intense undergraduate curriculum and because science may be held in greater esteem in the student's country of origin.

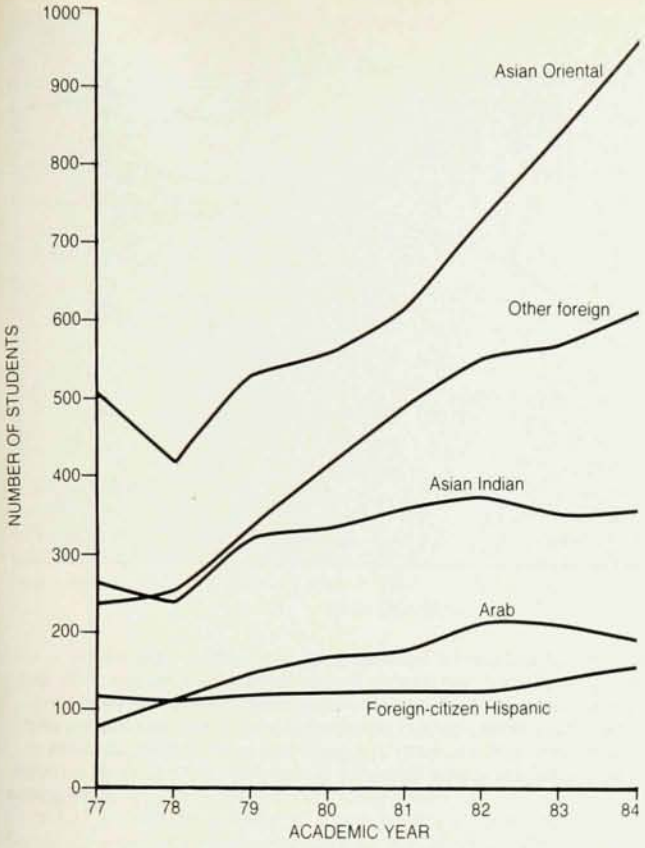
A very small proportion of students are sent to the United States with financial support from their governments. These students have presumably been selected carefully and are committed to return to their home countries after graduation to contribute to national development.

Stringently selected foreign students also come out of two recruitment schemes operated by US-based organizations. For 17 years Michael Moravcsik of the University of Oregon has operated[4] the Physics Interviewing Project, which periodically sends a team to interview potential students in less developed countries. Participating institutions receive a report on the interviews and are responsible for continuing the recruitment process. The program has interviewed about 2000 students over the years, principally from Asian nations; the program has never covered Taiwan or the People's Republic of China and ceased covering India some years ago because of that country's concern that its best students were being attracted away.

The China–US Physics Examination and Application program, organized[5] six years ago by T. D. Lee of Columbia University, involves examinations in physics and English, supplemented by personal interviews. CUSPEA sends a report on the exam results and interviews to participating institutions, and students then apply in a standard manner to their choice of up to five of those institutions. Further negotiations are again the responsibility of the participating institutions. CUSPEA operates only in the People's Republic of China and is supported by the Chinese Ministry of Education and Academia Sinica; the Chinese government provides the transportation. In 1985 only 95 students were selected for interviews.

Both the Physics Interviewing Project and CUSPEA program are highly selective. The 95 students identified by the CUSPEA program represent only 1% of all students in China receiving undergraduate degrees in physics or physics-related fields. Based on a 1982 survey of physics-department chairmen,[5] the CUSPEA program classified 42% of its students then in the United States as excellent, 45% as very good, 11% as good and 1% each as fair and as poor.

Together the two recruitment schemes are identifying at most a couple of hundred potential foreign students per year, and government-supported students represent an additional small number of select students. There remains a group of at least 1000 students each year whom universities recruit directly by responding to student inquiries from overseas. What information can we get on foreign students for use in selection? Certainly we can make use of scores on standard examinations, such as the GRE, to



