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ABSTRACT

In this American Institute of Physics report, three questions are addressed: 1) What are the goals of undergraduate physics curriculum? 2) What are the common career paths of physics bachelors? 3) How well does the physics curriculum prepare our bachelors for these careers? The paper suggests that physics curricula 1) provide students with a knowledge of physics, 2) provide students with a set of skills that are important in a good physicist, and 3) provide students with educational experiences that develop the traits important in a good scientist. Data are presented on the career choices of physics degree recipients. Physics graduates pursue a variety of careers in today's job marketplace. They value skills acquired through study of physics, however job skills valued in the job market are not part of the curriculum. According to data, about a third of physics graduates enter the labor force with only a bachelor's degree. Over a third pursue master's degrees, and about one quarter receive Ph.Ds. Six tables and three figures are included, and present data on career choice, important skills, and work environment, and provide information on the link between physics education and career. (HB)

The Physics Bachelors as a Passport to the Workplace: Recent Research Results

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Today I will address three questions:

- What are the goals of undergraduate physics curriculum?
- What are the common career paths of physics bachelors?
- How well does the physics curriculum prepare our bachelors for these careers?

I propose that the answer to the first question is that the undergraduate curriculum in physics has three basic goals. This is not intended as the definitive set of possible goals. Other goals and priorities do exist in different departments. Rather, the following is a framework against which to consider the data I will be discussing this morning.

(1) *Provide students with a knowledge of physics*, that is, an in-depth understanding of the fundamental principles that govern the physical world around us.

(2) *Provide students with a set of skills that are important in a good physicist.* These include cognitive skills such as critical and analytical thinking, problem solving skills, and learning how to define a problem. They also include technical skills such as advanced mathematics, computer skills, and developing the ability to use, design, and even build sophisticated lab equipment.

(3) *Provide students with educational experiences that develop the traits important in a good scientist.* These include being hard working, creative, meticulous, persistent, tenacious and self confident.

This morning I will present data on what our graduates are doing for a living and where they are doing it. I will also present some data on those aspects of the physics undergraduate education that our graduates say have helped them the most in their careers. From these data we will be able to identify the knowledge and skills that the job market values today.

It is essential that we remember, however, that today's physics bachelors will be in the workforce for about 45 years. We can only imagine the technological challenges that they will be asked to solve 10, 20 and 40 years from now. But, some of us are old enough to remember how different the world was 45 years ago. As Dr. Rigden noted in his talk this morning, the Ford Motor Company hired its first engineer with a college degree in engineering less than 45 years ago. Engineer was a position that employees were promoted into, mostly from draftsman which is an occupation that does not exist anymore. Ten years ago, one sixth of their salaried work force had an engineering degree and today that is up to one third. While part of this is due to changes in how they do their work, a significant part is that Ford has made a conscious and deliberate decision to hire engineers to work throughout the corporate structure, including management, planning, marketing, and sales.

Thus, we are faced with an extremely important and difficult, perhaps even impossible, task. How do we design an undergraduate curriculum that provides our graduates with a balance between the knowledge base that they will be able to draw upon throughout their working lives and, at the same time, provides the skills that are important for getting their careers started, for getting that first career-defining job?

Our physics bachelors pursue a remarkable variety of careers, mostly within the science and engineering enterprise. Their career paths depend, in large part, on three factors:

- the level of their highest degree,
- the field of their highest degree, and
- the employment sector within which they work.

We estimate that about a third enter the labor force with their physics bachelors and do not pursue any advance degrees. Over a third go on to earn a masters degree, about one-quarter go on to a PhD and another 6-8% earn professional degrees, mostly in medicine, some in law and a few in dentistry and other professional occupations.

While the majority of those who earn a PhD do so in physics, many go into engineering, mathematics, chemistry and the geosciences. However, at the masters level, fewer than half (about 40%) stay in physics. The other large degree fields are engineering, MBAs, computer science, mathematics, and education. Still others enter such fields as philosophy, social work and religious studies. In short, our graduates pursue educational routes in virtually every field and it would be a serious error to believe that undergraduate training in physics exists principally to lay the groundwork for graduate training in physics. That route is not the norm; it is the exception. We estimate that only about 15% of physics bachelors ever earn a PhD in physics.

