# THE MYTH OF THE SUPERHUMAN PROFESSOR*

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*Your car has been making ominous clunking sounds lately and you've brought it in for a checkup. The mechanic says there are some minor transmission problems, which he'll fix while you wait. You position yourself in the grimy lounge with the stack of four-year-old issues of* Road and Track *and wait. And wait. After an hour you poke your head into the garage and ask what's going on, and the mechanic tells you he's right on top of the problem and is almost finished. After two more hours you storm out and find a maze of parts scattered all around and the mechanic thumbing through a repair manual and looking perplexed. You ask him what he's doing, and he says he thinks he needs to replace the torque converter but he's not sure where it is and the diagram in the book is no help. Seriously worried now, you ask him if he's really a trained mechanic, and he says that actually he's not—he's a body repairman—but the shop policy is that everybody is supposed to work on everything and if you'll just have patience he'll figure it out sooner or later...and while he's got your hood up he might just have a look at a couple of valves that seem like they're about to go. You start to whimper and plead with him to put your car together and let you go.*

Pretty frightening, eh? Wait—it gets worse.

*You started experiencing severe chest pain a couple of hours ago and managed to get yourself to the emergency room. "Heart," they say, and in a little while you find yourself being trundled into the operating room...except that instead of putting you on a conventional operating table they roll you onto a large mahogany desk. The orderlies bustle around in their surgical gowns and masks, getting everything ready for the operation, and then the surgeon strides in, wearing a gray pinstripe suit and a power tie. He opens his briefcase, takes out a letter opener, and prepares to make the first incision. "Wait a minute," you say anxiously. "Are you really a surgeon?" "Well, technically no," he replies. "I'm the accountant from psychiatry. It's just hospital policy that all staff members have to pull their weight in the operating room. Now hold still—I've never done one of these before and it may sting a little." As you grab a ball point pen to fend him off you wake up.*

These are of course absurd and unrealistic nightmares (at least the second one is). Hospitals would never require accountants to perform open-heart surgery—nor dermatologists, for that matter. If I drive across a bridge I can safely assume it was not designed by a civil engineer whose specialty was sewage treatment. We expect professionals to perform jobs for which they were trained: the idea of requiring them to perform every task in their field, regardless of their training and experience, is ludicrous and not subscribed to by any profession. Except college teaching.

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Consider the universal vision of the professor of the 90's. She does pioneering research in a critical area and brings in big bucks to support the research, including several six-figure NSF grants and 60% release time. She publishes 5-10 papers each year in the most prestigious journals in her field and is a shoo-in for the National Academy. She is a dedicated and stimulating instructor and wins teaching awards at her university and nationally. She does more than her fair share of the tedious but vital service chores that no one wants to do and does them excellently.

She is mostly imaginary. The classical academic fantasy is that every professor should resemble this combination of Leonardo, Socrates, and Mother Teresa, but the reality is that very few can pull it off—certainly not enough to populate every engineering department. Nevertheless, requiring every new engineering professor to be first and foremost a researcher has become standard academic policy in the past several decades, with dramatic effects on every aspect of academia from the makeup of the faculty to the structure and content of courses and curricula. You might presume that there were compelling theoretical or empirical reasons for so many universities to adopt a policy with such profound ramifications, and that there must be equally compelling arguments for maintaining the policy.

You would be wrong. The usual justification for trying to make all professors researchers is the argument that teaching and research are inextricably linked, to an extent that the first cannot be done well in the absence of the second. This argument is a strange one. Its proponents—usually academicians, trained in scientific method and the rules of logical inference—offer it with unbounded conviction, passion, and a total absence of evidence. They argue that only researchers are aware of recent developments in their field, so that courses taught by nonresearchers must be irrelevant or obsolete. They add that nonresearchers whom students rate as good teachers must be merely "entertainers," providing style without substance. When challenged to produce some evidence for the linkage between research and teaching, they name professors they know who have both admirable research records and teaching awards, which is like claiming that you can only be a world-class organist if you practice medicine in Africa and pointing to Albert Schweitzer to prove it.

In this essay I want to take a closer look at the purported linkage between teaching and academic research, to see how it stands up to the tests of common sense and educational research. I will argue that it stands up to neither. Before I get started, though, perhaps I should clarify a point. I am not saying that research and teaching are *necessarily* in conflict; I cheerfully grant that in some cases the two activities are indeed complementary. An advanced graduate course on a currently hot research topic, for example, is likely to be taught best by an instructor actively doing research on that topic. There is no logical basis, however, for requiring active research involvement to teach an introductory course on engineering mechanics or mass and energy balances. My discussion of teaching in the balance of this paper should therefore be understood to relate mainly to courses that stress engineering fundamentals, practice, and problem-solving methodologies—which is to say, most undergraduate engineering courses.