Regional origin of foreign students in physics graduate school, 1977–84. Data come from students' self-identifications on AIP survey questionnaires[6] and are estimated to be about 80% of the true figures. The "other" category includes students from European, African and non-Arab Middle Eastern countries. Figure 3

ensure competence in formal studies. The applicants' undergraduate institutions, however, are often unfamiliar to us, and their letters of reference are often from persons with whom we have had no previous contact. The other important aspect of selection is competence in English. Many institutions require the Test of English as a Foreign Language and consider that test an adequate measure of the student's ability to manage a class taught in English. The ability to speak English, so essential to performance as a teaching assistant or in discussing research work, can be assessed by the Test of Spoken English, but this is rarely available overseas, and even when it is, the cost of taking it can be prohibitive to prospective students. (The TOEFL and TSE exams are administered by the Educational Testing Service, Princeton, New Jersey.) The general perception among university faculty is that in recruiting overseas students we are making satisfactory assessments of scientific competence but are not always successful in assessing language competence.

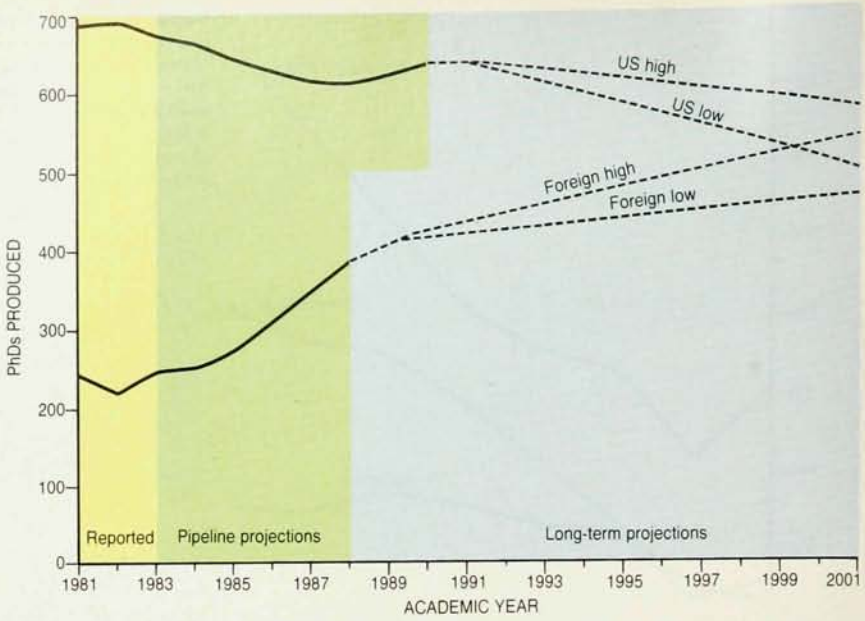
Face-to-face interviews with foreign students are often impractical. Some schools have adopted the novel strategy of asking the applicant to call collect for a telephone interview. Some argue that any student who can accomplish such a call from a Third World nation has considerable initiative. The interview, which is tape recorded, can shed light on communication skills. Alternatively, a university can sometimes arrange for a reliable contact, such as a former graduate, to meet with the applicant.

Teaching assistantships

The graduate assistantship is an essential element in the training of a professional physicist. Not only is it a valuable part of the graduate student's physics education, it is the chief source of support for the majority of physics graduate students. At this time 33% of physics graduate students work[6] as teaching assistants and 41% as research assistants. The general practice is to give the teaching assistantships to beginning graduate students, so such assistantships are especially important for foreign students, many of whom are not eligible for the limited number of fellowships offered and have little or no other support.

It is in the role of teaching assistant that the foreign student is most noticeable to undergraduates. Teaching assistants from Third World countries instructing undergraduates predominantly of American cultural background may encounter difficulties in both pedagogical style and language. There has been no systematic study of foreign physics TAs but the national press has given[7] publicity to the issue. In many countries the teacher is the absolute master of the classroom and gives a packaged formal presentation that does not encourage questions or comments from the listener. The American student wants the opportunity to question the teacher and expects a lively, impromptu response; the teacher is frequently expected to be an entertainer and to make the class interesting. Stimulation of the class is particularly important in physics, where the undergraduate student is likely to be a major in another discipline, with no great dedication to physics.

