Postdoc Academic Chat #2

Differences Across the Disciplines - How Teaching and Research Vary Across Departments and Schools

Tuesday, October 21, 2014

Questions/Discussion Items to Consider

1. What are some of the biggest differences between your discipline and others mentioned in the readings?

2. Is there anything you can learn or adapt from other disciplines that might help in teaching and research in your discipline?

3. What are some of the things you can do while still at Stanford that will prepare you to interact more effectively with other disciplines once you leave campus?

READINGS

1. **Differences Between the Sciences and the Humanities**
2. **Discipline Comparisons Across the Institution**
3. **Faculty Salaries Vary by Institution Type, Discipline**

1. Differences Between the Sciences and the Humanities

From: Small Pond Science http://smallpondscience.com

By Amy Parachnowitsch, assistant professor, Uppsala University and Terry McGlynn, associate professor at Cal State Dominguez Hills

Standard

One of the great things about being on a small campus is that I have lots of opportunities to interact with colleagues in different departments and colleges. One positive side effect of being sucked into university-level obligations is that you get to know people you otherwise wouldn't interact with.

* Over the years, I've observed some huge differences between the research cultures of

the sciences and the humanities. Most of these things are obvious, I realize. Understanding these differences can help bridge cultural gaps.

* In the sciences, journal articles are the primary metric of productivity and success. In the humanities, it's books. Scientists can write books, and humanities people can write journal articles, but they're not as important.

* In many humanities fields, giving a paper at a conference involves actually giving a paper. Standing at a podium and reading, page after page after page. Science talks are far more informal.

* Research in the sciences is highly collaborative. Many humanities scholars work solitarily.

* Student mentorship happens everywhere. In the sciences, students often adopt a piece of a larger lab project, whereas in the humanities more often students work on entirely separate questions from their mentors. On average, science professors take on a greater number of student researchers than in the humanities.

* Scientists are often expected to fund their research programs with external grants. Humanities researchers aren't necessarily expected to bring in outside funds in order to be perceived as successful, as long as they create the research products in the end.

What constitutes a huge grant in the humanities is a small grant in the sciences. An award of $50,000 from the NEH or NEA is a massive success and a windfall, whereas in the sciences this is useful money but not even close to a "big."

* Scientists can get big pools of money to start up their labs. In the humanities, you get moving expenses, a computer, maybe some reassigned time and maybe a little bit more.

* In the humanities, receiving a PhD from a "top 10 program" in the field is critical for professional success. Program prestige matters in the sciences, but not as much. (I couldn't even tell you what the rankings are in ecology/evolution.)

* The academic job market is way more messed up in the humanities. Here are two contributing factors: First, the degree of adjunctification is higher outside the sciences because tenure-line science faculty are more likely to bring in overhead to cover salary costs. Second, the job market for research scientists is more robust than for academic (say) historians. In the humanities, it's more challenging to parlay a PhD into a salaried academic position outside a university.

* All worthwhile doctoral programs in the sciences fund the students, so tuition and living expenses aren't covered by loans. Graduate students in the sciences are paid to teach and do research, albeit poorly. In the humanities, PhD recipients often emerge with substantial debt.

* Scientists need good library access to get current articles. However, physical access to great libraries is far more important in the humanities, as original papers and actual books remains important for research. The physical location of an institution, relative to an impressive library, is important for the humanities scholar.

* Humanities scholars use the phrase “digital humanities,” and it means something to them.

* Science professors are less likely to use elbow patches on their tweed jackets, but professors in the humanities are more likely to smoke a pipe.

Feel free to make new contributions, or disabuse me of any mistaken notions, in the comments

Comments

Jeff Walker 6 months ago

Some subcultures within the humanities cite in a very different way than how scientists cite. That is, in the humanities, a paper (read at a podium) is often a long string of citations (direct quotes really) from the “big names” in the field with what seems to me to be little additional organization or insight from the author. So the author starts with a question and uses lots of quotes to (kind of) answer the question. So citations are used as authoritative (almost guru-like) knowledge (but knowledge in a very different sense then knowledge in the science). And of course this then generates new knowledge (but again, a very different sort of knowledge than in the sciences).

As for knowledge, there seems to be a different method for “testing” hypotheses. One of the most disappointing books that I’ve read was “The Godless Jew” by Peter Gay (a big name in the humanities) which opened with the argument that it took an atheist AND a jew to invent psychoanalysis. I thought that an interesting thesis. But in 100 or so pages all Gay showed was that Freud was indeed Jewish (literally quoting dozens of family and friends talking about how Jewish Freud was) and indeed an atheist (literally quoting dozens of family and friends talking about godless Freud was) and founded psychoanalysis. Case closed!

Terry McGlynn 6 months ago AUTHOR

Well, there goes that cultural-gap-building thing.

Lirael 6 months ago

In computer science, the talks themselves are presentations like other sciences do, not just reading a paper, but what’s being presented is an actual peer-reviewed paper, which was reviewed by the conference reviewers and published in the conference proceedings. A conference paper is a legitimate publication – in my subfield the best conferences would be considered more prestigious as publication venues than most regular journals.

Noam Ross (@noamross) 6 months ago

I worked on an interdisciplinary team of ecologists and a historian once, and learned a lot about the intellectual methods of historians [at least those of the school of thought of my collaborator]. Two important things struck me. First, many historians are *not* hypothesis driven. They think that defining a hypothesis at the outset of a project narrows the scope of the discovery process. Their research is more akin to descriptive natural history or geology. Secondly, philosophy is a fairly important part of how historians approach their material, and part of that philosophy is deep skepticism towards the idea of objective truth.