If we look at just those people who are in the labor force with a degree in physics, we see that they are employed throughout the economy. However, their concentration within different employment sectors varies by the level of their highest physics degree (see **Table 1**). As you review these trends, I would like to make a few comments about the categories. Industry refers to medium and large companies, while the term autonomous private sector includes people working in small companies, consulting firms, the self employed and those employed by a professional practice such as law and medicine. Industry and the autonomous private sector combined employ about 60% of our bachelors and masters.

Academe refers to a very different slice of the education system under each degree level. The bulk of our bachelors and masters teach in high schools, but others are spread out. They work in administrative positions at the district level, teach in two-year colleges or hold technical support positions in universities. At the PhD level, the majority hold faculty positions in universities and most of the rest are in 4-year colleges.

Finally, government refers to federal agencies and the Federally Funded Research and Development Centers such as Brookhaven, Fermi Lab and Los Alamos. However, the government category also includes state and local government and the military.

TABLE 1. Sector of Employment by Level of Highest Physics Degree, 1994

Employment Sector	Bachelors %	Masters %	PhD %
Industry	42	33	21
Autonomous private sector	19	27	9
Government	21	18	23
Academe	11	17	42
Other	7	5	5

The latter are significant employers of our bachelors but employ comparatively few PhDs. By way of example, among physics bachelors who enter the work force after their degrees, twice as many go into the military as go into high school teaching. It should be noted that many, but not all, of the former earned their degrees from military academies.

While each of these groups is interesting and important, given the time constraints, I have decided to focus the rest of my talk on the career paths of our graduates who are in the workforce with a bachelors in physics. We have data on the others and have recently published a report titled, *"What are Masters doing?* You can request this report by contacting the author, Don Rosdil, of the AIP Statistics Division.

One way of looking at what physics bachelors do for a living is to examine their occupations and job titles. The data I will cite refer to physics bachelors across the career spectrum. As you look at **Table 2**, three trends jump out at you. First, the distribution of occupations is different within each of the largest employment sectors. Second, a handful of occupations reoccur. Third, none of the most common occupations is physicist.

Why do virtually none of our bachelors refer to themselves as physicists and is it good news or bad news? There are a number of likely explanations for this trend. First, the physics community has historically not considered its bachelors to be physicists. That title has been reserved for PhDs. Although recently, there has been a push to consider people with a masters degree as "professional physicists". Second, employers do not hire our graduates as physicists. Part of the reason for this is the

TABLE 2. Predominant Occupations for Physics Bachelors by Employment Sector, 1994

Industry	Autonomous Private Sector	Government	Academe
Engineer	Manager	Scientist	Teacher
Manager	Engineer	Engineer	
Computer Scientist	Computer Scientist	Military	
Technician		Computer Scientist	

* The occupations listed account for 75% or more of the positions noted by Bachelors within each sector.

work that they are hired to do. But part is that the bulk of them work in the private sector and, unlike chemistry, engineering, computers and geology, there is no "physics" industry.

When I display these data to students, I am often asked, "If I am going to work as an engineer , computer scientist or manager, why should I major in physics and not in one of those fields?" We have some data that answers this question and they appear in the report I cited earlier, "*What are Masters doing?* I do not have the time to give you the full answer but can give you one example. We compared the work activities of people who earned a masters in physics and called themselves managers with those who earned a bachelors in physics followed by an MBA and called themselves managers. There were interesting similarities and differences. All managers regardless of their degree path, plan at the operational level. Those high enough within their companies plan, at the organizational level. These findings are not surprising; they reflect what managers are paid to do. However, the next most common activities do vary by degree path. Physics masters manage technical projects such as product development, while our graduates with MBAs tend to be involved with marketing and sales.