In some cases language problems have touched off complaints by undergraduates. When the departments do not identify and address such dissatisfaction, legislators and administrators are likely to inflict onerous rules to alleviate the problem. In Ohio, legislation now requires all teaching assistants at state colleges and universities to pass an oral proficiency test in English. The bill was drafted by state Representative Barbara C. Pringle, whose daughter, a student in the speech communications department at Kent State University, had difficulty understanding her foreign-born instructor's lectures in a statistics course; the Ohio House passed[8] the bill 94 to 1. In Arizona, state Representative Sterling Ridge introduced a bill to limit foreign students and professors to 10% of the student body and faculty at each state college and university, with a limit of 25% on the proportion of foreign students in any one department.[9] The bill did not pass in that form but was amended to require oral proficiency in English of all instructional personnel. Nevertheless the warning is clear: It is in our best interests to solve this problem before



Physics PhD production in the United States, by citizenship, 1981–2001. The low US prediction assumes that first-year students will decline in number by 22% between 1985 and 1997, tracking the decline in the number of 22-year-old males, while the high US prediction assumes only a 10% decline. The low foreign and high foreign predictions assume 1% and 2.5% annual increases, respectively, in the number of foreign first-year graduate students in 1985–97. Projections are by the AIP Manpower Statistics Division and are based on statistics available in 1983. Figure 4

restrictive legislative measures and cumbersome testing procedures threaten our graduate programs. Improvement of classroom communication and instructional skills is long overdue and will be as valuable to American graduate students as to foreign graduate students. Programs to address this need exist already and will undoubtedly become more widespread.

The most frequent response to the language problem has been to require some minimum proficiency in spoken English of all TAs. Thus some universities supplement the TOEFL exam, which is a test of written English, with a test of spoken English. If the oral exam is administered upon the student's arrival in this country the problem then becomes what to do if the student does not meet minimum standards for a TA but has come expecting TA support. If grading or other duties that do not require direct student contact are available a partial solution is possible; however, most departments have limited capacities to offer such positions. A more desirable approach has been taken in institutions such as Ohio State University, where the physics department runs an extensive workshop prior to the beginning of classes. Such efforts are expensive but are very likely more effective and better suited to the needs of physics graduate TAs than the courses in English as a second language found on most campuses.

It is clear we should not assign TAs to classrooms without confirming their competence in English. It is also clear that we are likely to continue to recruit foreign students who have superb credentials in physics but who need help with English. This help will certainly be accomplished best if physics departments take a direct hand in the necessary training.

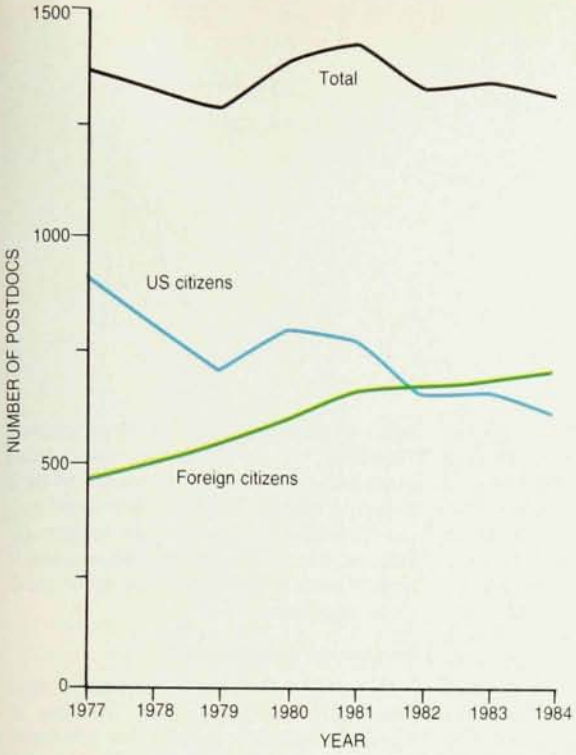
Impact on standards and programs

Do some US students fail in the competition for admission and assistantships because they are perceived as inferior relative to foreign applicants, increasing the already high proportion of foreign students? We find no evidence for this. The general feeling is that all interested and qualified US students are accommodated, and that the foreign student is filling a position that would otherwise be vacant. Figure 2 shows that 15 years ago universities took in far more graduate students than they do today; we would imagine that more US graduate students could be accommodated if they became available.