Jeff Walker 6 months ago

OK, scientists tend to investigate the world without regard to the political consequences. Humanities (and social sciences) faculty tend to be much more sensitive to political consequences of scholarship.

BEC 6 months ago

It seems to me there is a strong interest in, and a moderate incentive for, distilling research findings and sharing them with the public in science. There are far more news stories, popular writing, etc., on active science than on recent progress made in philosophy, literature, etc. (maybe history/archaeology is the exception). Which is a shame, because I'd like to better know what they are often talking about in the humanities.

Paul Klawinski 6 months ago

Getting big funds to set up a lab depends on the type of institution you arrive at. Not a given for scientists.

jeffollerton 6 months ago

Terry – like you I work in a relatively small university and have an opportunity to interact with colleagues from the arts, humanities and social sciences. It's a great privilege that I'd like to think gives me a broader perspective on my work than I might otherwise have. In addition I've collaborated with a historian on supervising a joint ecology-history PhD (with mixed success), plus I research and publish papers within the field of history of science. So I'd like to think that I have a reasonable idea of differences between humanities and sciences. Some of what you write above I can recognise in colleagues from both the sciences and humanities, some I don't see as being a major difference (at least in the UK).

One difference you did miss was that wine is sometimes served during arts and humanities research seminars, but that's rare in ecology (in my experience) – see:

http://jeffollerton.wordpress.com/2012/03/18/whisht-lads-haad-yor-gobs-an-aall-tell-ye-aall-an-aaful-story/

What's more interesting, I think, is similarities between ecology/evolutionary biology and the humanities. Stephen Jay Gould pointed out many years ago that some lines of scientific inquiry were more like historical research than "real" science. That idea has stayed with me throughout my career, which I think is why I've such an interest in how a historical perspective informs our present day understanding of the subject.

2. Discipline Comparisons Across the Institution

From Chapter 2, Science and Engineering in Higher Education, in *Tomorrow's Professor: Preparing for Academic Careers in Science and Engineering*, Richard M. Reis, IEEE Press, 1997.

NOTE: While the specific statistics presented in this chapter are dated, the percentages in each category have remained roughly the same. R. Reis, 2014

Disciplines and departments are ranked into hierarchies, with the traditional academic specialties in the arts and sciences along with medicine and, to some extent law, at the top. The 'hard' sciences tend to have more prestige than the social sciences or humanities. Other applied fields, such as education and agriculture, are considerably lower on the scale. These hierarchies are very much part of the realities and perceptions of the academic profession. *Philip Altbach, professor of higher education, Boston College.* [1]

Clark Kerr, president emeritus of the University of California, once joked that universities consisted of hundreds of individual faculty united only by their common desire to find a parking place. Faculty do indeed act more independently than other types of employees as was pointed out in Chapter 1. Nevertheless, how they think, and what they actually do, depends to a large extent on the specific discipline to which they belong. Power and influence, financial compensation, types of students, ease of publication, expenditures for research and development, number of like-minded colleagues, and even agreement on what constitutes quality work in a given field, can vary considerably across departments within a college or university.

These factors are examined in Chapter 2, with particular attention to their impact on science and engineering. Similarities and differences among science, engineering, and other disciplines, such as the humanities and social sciences are examined first. We then look in more detail at departments within science and within engineering. This examination is followed by a discussion of the prospects for cross-disciplinary collaboration among the various fields. We then return to the model of scholarship introduced in Chapter 1 with a look at differences in its various forms across disciplines. The chapter concludes with a vignette on the issues faced by a dean of science at a major master's granting institution.

2.1 Comparisons Across the Institution

Faculty assign different levels of importance to their discipline, their department, and their college or university. In a recent survey, 77% of the faculty respondents said their academic discipline was very important to them, while 53% said the same thing about their department, and only 40% felt this way about their college or university. [2] While faculty identify closely with their discipline, an understanding of other disciplines is also important. As a prospective faculty member, you need to consider the following:

- Those outside your department and discipline will be your institutional colleagues. You will share the same employer and higher level administration, many of the same resources, a number of the same problems, and at the undergraduate level at least, many of the same students.

- In many cases, interesting cross-disciplinary scholarship, opportunities will exist with colleagues in other departments and disciplines.

- You will compete with colleagues outside your department and discipline for resources, influence, and attention.

- At times you will find it is easier to learn from, confide in, and be mentored by, colleagues in other parts of your college and university.

For these, as well as other reasons, you will want to become knowledgeable about the similarities and differences existing across the college or university where you become a professor. In Chapter 4, Your Professional Preparation Strategy, we suggest ways to begin acquiring this understanding by "practicing" at the institution you now attend. In this chapter we set the stage for this examination by looking at the differences with respect to degree of development, power and influence, type of graduate students, number of postdocs, number of faculty, financial compensation, ease of publication, and expenditures for research and development.