Although our graduates work, and have historically succeeded, as engineers, computer scientists and managers, there is anecdotal evidence to indicate that they do have problems getting that first job, especially during tight job markets. Part of their problems result from the way that Human Resources Divisions within the private sector often fulfill their responsibilities. If job postings specifically call for individuals in particular occupations, e.g. software engineer, then it appears that many H.R. people pass along only the resumes of individuals with degrees or prior work histories in those occupational categories. Thus, physics bachelors are faced with the pragmatic problem of getting their resumes past the H.R. Division to the people actually doing the hiring. I will mention some strategies for dealing with this problem near the end of this talk.

Next we will dig a little deeper into what physics bachelors do by examining their principle work activities. Respondents to a recent survey were asked to identify their three most important work activities from a list of about 37 possible choices. **Tables 3 and 4** describe the most common work activities of physics bachelors in the largest employment sectors. These data begin to give one a feeling for the variety of activities in which our graduates are involved. In medium and large companies, a third of physics bachelors are engaged in operational planning, that is, they manage projects and groups of people. Consistent with their occupations as noted in **Table 1**, they are also heavily involved in product design and software-related activities.

TABLE 3. Predominant Work Activities for Physics Bachelors in the Private Sector, 1994

Industry	Autonomous Private Sector
Operational planning	Consulting
Product design	Software development
Software development	Product design
Programming	Programming
Synthesizing information	Marketing
Supervising	

* Respondents were asked to identify their three most important work activities from a list of about 37. The activities above were noted by at least 16% of the Bachelors within each sector.

Within the autonomous private sector, our graduates are engaged in activities similar to those in larger companies However, given the nature of this sector, their dominant activity is consulting. We also see some indication of the growth in the small computer-related companies as a significant employer.

Within government employment, we see the importance of data interpretation and modeling. As for the latter, a significant number of our graduates are employed at the state level modeling such phenomena as weather patterns, earth quakes and traffic patterns.

TABLE 4. Predominant Work Activities for Physics Bachelors in Academe or Government, 1994

Government	Academe
Operational planning	Teaching
Synthesizing information	Counseling
Product design	Providing services
Organizational planning	Presenting
Modeling / Simulation	

* Respondents were asked to identify their three most important work activities from a list of about 37. The activities above were noted by at least 16% of the Bachelors within each sector.

To help us understand their careers more fully, we asked physics bachelors what skills they frequently used in their positions. As **Figure I** illustrates, virtually all physics bachelors in the private sector reported that they are frequently engaged in problem solving. This is good news. This is what we train them to do. However, about 80% reported that they use interpersonal skills frequently. In all honesty, we have to admit that the stereotype of the typical physics major does not include strong people skills. We will get back to this issue soon.

The remainder of the skills profile in the private sector begins to paint a clearer picture of the varied career paths that our graduates pursue. One can see those involved in management and administration in the high use of management skills and business principles. The use of computer skills reflect many of our graduates engaged in computer hardware and software development as well as networking activities. Those who work as technicians or in related occupations show up in the high use of lab equipment skills.