We are concerned as to whether the distribution of graduate students among the various subfields of physics gives our science the balance that it requires. Undergraduate training in the less developed countries tilts toward theoretical physics in part because of the limited availability of equipment. Foreign students tend to choose theoretical studies for this reason and because their best prospects for employment if they return home are in such areas. Statistics for the 1982–83 and 1983–84 graduating classes show[10] a three-to-one ratio in the numbers of students finding employment as experimenters and as theorists. Among the foreign students, however, experimenters and theorists are approximately equal in number. As the foreign component of graduating classes increases in the next five years, there should be a perceptible shift toward theoretical specializations.

What is the distribution of foreign students among the various subfields of physics? Statistics for the 1984 academic year show that students from the major foreign group, Orientals, have approximately the same interests as US students, with perhaps a slight preference for solid-state physics—46% of these foreign students specialize in solid-state physics, compared with 32% for all students—and a bias against elementary-particle physics—8.5% versus 12.4%. In general, the subfield specializations of foreign students parallel rather closely those of their US counterparts.

In reviewing the impact of foreign students on the distribution of gradu-



Postdocs in physics working in the United States, by citizenship, 1977–84. In 1982 the number of foreign postdocs in the United States surpassed the number of American postdocs. (Data from reference 14.) Figure 5

ate students among the subfields of physics, we must of course try to determine whether student demand drives enrollments in the various subfields or whether students respond to the opportunities that are available. We would argue that the incoming student is selected largely on the basis of quality, so that any specialized interest that the student may have before admission is not a major factor in the decision to admit. Thus the bias of foreign students toward theoretical physics is probably increasing the demand for theoretical thesis research. This demand is driven by factors that are not directly under our control and may possibly be distorting the distribution of interests away from the requirements of the US job market.

Approximately half of all PhD graduates take postdoctoral positions. Many regard these temporary jobs as an essential step in preparation for an academic career. Foreign students, particularly theorists, are far more likely to take such positions than are their American colleagues. Typically 75% of foreign theorists and 50–75% of foreign experimenters are working[10] as postdocs a year after graduation. Visa regulations may explain these high percentages: It is relatively simple to change a student visa to a status representing "further training," which encompasses postdoctoral work; it is far more difficult to change directly to permanent-resident status, which permits permanent employment. Thus, as figure 5 shows, the number of foreign postdocs has surpassed the number of US postdocs and continues to grow.

Attitude of foreign governments

In forming one's attitude toward the foreign graduate student one should review not only the reasons the student comes to the United States, but also the attitude of the foreign government toward the student seeking graduate-level training in this country. We consider as examples students from India and from the People's Republic of China—two large groups having rather different objectives.

Virtually all Indian students arrive here as a result of direct recruitment by US universities. The Indian government gives only 50 scholarships each year for professional training in the United States, and no significant fraction of these are for physics graduate school. Many university faculty in India themselves studied in the United States or Western Europe, and they in turn encourage their brightest students to follow the same route. In the 1960s many academically oriented positions were available in India and there was a strong incentive for PhD graduates to return home. Today the Indian student finds the opportunities in India limited, apart from a few areas such as microelectronics, nuclear physics and plasma physics. Good positions are scarce, so recent graduates tend to stay in the US, where they can find research positions.

A representative of the Indian Embassy in Washington admits that even though India produces more highly trained scientists than it can usefully employ, the Indian government is concerned about the loss of excellent young scientists to Indian society. While the Indian government does not actively recruit recent graduates, it does make return to India easier by maintaining a "scientist pool"—a fund that gives returning scientists basic incomes while they seek permanent positions. Because the students make their own arrangements to come to the United States, and because the Indian government does not seek to control this movement, there is little likelihood that the scientific emigration from India will change.

The case of the People's Republic of China is a little different. Due to the disturbances caused by the Cultural Revolution a whole generation of young people has missed the opportunity for formal scientific training. The government of China sees sending students to the United States and Western Europe as a means of rectifying this loss of expertise and upgrading the

technological competence of the nation. The government helps arrange this flow of students and expects most of the students to return to contribute to the nation's development. Positions are assured and efforts are under way to provide adequate facilities for professional development. When rectification of the perceived deficiencies is complete, the officially encouraged flow of students is likely to be much reduced. Thus most students from the PRC are not candidates for the US labor pool, and the contribution of Chinese students to our graduate enrollment might be greatly reduced when China determines that it no longer needs this program.