Degree of discipline development

Disciplines and fields differ in their degree of development. This differential is particularly evident across the natural and social sciences. "Hard" sciences such as physics and chemistry are regarded as more developed than the "soft" sciences such as the political and the social sciences.[3] In this context "more developed" means those disciplines having more evolved paradigms or shared theoretical structures, and which in general share a greater level of consensus about methods, what constitutes quality research, and course prerequisites. [4]

Sociologist Steven Cole uses six measures to determine the degree of development of a scientific field. They are: (1) development of theory, (2) degree of quantification of ideas, (3) degree of cognitive consensus, (4) level of theory predictability, (5) rate at which work becomes obsolete, and (6) rate of growth of knowledge. [5]

According to this scheme, physics, chemistry and biochemistry are relatively developed fields, geology, botany, and zoology are less developed, whereas economics, sociology, anthropology, and political science are the least developed. [6]

Cole does make a distinction between knowledge at the research frontier, and knowledge at the core. Physics has greater agreement at the core, where there are a relatively small number of theories or exemplars, than does sociology, but both have considerable disagreement at the frontiers of knowledge where knowledge is broader and more diverse. [7] Nevertheless, the overall perceptions among faculty as to the degree of development of their fields is pretty much as stated above. [8] Philosopher Lawrence Laudan puts it this way:

> To anyone working in the humanities or social sciences, where debate and disagreement between rival factions are pandemic, the natural sciences present a tranquil scene indeed. For the most part, natural scientists working in any field or subfield tend to be in agreement about most of the assertions of their discipline. They will typically agree about many of the central phenomena to be explained and about the broad range of quantitative and experimental techniques appropriate for establishing 'factual claims.' Beyond this agreement about what is to be explained, there is usually agreement at the deeper level of explanatory and theoretical entities. Chemists, for instance, talk quite happily about atomic structure and subatomic particles. Geologists, at least for now, treat in a matter-of-fact fashion claims about the existence of massive subterranean plates whose motion is thought to produce most of the observable (i.e. surface) tectonic activity - claims that, three decades ago, would have been treated as hopelessly speculative. Biologists agree about the general structure of DNA and about many of the general mechanisms of evolution, even though few can be directly observed. [9]

Where does engineering fit into this picture? The likely answer is, somewhere in between the "hard" and the "soft" sciences. Engineering disciplines that "derive" from the more developed natural sciences, such as chemical engineering (chemistry), electrical engineering and mechanical engineering (physics), civil engineering (geology and physics) share some of the developmental characteristics of these disciplines. Fields such as industrial engineering, management engineering, and operations research, share more of the characteristics associated with business, economics and sociology. As a colleague in industrial engineering noted, "We often beat-up on each other in low paradigm fields such as organizational behavior. In such fields there is always a subgroup of people who think what you do is garbage, and you just have to learn to live with it."

Politics and Influence

The discipline differences discussed above can have a very real impact on academic politics as sociologists Beyer and Lodahl noted in their study of the governance in British and American universities:

> ...the higher predictability of greater paradigm development tends to increase consensus over means and goals.... This serves to reduce conflicts within departments, and may reduce the potential for conflict and misunderstanding with the administration. Second, faculty members who have more consensus can form stronger and more effective coalitions than those in fields rife with internal conflicts. [10]

Jeffrey Pfeffer, professor of organizational behavior in the Stanford University Graduate School of Business has studied politics and influence in organizations extensively. He found that more paradigmatically developed academic disciplines such as physics and chemistry had department heads who tended to stay in their jobs for longer periods of time. According to Pfeffer:

> When there is consensus in the department about research methods, curriculum content and other such issues, it matters less who heads the department.... This unity has obvious advantages for dealing with other units. There is more stability, and the leader knows that his or her position is relatively secure. [11]

Pfeffer also notes that departments in more developed fields tend to have longer chains of courses, that is, one course serving as a prerequisite for another. He sees such chains as a reflection of the relatively high agreement on the core concepts in the field and how these concepts and skills are allocated to specific courses. [12]

Types of Graduate Students

Another area where there are significant differences among disciplines is in the nationality and gender, race and ethnicity of graduate students. These differences bear directly on the future faculty population in various fields, since it is from this pool that the vast majority of new faculty will come. Table 2.1 compares the number of foreign students with the total number of students in various fields who earned doctorates in the U.S.

Table 2.1 See end or chapter

The high percentages of foreign students, 44 percent, in mathematics and computer science, and 51 percent in engineering, reflect the relatively great paradigm development of these fields. Also, to a large extent they are, "culturally and politically neutral." Add to this neutrality, their relative practicality as seen by many countries throughout the world, and it is not surprising most foreign students are in these fields. A similar situation exists in Canadian universities. [13]

Given the world-wide pool from which to draw, it is also not surprising that foreign students are often among the best in their fields. About 50% of the foreign students in U.S. and Canadian universities seek academic positions in North America after graduation or a period as a postdoc. In so doing they add to the cultural mix and diversity which enriches academia. They also contribute to the current large supply of students seeking postdoc and academic positions. Also, most of these foreign students and postdocs did not attend U.S. or Canadian schools as undergraduates, so they often do not share the same understanding about college life as their North American counterparts.

Table 2.2 looks at doctorate degrees by sex and field in the U.S., and Table 2.3 does the same for race/ethnicity.

Table 2.2 See end of chapter

Table 2.3 See end of chapter

Women received almost half of all social and behavioral sciences, and almost one third of the natural science degrees at the doctoral level. These numbers represents a doubling of the female participation rates over the last 15 years. However, women still received relatively few engineering or mathematics/computer science degrees at the doctoral level, nine and 20 percent, respectively.

The number of doctorates obtained by underrepresented minorities has increased over the last 15 years in all fields of science and engineering, especially in the social and natural sciences. However, this growth is from a small base. These populations still represent only four percent of all natural science and two percent of engineering and computer science doctoral degrees. [14] Similar patterns exist in Canadian universities. [15]

One way to help increase the number of minority graduate students in science and engineering is to have more faculty role models who can mentor such students. This mentoring can be a source of considerable pleasure and satisfaction. As with all mentoring, it can also take a great deal of time. Furthermore, it is not always a good idea for women and minority faculty to be seen as only mentoring women and minority students. In addition to pressures to serve as mentors, there is often the pressure to serve on faculty committees. As one woman colleague noted: "Every committee seems to feel they need to have an X (where X equals your group, i.e., Hispanics, Blacks, women, etc.). The fewer the X's around, the more likely it is that you will be contacted." [16] To help with this problem, administrators and mentors of women and minority faculty must take the lead in providing support, and in some cases, off-setting time, for new faculty. We will look more closely at how to balance these pressures in a later chapter.