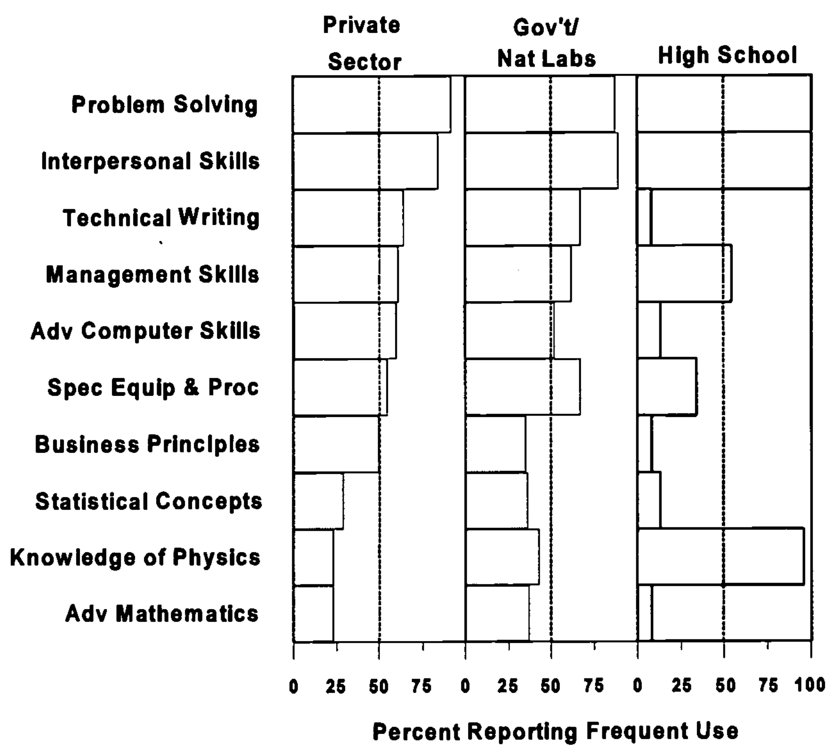

FIGURE I. Skills used frequently by physics bachelors in selected employment sectors, 1994. Respondents were asked to rate the frequency with which they use each skill in their current position on a scale of 1 (Not at all) to 5 (Extensively). These data reflect the percent who chose 4 or 5.

Physics knowledge is cited frequently by only 20% of our graduates in industry. However, this too can be interpreted as good news for at least two reasons. First, virtually none of them are employed as physicists, and thus, the fact that 20% say they use physics frequently appears to be rather positive. Second, this data point could be viewed as a low estimate since many of the cognitive skills that they learn as physics majors are doubtless applied under the high use of problem solving skills.

The profile of skills used in government and high schools is similar in some ways and quite different in others to that of our graduates in industry. Once again, problem solving skills are ubiquitous. However, it is important that we recognize that the problems that high school teachers face are qualitatively different from those our graduates in industry or in the government sector are asked to solve. It is encouraging to note that the vast majority of high school teachers report that they frequently use their knowledge of physics.

Government employees use physics knowledge much more frequently than do those in the private sector. This combined with the high use of technical writing and computer skills reflect, in part, those of our graduates who are working as scientists in places like radiation regulatory agencies as well as those developing technical reports on and carrying out computer simulations of a variety of physical phenomena.

The pronounced bump in specialized equipment use among those employed in government reflects many of our graduates who are in the military. Many hold such positions as officers on nuclear submarines and jet pilots. Specialized equipment use indeed. It should be noted that these individuals also report that they regularly use their knowledge of physics principles.

We asked physics bachelors what aspects of their work they found most rewarding. Two points about these data. First, this was an open-ended question and respondents could have written anything. Second, the data are based on our categorizations of these free-form responses and you will have to trust that we did an accurate job. As indicated in **Table 5**, the comment that was forwarded the most often was "the challenge of solving interesting and complex problems". The specific problems were in a variety of disciplines including: physics, engineering, computer hardware and software, biology, medicine and business. As two respondents noted, its the

TABLE 5. The Most Rewarding Aspects of their Current Positions as Reported by Physics Bachelors Employed in the Private Sector, 1994

Challenge of solving interesting and complex problems
Working with people
Seeing a project yield a successful and useful product
Developing new methods, processes and designs

satisfaction of "developing creative solutions to problems" and "troubleshooting". The second most cited rewarding aspect of their jobs was working with people. These comments help explain the high use of interpersonal skills illustrated in the previous graph. The people-related comments fell into three categories. First, the satisfaction of working with intelligent and creative co-workers. Second, the rewards of supervising, that is, hiring and training new employees and helping people develop to their full potential. The third category was the rewards of working with customers and briefing clients.

Our graduates get a great deal of satisfaction out of seeing a project yield a successful and useful product. The kinds of comments that we received included: the rewards of successfully bringing an idea from inception through design and to production; seeing hard work pay off; and developing a product that exceeded the performance expectations of the customer. As one respondent noted, it is the satisfaction of developing a product that is so good that people want to buy it.
The last major category of rewards reflected the intellectual satisfaction of developing new methods, processes and designs. These responses included such comments as developing new methods of testing and analysis, developing new design concepts, e.g. electronic circuits, and developing new processes for production and quality control.