Federal and state attitudes

Whether or not the number of foreign graduate students in physics continues to increase as projected in figure 4 depends not only on the policies of a number of quite different foreign governments but also on the receptiveness of the US government and the various state governments that provide much of the initial support for foreign students. The attitude of both at this time seems quite positive; however, there are some danger signs that we should not ignore.

Although we could not find a statement that represents official US policy toward foreign students, a look at the government's practice suggests that the policy is to encourage the training of foreign students in this country. For many years no limitation has been placed on the total number of student visas. The government exercises control to verify that visa holders are enrolled in legitimate courses of study and are not entering the country for purposes other than study. The government also requires that students have sufficient resources to meet their expenses during their stays. The F-1, or student, visa extends through the duration of the degree program and permits up to half-time employment on campus. It is thus well suited to the current mode of supporting foreign PhD candidates through teaching or research assistantships.

An even more receptive attitude seems to characterize the exchange programs administered by the United States Information Agency. Exchanges were transferred to this agency from the State Department to help implement a "President's initiative" directed at encouraging foreign exchanges at the high-school level. USIA also handles J-1, or exchange, visa arrangements for most postdocs and faculty. There is no limit on the total number of these visas either, but the visits are generally limited to three years.

No one agency is responsible for policy toward foreign students, and with the increasing awareness of the importance of these students in maintaining graduate programs and supplying trained manpower in the sciences and engineering, a number of agencies have begun to show interest. The National Science Foundation's Division of Science Resources Studies, which in the past has published citizenship data for scientists and engineers, has now added data on students to its publications. Congress has taken note of the situation and has had the General Accounting Office use NSF data to address[11] questions about the postgraduate plans of US-trained foreign students in science and engineering. It therefore appears that US dependence on foreign citizens in science and engineering is now known and is being monitored, but it has not generated a particularly high level of concern.

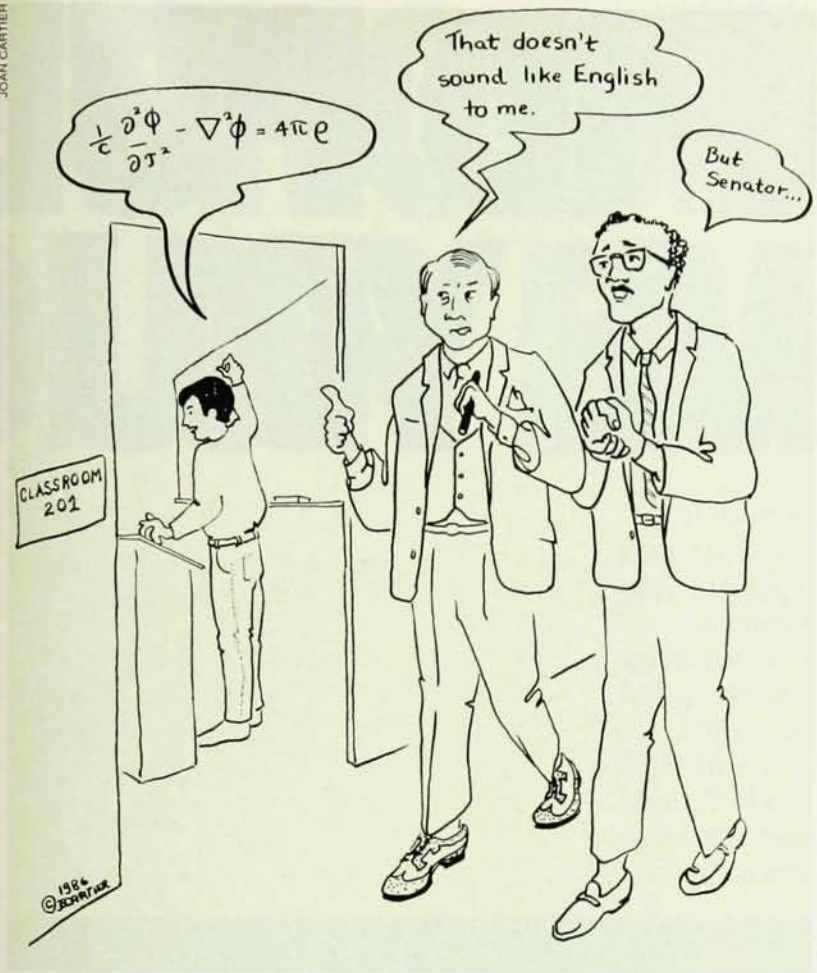
More attention has been paid to the impact of foreign students at the state level. State governments not only are some of the chief sources of support for foreign students, they are also the sources most sensitive to some of the problems associated with these students' presence. Nearly all the recently publicized efforts of state legislatures to regulate the numbers or qualifications of foreign graduate students have grown out of state concern about the effect of English-language competency on the quality of instruction. On the other hand, states have not shown any conspicuous concern over the costs of educating foreign students. This is somewhat surprising at first glance. However, it is apparent that states often consider foreign students to be a revenue source when student-paid tuition covers full costs. In other instances states recognize the academic importance of foreign students to graduate programs.