Number of postdocs

Another element of interest to tomorrow's professors is the number of postdoctoral appointments in various fields. As can be seen from Table 2.4 there are far more appointments relative to earned doctorate degrees in the natural sciences than in mathematics and computer sciences, the social sciences, and engineering.

Table 2.4 See end of chapter

While it is fairly common for an engineering Ph.D. to go directly into a tenure-track faculty position, such is not the case in the natural sciences. This difference has significant implications for the preparation and job search strategy of future science and engineering professors, and will be examined in detail in Part III, Finding and Getting the Best Possible Academic Position.

Number of faculty

Across all institutions of higher education in the United States, the natural sciences has the largest number of full-time faculty, 101,681 out of a total faculty of 526, 222. By contrast, engineering has only 24,680 full-time faculty. Eighty per cent of the natural sciences faculty are male and the comparable percentage in engineering is 94.2. [17]

There is some evidence that the male/female ratio is beginning to shift. While current data are not available by discipline, a recent study of all full-time faculty shows that women make up almost 41 per cent of faculty in their first seven years of their academic careers. This number compares with 28 per cent at the senior faculty level. Newly hired women outnumber newly hired men at liberal arts colleges, although only a third of the new hires at research and doctorate institutions are women. [18]

Financial Compensation

Another dimension of obvious interest to prospective, as well as current faculty, is financial compensation. Table 2.5 gives the average salaries of full-time science and engineering faculty at four-year public and private U.S. academic institutions.

Table 2.5 See end of chapter

These figures are for full-time faculty members on nine or ten month contracts. Most faculty receive additional compensation during the summer for teaching, research, consulting or employment in government or industry. For our purposes, the absolute values are less important than are the relative rankings. The position of engineering at the top is due in large measure to competitive pressures from employment opportunities in government and industry.

Ease of Publication

Another interesting difference among disciplines is the ease or difficulty of publishing scholarly papers. Journals in the natural sciences have significantly lower rejection rates than those in the social sciences. [19] This difference is often taken as evidence of higher levels of consensus in the natural sciences, but other factors such as the space available in journals, the number of subdisciplines, and what are called field-specific norms can also have an impact. As sociologist Steven Cole points out:

> Physics journals prefer to make 'Type I' errors of accepting unimportant work rather than 'Type II' errors of rejecting potentially important work. This policy often leads to the publication of trivial articles with little or no theoretical significance, deficits which are frequently cited by referees in social science fields in rejecting articles. Other fields, such as sociology in the United States, follow a norm of rejecting an article unless it represents a significant contribution to knowledge. Sociologists prefer to make Type II errors. [20]

Another factor which affects, if not the ease of publication, then at least the number of publications, is collaboration with other investigators. Today, single author publications are rare. Of the ten most cited articles of 1993, none were by a single author. When it comes to multiple authorship nothing beats high energy physics. Carlo Rubbia and Simon van de Meer were awarded the 1984 Noble Prize in physics. The results of the experiments which led to this prize were reported in two articles in the journal Physics Letters published in 1983. The articles were published under the names of 59 and 138 joint authors, respectively! [21]

Different publication rates may also correlate closely to differences in the perceived rate of advancement in the field. In a recent survey 80% of the faculty in the biological sciences, 59% in the physical sciences, 55% in engineering, yet only 38% in the social sciences and 32% in the humanities strongly agreed with the statement, "exciting developments are now taking place in my field." [22]

Expenditures for R&D

Perhaps nowhere are the differences among the disciplines more evident than in the sums of money spent on research and development. Table 2.6 shows the expenditures for academic R&D by field in the U.S.

Table 2.6 See end of chapter

The figures are from both federal and non-federal sources. Given our earlier discussion, it is not surprising that engineering and the physical sciences receive so much more support than the social sciences. Most interesting, however, is how the life sciences dominate the picture, consuming $10.828B or 56% of the total. While more than half of this life sciences figure goes for medical research and development, $3.536B, or 18% of the total science and engineering R&D budget still goes to the biological sciences.

We will discuss the impact of changing academic R&D funding on the preparation of science and engineering professors in greater detail in the next chapter, New Challenges for the Professorate.

2.2 Departments of Science

There are approximately 1,500 colleges and universities in the United States and Canada that offer at least a bachelor's degree in one or more of the natural sciences. The most common fields are biology, chemistry, geology, mathematics and physics. Even schools offering no degrees in these fields will usually offer courses in them as part of a general education requirement. A number of schools also offer degrees in astronomy and geophysics, while a smaller number do so in meteorology, statistics, and other natural sciences.

Since biology, chemistry, mathematics and physics are taught at most four-year schools, at least the potential pool of openings for science professors is quite broad. This breadth is clearly not the case for fields such as geophysics and meteorology, but of course there are also far fewer doctoral graduates in these fields. The ratio of academic openings to available doctoral graduates may even be higher than in high volume fields like biology and chemistry. However, if the number of such schools is small, then so is the range of opportunities.