The next illustration (**Figure II**) helps to further put the interpersonal skills into perspective. We asked physics bachelors about their working environment, that is, do they work independently, work in a team or group, or supervise a team or group. Whereas most of our physics bachelors in academe report that they work independently, the norm in all other sectors is to work in a team environment. The autonomous private sector has a significant number of physics bachelors who work independently by the nature of the sector, that is, they are either self employed or work in a firm that is too small to qualify as a team environment. However, even here we see that at least half of the respondents note that a significant portion of their jobs is customer or client contact.

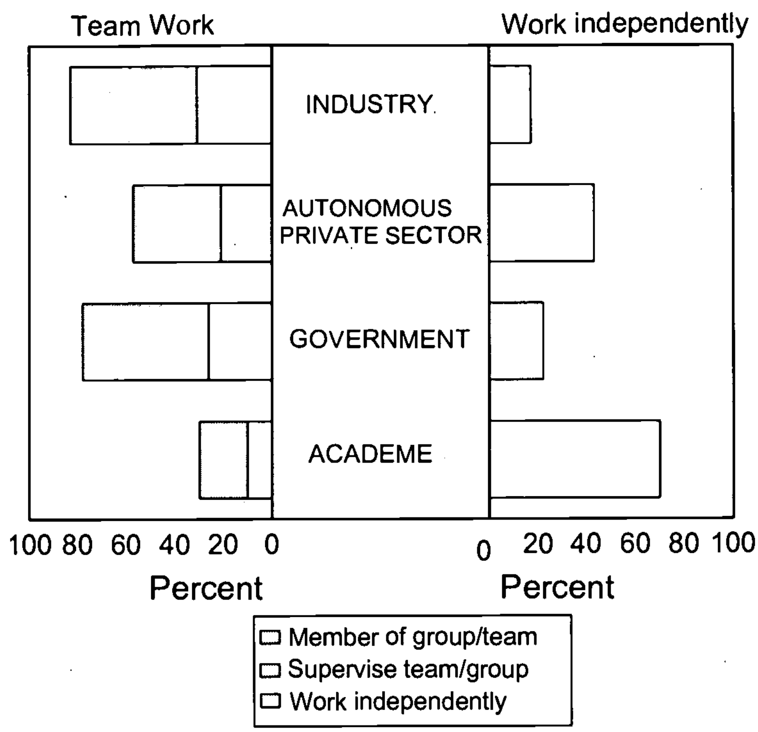

FIGURE II. Work environment for physics bachelors by employment sector, 1994.

We have now seen where physics bachelors work, what they do in their positions, their work environment and the sources of satisfaction in their work. The conclusion is that physics bachelors are employed throughout the economy, they solve problems and they work with people.

It is time to turn to what they report were the most important aspects of their physics education in terms of shaping their careers. These data were derived from another open-ended question and **Table 6** describes the reoccurring themes that they cited. Virtually all of our graduates state that the most important aspect of their physics background was their training in cognitive skills. Specifically, they noted problem solving, critical thinking, analytical skills, and learning how to learn. As one respondent noted, "Physics education gave me the ability to break any problem or system down to its most elementary parts. This is important in terms of understanding systems and analyzing real-time problems".

They also frequently cited their knowledge of physics. The most common comments here focused on a broad understanding of basic principles and the foundation they received for acquiring new knowledge. Physics bachelors often commented that their

TABLE 6. The One or Two Most Important Aspects of Physics Education in Terms of Shaping the Careers of Physics Bachelors, 1994

COGNITIVE SKILLS
Problem solving, critical thinking, analytical skills, and learning how to learn
PHYSICS KNOWLEDGE
Broad understanding of basic principles
Foundation for acquiring new knowledge
TECHNICAL SKILLS
Advanced mathematics, computer skills and lab skills
PERSONAL TRAITS
Self confidence, mental discipline, perseverance and strong work ethic
INVOLVEMENT IN INDEPENDENT RESEARCH
PROFESSORS
Role models and mentors

physics education was valuable in the technical skills that it provided including advanced mathematics, computer skills and equipment skills. Many physics bachelors credited their physics education for important personal traits such as mental discipline, perseverance, a strong work ethic, and the self confidence of having completed a difficult and challenging course of study. Finally, some of the respondents said that the most important aspect of their physics background was their involvement with independent research and their professors who served as role models or mentors.