Impact on employment

Certainly the most sensitive issue raised by the increasing fraction of foreign students in physics graduate programs is the impact the foreign students will have on future employment for physicists. Any attempt to project very far into the future is fraught with large uncertainties in nearly all of the relevant factors. Will physics PhD production continue to rise? Will the fraction of foreign students grow even larger? What types of jobs and how many will be available? What fraction of the foreign PhDs will compete for these jobs rather than return to their countries of citizenship? The answers to these questions will determine whether, at one extreme, foreign PhDs whom we have trained will compete with US PhDs for an inadequate number of jobs or whether, at the other extreme, the two groups together will be insufficient to meet future manpower needs. Current trends suggest the latter situation will prevail by the mid-1990s and therefore indicate that the US may have a very strong interest in welcoming foreign graduate students.

The PhD-production projections in figure 4 assume that the entry and retention rates in doctoral programs will remain about the same as they are now or will increase slightly. The drop in the US component is solely the result of the 20% decrease in 18–24-year-old Americans that we know will occur by 1996. The number of foreign students is derived from assumptions about the rate of increase in this group but is of course very much subject to governmental policies both here and abroad.

Critical to the supply calculation is the number of foreign PhDs who elect to stay in this country. The American Institute of Physics assumes a constant



50% but this figure is not verified even for the most recent PhDs. As pointed out earlier, foreign PhDs take postdoctoral positions to a much greater extent than do US PhDs. The foreign PhDs have generally not been tracked beyond the postdoc stage, so the fraction of students who eventually leave the US is very poorly known. Evidence indicates that increasing numbers are remaining in the US. An NSF study covering all of science and engineering says[12] that in 1972, 51% of foreign PhDs planned to remain in the US, compared with 60% in 1984. Extrapolating trends is dangerous, however, and the number electing to stay, like the number coming for study, is essentially unpredictable.

The number of academic positions that will open up as faculty hired in the booming 1960s reach retirement is an important—and predictable—driver of future demand. An immediate consequence, should supply follow the forecasts discussed above, will be a higher fraction of foreign PhDs among faculty hired in the 1990s.

Even with increased demand in the academic sector, a declining college-age population will almost certainly mean that the majority of jobs for physicists will continue to be outside academia. There economic growth and defense spending will govern the job market. In all, it appears a good bet that with a society increasingly dependent on technology, and with the well-known mobility of physics PhDs, the number of nonacademic jobs that physicists can fill will increase substantially. The Manpower Statistics Division of AIP projects[13] a rough balance between supply and demand through 1991, with a shortage of PhDs developing later in the 1990s.

The future

Projections based on past statistics are hazardous due to the changing composition of the foreign-student population. It appears that, barring any major political changes in the nations of origin, the number of foreign students entering graduate school in the US is likely to remain constant for the foreseeable future. Our faculty colleagues are remarkably unconcerned about this situation and are delighted to have bright students to fill their classes and to staff their research activities.

We believe that physicists should focus their concern not on the large numbers of foreign students but rather on the very small number of US students who seek the highest qualification in physics, a subject that underpins the very fabric of our technologically oriented society. This very low level of career interest is unhealthy and may eventually erode the support that our profession requires.

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