Earlier in this chapter we looked at the relationship among the sciences in terms of a developmental hierarchy. You can see this hierarchy in the course requirements for different science majors. Table 2.7 shows the relationship between mathematics and science course requirements for various mathematics and science bachelor's degrees at Stanford University. Mathematics majors are not actually required to take any science courses to receive their degree. Physics majors must take physics and mathematics. Chemistry majors must take chemistry, physics and mathematics, and biology majors must take all of the above in addition to biology. Of course, majors in each of these fields often take other science courses. Yet, the actual requirements tell you something important about the hierarchy in science, and also the number of faculty needed in various fields. Mathematics courses of one kind or another are required of every bachelor's degree graduate, no matter what his or her major. This requirement is less so for physics, and even less for chemistry and biology. In almost all schools mathematics majors are a very tiny percentage of the total student body. But the number of mathematics faculty at these schools can be quite large due to the demand for "service" courses for other majors.

Table 2.7 See end of chapter

Supply depends not only on the number of doctorates awarded in the various sciences each year, but also on the percentage of such degree holders who seek academic positions. This percentage can vary quite a bit among the different science disciplines. We will look much more carefully at this variation, as well as the whole demand/supply situation, in Chapter 4, Your Professional Preparation Strategy, and Part III- Finding and Getting the Best Possible Academic Position.

As a future science professor it is important for you to have some idea of what goes on in science departments other than the one to which you will be appointed, since as we will see, cross-disciplinary interactions are becoming more common. A first step is to take a look at what is taught in other fields. The easiest way to obtain this information is to peruse course descriptions in college catalogs or on the Internet. Also take the time to wander around the buildings, classrooms, offices and laboratories of other science departments. It can actually be quite interesting to compare the activities, layouts, overheard conversations, displays, and even laboratory smells, with those of your own department. The differences will be quite revealing and can tell you much about the professional activities of your future colleagues.

2.3 Departments of Engineering

There are approximately 425 colleges and universities in the United States and Canada that offer at least a bachelor's degree in one or more fields of engineering or engineering technology. Represented across these 425 schools are over 261 different engineering degree programs ranging from aerospace engineering, to manufacturing systems engineering, to nuclear engineering. Some of these programs, such as computational and neural systems engineering (California Institute of Technology), and fire protection engineering (University of Maryland, Worcester Polytechnic Institute) are unique to one or two schools. Others such as electrical engineering, civil engineering, and mechanical engineering are found in almost all the schools.

The ten most common graduate engineering departments, in decreasing order, are:

Electrical engineering/electrical and computer engineering

Mechanical engineering

Civil engineering/civil and environmental engineering

Chemical engineering

Computer science/computer systems engineering

Industrial engineering/engineering management

Materials sciences and engineering

Nuclear engineering

Aeronautics/astronautics engineering

Biomedical engineering [23]

There are many more electrical engineering departments than there are industrial engineering departments and as you would expect there are fewer faculty openings in any given year in industrial engineering than in electrical engineering. However, there are also fewer Ph.D. graduates in industrial engineering than in electrical engineering so the ratio of the number of openings to the number of graduates could be the same or even higher in industrial engineering. Of course it could also be lower. The situation is complicated further by the fact that approximately 90 percent of industrial engineering Ph.D.'s seek academic positions after graduation, whereas approximately 30 percent do so in electrical engineering. As with meteorology and physics, the number of schools from which you will have opportunities is much smaller in industrial, than in electrical engineering. Since virtually any school that offers engineering has an electrical engineering department, your potential pool of schools covers all regions of North America and all types of institutions, (Research, Doctoral, Masters, and Baccalaureate).

As with future science professors, future engineering professors should have some idea of what takes place in other engineering departments. The comment made earlier with respect to college catalogs, the Internet, and looking around different science departments applies to engineering as well. Engineering fields are connected to each other. There is much overlap among them, particularly in fields derived from similar scientific disciplines. Table 2.8 shows the relationships among 10 engineering fields, and 28 disciplines which support these fields. Fluid mechanics, for example, is fundamental to aeronautics and astronautics, chemical engineering, civil engineering, mechanical engineering and petroleum engineering. The controls discipline is fundamental to aeronautics, electrical engineering and mechanical engineering. The study of thermodynamics is critical to aeronautics and astronautics, chemical engineering, civil engineering, electrical engineering, materials science, mechanical and petroleum engineering. This distribution of disciplines across departments can form the basis for faculty cross-disciplinary collaborations, a subject we will turn to next.

Table 2.8 Not available

2.4 Interdisciplinary Collaboration

> The best institutions of the future are those that can reorganize themselves to address scientific and educational questions in an interdisciplinary way. The institutions that will have difficulty are those that keep the same rigid structure that prevents pollination among disciplines. *Mark C. Rogers, vice chancellor for health affairs, Duke University* [24]

Programs to promote interdisciplinary interaction are evident in many university based research centers that in one way or another attempt to bring collaborators together around common problems or themes. A number of these centers are supported by a combination of outside funds from industry and government. There are currently over 6,000 university-related and other not-for-profit centers devoted to research in the physical and life sciences and engineering in the United States and Canada. [25] While there is some evidence that a shake-out is occurring in a number of such centers, many will survive and prosper over the coming years.

It is simply no longer true that all problems must be solved in a disciplinary context and this change is one of the reasons for the prevalence of such centers. True, the disciplinary context does provide a way of focusing thinking and resources, and over the years has resulted in significant advances in all areas of science and engineering. Yet, increasingly, many of the problems faced by society are "systems level" problems whose solutions, if they exist at all, require expertise and perspectives from more than one discipline. Furthermore, working with colleagues in other disciplines can produce fresh insights into one's own discipline-based research.

Another reason for the development of such centers is that industry, under the right circumstances, will support them. As the shrinking federal research dollar is spread over a greater number of institutions, higher education has turned to industry for additional support. This support still provides less than 10% of the total R&D funding at colleges and universities, and his not likely to grow significantly in the near future. However, these funds are usually discretionary. They often support seed projects that form the basis for follow-on government support.