It should be noted that virtually none of our respondents stated that the most important aspects of their physics education was learning technical writing, communication skills or interpersonal skills. There are several caveats here. It may be that these are developed within the physics curriculum but are not among the one or two most important aspects. It is also possible to interpret these findings by sayings that those skills ought to be developed by undergraduate course work in other disciplines. It is, however, true that if our goals include preparing our graduates for the workplace, then we must ensure that they are exposed to such experiences within our curriculum or that we have provided them a road map of courses in other fields that they should take and that are designed to foster such skills.

The last point of my talk focuses on the perspective of potential employers. What are they looking for and how well do our graduates match that profile? The last illustration (see **Figure III**) portrays the four general skills and traits that a large technical consulting firm says it looks for in new employees. Based on conversations with many recruiters, I believe that these are generalizable to the broader job market. One of these areas is problem solving skills. Subsumed under this are intelligence, quantitative skills and a practical orientation. Another is drive and aspirations including persistence and a high standard of excellence. From the employer point of view, our graduates do well in both of these categories.

A third area is leadership, which includes initiative and entrepreneurship. Employers are looking for people who can assess the strengths of their company, the strengths of their team and propose an idea for a new product or service that is both consistent with the company's goals and can make a profit. A fourth area is personal impact which includes such traits as communication skills, ability to work within a team environment and a personal presence.

It is essential that we recognize that our graduates will be working with people and that those people will be trained in other disciplines: engineers, chemists, materials scientists and administrators to name a few. The ability to communicate includes listening skills and these should not be under-rated. People from other disciplines often describe problems using a language with which our graduates are unfamiliar. Thus, terms like "management by objective" are common within the industrial sector but are never uttered in the halls of our physics departments.

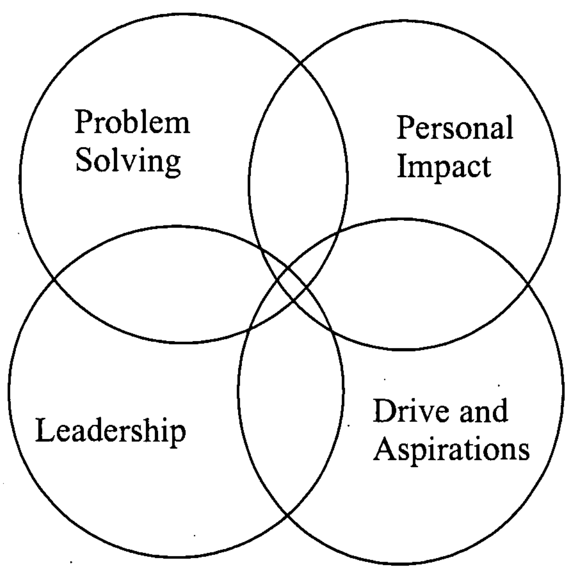

FIGURE III. What PhD recruiters in the private sector look for in candidates.

Terms such as the ones on this last figure are the sorts of phrases that recruiters in the private sector use. Your students should use them in their cover letters. In addition they should make the links for the potential employer including Human Resources between the skills noted in the job description and the skills that they have presumably noted in their resumes. There is nothing wrong with admitting that you have a bachelors degree in physics. In fact, many people believe that physics majors are really smart and that stereotype can be beneficial if used properly. However, at the bachelors level, it could be a mistake in many cases to sell yourself as a physicist rather than as a person with a particular set of skills and knowledge.

You and your colleagues should use such terms in letters of recommendation. You should note the physics knowledge as well as the cognitive and technical skills that your students possess. However, most employers will be hiring your graduates into a team environment. They want you to describe the whole person so that they can assess whether this is an individual who is likely to fit in. Thus, take the time to note your student's personal strengths and interpersonal skills.

In conclusion, we have seen that physics bachelors pursue a broad range of careers. We have also seen that they value their physics knowledge as well as the cognitive and technical skills they learned as part of their undergraduate physics background. In addition, there are other skills that the job market values, skills that typically are not part of our curriculum. Thus, we return to a critical question. What is the appropriate balance in the physics curriculum between providing knowledge and skills?

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