## THE TEACHING/RESEARCH LINKAGE IS MOSTLY FICTION

### Teaching and research have different goals and require different skills

Rugarcia(1) points out several distinctions:

*The principal goal of research is to discover new knowledge, while that of teaching is to impart well-established knowledge and provide training in problem-solving.* Repetition of previous work using standard procedures may be necessary in research but what really matters is the result. On the other hand, prior knowledge and solution algorithms are (or should be) the focal points of undergraduate teaching. Glossing over them in one's zeal to get to the results misses the point.

*Ability to communicate is a desirable but not a necessary condition to be a good researcher and a mandatory condition to be a good teacher.* Some of the most eminent scientists in history—Gibbs and Einstein come to mind—are well known for the obscurity of their lecturing. Their lack of clarity in presentation in no way diminished their stature as researchers. However, an outstanding teacher who cannot communicate is inconceivable, a contradiction in terms.

*The personality traits associated with outstanding researchers are not the same as those associated with outstanding teachers.* Most excellent researchers are intensely involved with their work. They feel the greatest satisfaction when performing their experiments, interpreting the data, struggling through their derivations. Many of them feel compelled to minimize the time they spend on activities that distract them from their research, such as teaching: they view having to go over old material as a waste of time and may be impatient with students who don't get it quickly.

Outstanding teachers are more outwardly directed. They enjoy contacts with students and may get as much satisfaction out of delivering a good lecture or seeing a student finally grasp a concept as out of getting an experiment or derivation to work. They may or may not be dynamic or entertaining in lectures, but they share a clarity of expression and convey a sense of enthusiasm that may be noticeably lacking in their research-oriented colleagues.

**Good research and good teaching each take a lot of time. Doing both takes more time than most professors have.**

It is no secret that research is a major time sink. It takes time—preferably in large uninterrupted blocks—to define problems, generate support, collect, read, and understand all relevant published work on the topic, plan a method of attack, make false starts and wander down blind alleys, wait out the inevitable unproductive periods, clean out logical flaws or weak points, replicate experiments, explore possible consequences and applications of results, write papers, and give seminars. Doing all that is under any circumstances a full-time job; doing it well enough to gain national recognition—now the principal criterion for promotion and tenure almost everywhere—requires an intensity of effort that tolerates few distractions.

That excellent teaching takes just as much time and intensity of effort is not as well appreciated. Consider the preparation of lectures. Most course notes and texts are written from the point of view of someone who already understands the concepts; the trick is to find a way to make the ideas clear to someone approaching them for the first time. Just stating a concept is likely to be useless. To make it comprehensible to most students, the instructor must first provide examples to establish relevance and motivate interest, then imbed the concept in a web of alternative expressions and visual representations, and finally provide more examples and participatory exercises to solidify understanding. Finding a way to do all that for just one relatively straightforward concept can take hours or even days—and a course contains lots of concepts.

Making up good problems is another time-intensive chore. Students almost never learn anything nontrivial in formal lectures; they only start to get it when they try to solve problems. For true learning to take place, however, the problems must vary in scope and difficulty—some drilling basic concepts, others integrating new and prior material, and still others challenging the problem-solving skills and creativity of the best students. Relatively few textbooks offer problems that provide the necessary variety and scope; the burden on the instructor is to collect problems from several sources and to make up and work out solutions to others. Doing so takes *immense* amounts of time.

**Educational research does not confirm the purported linkage between teaching and academic research**

Reviewing studies done before 1965, Brown and Mayhew(2) concluded that "Whenever studies of teaching effectiveness are made as judged by students, no relationship is found between judged teaching effectiveness and research productivity." Finkelstein(3) and Feldman(4) reviewed more recent research studies and found that the correlation between good teaching and strong research was either nonexistent or, in a minority of cases, slightly positive. Interestingly, quality of publications (as assessed by frequency of citation) was considerably more likely than any other publication measure to correlate *negatively* with teaching effectiveness, and individual authorship of books and first authorship of articles also showed strong negative correlations. The implication is that professors doing individual research good enough to gain widespread peer recognition are least likely to be judged effective as teachers.

Perhaps the most telling indication of the nature of the research-teaching interaction is provided by Alexander Astin (5) in a landmark study conducted in the late 1980's. Astin accumulated data on faculty members and almost 25,000 students at 309 institutions of higher education. For each institution, he assessed the faculty's *research orientation* (as measured by research publications, research funding, time spent away from campus on research-related activities, and self-rated importance of engaging in research and being recognized for research achievement) and *student orientation* (level of interest in students' academic and personal problems, sensitivity to minority issues, accessibility outside office hours, opportunities for student-faculty interaction), correlating each orientation with a variety of measures of student performance and attitudes.

The results are striking. Research orientation of the faculty correlates negatively with completion of the bachelor's degree, various other measures of academic performance, and student satisfaction with quality of instruction and the overall college experience (p. 338). Student orientation of the faculty correlates positively with bachelor's degree completion, overall academic attainment, student satisfaction with quality of instruction, and self-reported growth in preparation for graduate school, writing skills, leadership abilities, general knowledge, and public speaking skills (pp. 341-342). Research orientation and student orientation are negatively correlated (p. 338).