Interdisciplinary centers also expose graduate students to the thinking of other scientists and engineers outside their immediate discipline. Working with a range of individuals who have differing perspectives and skills is excellent training for the interdisciplinary opportunities that await these students as new professor.

Nevertheless, the challenges these interdisciplinary collaborations present are formidable. First there is the problem of the participants not having a common language or of assigning different meanings to the same words or terms. In the Stanford Integrated Manufacturing Association, with which I am associated, the word "manufacturing" has a very different meaning to a professor of operations research, than it does to a professor of mechanical design. To the former it may mean organizing the work flow in a system with various equipment constraints or bottlenecks; to the latter it may mean redesigning the equipment to function more effectively.

Then there are the challenges of interacting with industry that result from different cultures, expectations, and reward systems, as well as the conflicts around the trade-offs between short and long-term goals. It is not always easy for faculty to work on research problems leading to publications and Ph.D. dissertations, while at the same time meeting industry's desire for shorter-term payoffs.

There are also potential conflict of interest issues. As Ami Zusman, coordinator for Academic Affairs, Office of the President, University of California system points out:

> Industrial support may hinder the flow of research information because industrial sponsors often require researchers to delay release of potentially marketable results. It may also alter research priorities; a 1985 Harvard study found that 30 percent of a national sample of researchers said that they choose research topics based on how marketable the results might be. [26]

We will look at all these issues in greater detail in Chapter 12, Insights on Research. For now it is worth keeping in mind the admonition of Robert Tschirgi, former professor of neurosciences at the University of California, San Diego, who notes that:

> Interdisciplinary collaborations occur when the practitioners reach a development in their field that clearly requires input from other fields. It is not something that can be imposed by the administration, or by pious conviction that it is simply a 'good thing.' [27]

2.5 Scholarship Across the Disciplines

In Chapter 1 we introduced the broader concept of scholarship developed by the Carnegie Foundation for the Advancement of Teaching. We also discussed how support for its various forms (discovery, integration, application, and dissemination) differs among academic institutions. Are there also support differences among disciplines within an institution? This question is difficult to answer because no specific surveys have been conducted on the subject. We can glean some insight into the matter by looking at how faculty respond to questions about the importance of teaching and research, and from informal observations by colleagues at various institutions.

There is not much evidence to suggest differences in activity among disciplines with respect to the scholarship of teaching. Measures such as the importance of student evaluations of courses taught, and the observations of ones teaching by colleagues and/or administrators in the granting of tenure don't vary much across disciplines. [28] There are, however, some differences in terms of teaching or research interests across disciplines. In a recent survey of full-time faculty at all institutions of higher learning, 53 per cent of education faculty, 51 per cent of business faculty, 44 per cent of physical sciences faculty, 33 per cent of biological sciences faculty, and 27 per cent of engineering faculty said their interests lie primarily in teaching as compared to research [29]

What about the scholarship of integration which seeks connections across the disciplines by placing specialties in a larger context? There is some indication faculty support such efforts. When asked to respond to the statement, "Multidisciplinary work is soft and should not be considered scholarship," 8 percent strongly agreed or agreed with reservations, 17 percent were neutral, while a striking 75 percent disagreed with reservations or strongly disagreed. [30]

The survey did show some significant differences among fields with 60 percent of the faculty in the social sciences, 53 percent in the biological sciences, 42 percent in the physical sciences and 39 percent in engineering strongly disagreeing with the statement. These differences are probably due to the types of problems these disciplines seek to solve. Greg Petsco, director of the Rosentiel Medical Sciences Center at Brandies University points out that biologists work primarily on systems level problems that lend themselves to contributions from a number of subdisciplines. The same can be said for the social sciences. Yet, there is also some movement in this direction in engineering and even in the physical sciences, as investigators in these fields respond to industrial and societal problems not restricted to disciplinary boundaries. We will examine this development more closely in the chapters to come.

Of course there is a difference between voicing support for the scholarship of integration and valuing it in the retention, promotion and tenure process. Steve Benowitz, writing in The Scientist notes that "most universities remain bound by traditional departmental structures for administrative and curricular purposes, including peer review, tenure and promotion." [31] He goes on to point out that, "many academic administrators advice, until young faculty have established a track record within a discipline, is that publications should be in that discipline and not outside or shared by too many colleagues. [32]

Finally, what about the scholarship of application? In general, fields such as engineering, business, education and agriculture are more open to this type of work than are the natural sciences. Within academia, engineering is usually viewed as an applied field, in part because of its close association with industry. How does this view impact tenure and promotion decisions? While the research emphasis in academic engineering remains focused on the discover of new knowledge, there has been some movement toward acceptance of a more applied scholarship. In recent years the school of engineering at Stanford University has awarded tenure or promotion to a number faculty for what is essentially applied research based in large measure on responses to industry problems in such areas as microprocessor design, compiler development, hydrology, rapid prototyping, and supply chain management. For the most part, the evaluation of these contributions remains in the hands of faculty, but even here there has been an increase in the acceptance of letters of support from researchers in government and industry.

Science has its applied side as well. It would be a mistake to put all of engineering on the technology side of the ledger and all of science on the theoretical side. Robert McGinn, professor of industrial engineering and engineering management at Stanford University and director of its Science, Technology and Society program, points out that engineering existed long before science, and that the relationship between the two has evolved into, "an intimate association of mutually beneficial interdependence." [33] Even a single individual's activities often defy simple classification as "science" or "technology": For example, a molecular biologist creating an organism with desired commercial properties may at times function as an engineer, at times as a scientist, and at times as both simultaneously. This dual role might also be true for an electrical engineer designing a microprocessor or a low power battery. In this sense, a technical activity can have a dual, scientific-technological character. Modern science and technology are not only interdependent, they overlap. [34]

2.6 Vignette #2: Science at a Metropolitan University

Master's institutions, many of which are also called Metropolitan Universities, face unique challenges with respect to science and engineering education The following vignette looks at some of these challenges from the perspective of a dean of science at San Jose State University in San Jose, California.

Gerald Selter San Jose State University

What is it like to be the dean of science at a large, public, metropolitan university undergoing major changes in mission, funding, student composition, and industrial relations? "Well it's not easy, but then again, it's certainly not boring," says Gerry Selter, dean of the College of Science at San Jose State University, a Masters I institution of over 26,000 students located in San Jose, California.

Selter has no trouble listing a dozen or so challenges which he and many other deans are currently facing. These include: responding to state funding cutbacks and the subsequent need to find additional sources of support; figuring out how to recruit and support new faculty in an area known for its high cost of living; determining the appropriate research/teaching/service mix for faculty retention, tenure and promotion; assessing the impact of advanced technology on faculty productivity; dealing with faculty accountability pressures from state legislatures, satisfying demands for a more interdisciplinary curriculum; promoting industrial interactions at a campus in the heart of Silicon Valley; and deciding on the proper relationship between the College of Science and an extension education program that enrolls an additional 30,000 students.

Unrelated as some of these issues might first appear, they are often connected in interesting ways. For example, cutbacks in state funding have led to prohibitions on faculty raises beyond the cost of living. This in turn has resulted in some pressure to promote faculty as the only means of providing real salary increases. "We have to be very careful here," says Selter. "It dilutes the promise of scholarship if we promote for the wrong reasons." With Selter's support, these pressures have led to a reexamination of the requirements for promotion and tenure, which in turn has led to a more comprehensive understanding of what it takes be successful as a science professor at this particular university.

"In the College of Science we have specifically moved to recognize different forms of scholarship as the criteria for RTP (retention, tenure and promotion)," notes Selter. He continues:

> Five years ago we were striving to be like the University of California. That has changed, and it was a big breakthrough for us to recognize and acknowledge that we are a metropolitan university and that teaching is really important. We believe that there are many ways to contribute, but high quality teaching is absolutely essential. Other forms of scholarship can, and do impact teaching, so we want to provide for a diversity of contributions. One model does not have to fit all. You can make your contribution through research, applications, and service to the University, but these must be in addition to a significant teaching contribution.

Another compelling issue is faculty productivity. If the state of California mandates productivity increases, but provides little financial support for doing so, what do you do? Well, for one thing you figure out how to get the college and the rest of the university more involved in raising funds from industry and through other sources such as extension education. Selter's strategy is to get faculty involved in fund raising by supporting them through time buy-outs to write large college-wide grants. His first attempt was successful. He gave a faculty member full release time for a semester to write a proposal to the National Science Foundation titled, Collaborative for Excellence in Teacher Preparation. According to Selter:

> This is a five million dollar, five year project encompassing San Francisco State University, four community colleges and numerous high schools. The goal is to significantly increase the number and quality of underrepresented students that become science and mathematics teachers, and to infuse multi-media technology into K-12 classroom instruction. This is the exactly the kind of project (to effect systemic reform) that characterizes us as a metropolitan university.

These are just a few of the many challenges that Selter and deans like him face every day. And yet Selter, who twice received his department's Professor of the Year award, seems up to the task. As one biology professor puts it, "He is very open with the faculty and consequently we know where we stand on all sorts of issues of importance to us." A chemistry professor echoes this view by noting, "He works extremely hard and always puts the needs of the college above his own. He has a great deal of respect from the faculty for his efforts on our behalf." Another professor in the college commented that Selter is still new on the job and that with an even "newer" president on board the jury is still out. "Yet," she says, "I have confidence that he has the ability to represent us well in what are going to be some difficult times ahead."

Selter has experienced meteoric rise from professor in the chemistry department to acting department chairman, to associate dean, to interim dean, to dean, all in just two years. "I didn't seek any of these positions," he says, "but at this point I have to admit that I do find it quite challenging."

2.7 Summary

We began this chapter by examining the similarities and differences among disciplines across the academic institution. We saw that there is a discipline hierarchy based on perceived development of the field. This hierarchy helps to determine such factors as status and prestige, politics and influence, financial compensation, types of students, ease of publication, and expenditures for research and development. We then took an overall look at science departments and engineering departments, the subjects taught in each discipline, and the possible relationships among disciplines within science and engineering. These relationships can form a basis for cross-disciplinary collaboration. The trend toward such collaboration was discussed next, with a look at both the prospects and problems associated with such interactions. We then return to the model of scholarship introduced in Chapter 1 with a look at differences in such scholarship across disciplines. The chapter concluded with a vignette on the issues faced by Gerry Selter, dean of the College of Science at San Jose State University, a large master's granting institution in San Jose, California.

This is an unsettling time for academic science and engineering. Significant forces are at work, both internal and external, that will almost certainly transform the way science and engineering is carried out at colleges and universities. In the next chapter we conclude our setting of the academic stage by examining some of these forces and their implications for tomorrow's professors of science and engineering.

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Table 2.1

Earned doctoral degrees by citizenship, 1993

	Foreign students	Total	% Foreign students
Total, all degrees	9,923	38,827	26
S&E	8,087	24,593	33
Natural Sciences	3,191	10,354	31
Math and CS	866	1,981	44
Social and behavioral	1,247	6,757	18
Engineering	2,783	5,501	51

Note: Natural sciences include all physical, environmental, biological andagricultural sciences. Social and behavioral sciences include psychology, sociology and other social sciences.

Source: National Science Board, Science and Engineering Indicators - 1996, Appendix A, pp. 58-59.

Table 2.2

Earned doctorate degrees by sex and field, 1993

	female students	Total students	% female students
Total, all degrees	15,108	39,754	38
S&E	7,652	25,438	30
Natural Sciences	3,221	10,530	31
Math & CS	401	2,024	20
Social and Beh. Scie	3,509	7,188	49
Engineering	521	5,696	9

Source: National Science Board, Science and Engineering Indicators - 1996, Appendix A, pp. 56-57.

Table 2.3

Earned doctorate degrees by race/ethnicity, and field, 1993

	White	Asian	Black	Hispanic	N.A.
Total, all degrees	23,993	2,009	1,275	972	119
S&E	13,535	1,602	452	536	41
Natural Scie.	5,943	684	135	228	17
Math & CS	886	156	14	23	2
Social & Beh. Scie.	4,684	237	253	220	20
Engineering	2,022	525	50	65	2

Note: N.A. = Native American

Source: National Science Board, Science and Engineering Indicators - 1996, Appendix A, pp. 58-59.

Table 2.4

Postdoctoral appointments and earned doctorate degrees in various fields, 1991

Field	Number Post Docs	Number Earned Doctorates
Natural sciences	19,153	10,141
Math and computer sciences	324	1,837
Social sciences	967	6,653
Engineering	1,953	5,042
Total	22,397	23,67

Source: National Science Board, Science and Engineering Indicators - 1993, p 292.

Table 2.5

Average faculty salaries in selected fields at public and private 4-year institutions, 1995-96

	New assistant prof.	All ranks
Engineering		
Public	47,081	60,640
Private	48,458	65,244
Physics		
Public	37,452	53,996
Private	36,007	55,273
Life sciences		
Public	36,120	49,451
Private	33,323	46,894
Mathematics		
Public	36,330	47,860
Private	34,782	47531
Social sciences		
Public	33,193	46,047
Private	32,677	47,783

The figures are based on reports covering 100,862 faculty members at 329 public four-year institutions and 53,459 faculty members at 531 private four-year colleges and universities. The figures cover full-time faculty members on 9 or 10 month contracts.

From: The Chronicle of Higher Education, Vol. XLII, no. 28, p. A18, March 22, 1996. Source: College and University Personnel Association, reprinted with permission.

Table 2.6

Expenditures for Academic R&D, by field, 1993

Field	millions of 1995 dollars
Natural Sciences	
Physical sciences	2,124
Astronomy	252
Chemistry	736
Physics	928
Other	209
Mathematical sciences	272
Computer sciences	597
Environmental sciences	1,318
Life sciences	10,828
Agricultural sciences	1,558
Biological sciences	3,536
Medical sciences	5,285
Other	446
Total	15,139

Engineering	
Aeronautics & Astronautics	206
Chemical	269
Civil	367
Electrical/Electronics	696
Materials	301
Mechanical	480
Other	830
Total	3,151
Social sciences	895
Grand total	19,185

Source: National Science Board, Science and Engineering Indicators - 1996, Appendix A, p. 173.

Table 2.7

Math and science requirements for bachelor's degrees in the following fields at Stanford University

Bachelor's degree fields

	mathematics	physics	chemistry	biology
Require courses in:				
mathematics	X	X	X	X
physics		X	X	X
chemistry			X	X
biology				X

Source: Stanford University, Courses and Degrees, 1993-94

3. Faculty Salaries Vary by Institution Type, Discipline

From: The Chronicle of Higher Education, April 11, 2011

How Much More (or Less) Full Professors Earned, by Discipline, Than the Average Full Professor of English Language and Liter to 2009-10

Discipline	1980-81	1985-86	1991-92	1996-97	2001-2	2005-6
Fine arts: visual and performing	-8.8%	-9.6%	-7.9%	-9.7%	-11.1%	-12.2%
Education	-4.0%	-8.0%	-1.2%	-0.8%	-2.5%	-3.8%
Foreign language and literature	0.9%	-1.8%	-1.5%	0.5%	-3.9%	-4.5%
Communications	-3.3%	-6.7%	2.6%	1.9%	-2.9%	-3.3%
Philosophy	2.3%	-4.8%	2.0%	1.1%	-2.9%	0.0%
Library science	-1.5%	-0.6%	9.9%	6.6%	3.5%	-2.1%
Mathematics	7.6%	4.4%	11.0%	11.5%	6.8%	6.8%
Psychology	5.0%	1.6%	9.5%	9.7%	8.3%	9.0%
Physical sciences	7.7%	8.0%	14.9%	14.5%	12.8%	12.1%
All-discipline average (including medical)	4.8%	5.1%	13.3%	13.9%	12.2%	12.0%
Social sciences	4.8%	3.2%	9.0%	8.7%	9.2%	14.1%
Health professions and related sciences	20.3%	19.8%	34.3%	36.4%	31.3%	18.1%
Engineering	8.1%	14.3%	29.0%	27.8%	24.0%	24.3%
Computer and information sciences	13.4%	17.6%	32.2%	28.1%	28.7%	27.5%
Economics	13.9%	11.3%	28.4%	25.7%	26.4%	32.4%
Business administration and management	11.4%	15.2%	33.8%	38.7%	40.8%	46.5%
Law and legal studies	33.2%	41.0%	54.2%	58.4%	53.5%	54.0%

Source: "Faculty Salary Survey by Discipline," Office of Institutional Research and Information Managemen
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