The quantitative results of the study led Astin to reject the assertion that research and teaching are mutually supportive. On the contrary, he concludes that "In certain respects, the two poles of this factor [research vs. student orientation] reinforce the commonly held notion that, in American higher education, there is a fundamental conflict between research and teaching" (p. 67) and that "Attending a college whose faculty is heavily Research-Oriented increases student dissatisfaction and impacts negatively on most measures of cognitive and affective development. Attending a college that is strongly oriented toward student development shows the opposite pattern of effects (p. 363)."

Certainly there are professors who are both good researchers and good teachers, but their presence on faculties (and hence the occasional slight positive correlation between research and teaching performance) proves nothing, since they are likely to get promotion and tenure where professors who are excellent teachers and fair or poor researchers are not. The real question is whether an institutional emphasis on research activity improves or detracts from teaching quality. The evidence clearly points to the latter.

## FORCING ALL PROFESSORS TO BE RESEARCHERS HURTS TEACHING QUALITY

Does *any* professor always do an optimal job of teaching—continually updating and improving lecture notes, providing concrete demonstrations of abstract concepts, making up fresh assignments and tests that cover the full range of thinking skills and problem-solving abilities? Probably not—no more than any professor always replicates all data points and reads all references he or she cites in research papers. There are simply not enough hours in the day to do everything as thoroughly as it should be done, and so shortcuts and compromises are necessary and inevitable in academic life. Given this necessity, the question becomes which activity to compromise.

Here the academic system stacks the deck. Professors at research universities who choose to emphasize teaching are likely to experience second-class citizenship and denial of tenure and promotion. To move up the academic ladder they must dedicate themselves primarily to research, doing what it takes to meet minimal local teaching standards and no more. And since the system uses the same performance criteria for every new faculty member, the students experience a continuing succession of instructors who have either voluntarily or reluctantly chosen to do a poorer job of teaching than they are capable of doing.

The low position of teaching on the academic scale of values manifests in several ways:

*Few of us routinely take the time and put in the effort required to teach as well as we could.* It doesn't take much effort to copy derivations from notes onto a chalkboard, or to assign problems from the text as homework and photocopy and post the solutions from the instructor's manual, or to throw a test together a day or an hour before giving it without working out the solutions. It's even easier to recycle the same notes, homework problems, and tests every time the course is subsequently given. The material may be outdated, the lectures mechanical, the tests familiar to the students, but at least the cost in professorial time and energy is minimal.

*Our instructional environment is less and less conducive to learning.* As institutions place increased emphasis on research, more teaching is done in large lecture classes or by graduate students and adjunct faculty members, more grading is done and corrective feedback given by teaching assistants, and more advising is done perfunctorily or by non-faculty members (5, p. 419).

*We have largely abandoned our responsibility to be mentors and role models to our students.* Just as it is hard work to prepare good lecture notes, homework assignments, and tests, it takes considerable effort for professors to memorize the names of all the students in their classes and take time to listen to students' problems when they have no time to attend to their own. Studies have shown that students with even one teacher who does such things are much more likely to succeed than students who never have one. Where are those teachers supposed to come from?

*We are not functioning as professional teachers in the way that we function as professional researchers.* Most engineering professors do not read education journals, attend education conferences, or belong to the ASEE. They do not develop innovative teaching methods themselves or try proven methods developed by others (e.g. cooperative learning, open-ended questioning, in-class brainstorming and trouble-shooting exercises). They especially do not write undergraduate textbooks. Why should they? The system offers few incentives to do these things and imposes severe penalties if taking the time to do them cuts down on research output.

*We do not practice what we teach.* We are supposedly training people to design and construct manufacturing processes and process equipment, devise and implement control algorithms, supervise startups, identify and overcome product quality problems, and assess environmental impacts of proposed processes. Unfortunately, the number of *us* who have ever done any of these things is small and shrinking. Since we are most comfortable teaching what we know best, we teach less engineering practice and more of the engineering science we know from our own graduate study and research. In the words of Reuel Shinnar, "We have become the only profession taught by nonpractitioners."

## ...AND ALSO HURTS RESEARCH QUALITY

Research—like most human undertakings—is performed best when it is motivated by a strong sense of mission, if it is "the passionate pursuit of a problem or vision that obsesses the researcher and will not let him/her rest."(6) Professors who work on a research problem not out of a passion to know and understand but simply to move up the academic ladder—or worse, to raise funds—are unlikely to produce worthwhile research. Rather, their goal will be to produce results in quantity and haste, publishing lots of papers that can serve as the bases of more proposals to raise additional funds to support more research. They will accept superficial explanations of results without critical scrutiny, ignoring contradictions or casually dismissing them as "outliers" or "anomalies."

A glance through any research-oriented engineering journal—at the complex mathematical models that will never apply to real systems, and the experimental data that will never be needed or could easily be obtained if the need ever arose—suggests that this situation has already come to dominate academic research. According to a recent study, 72% of the papers appearing in leading engineering journals were never cited(7). Imagine the educational uses that could have been made of the money and time spent on the research described in those papers.

## SUMMARY OF THE PROBLEM AND A POSSIBLE SOLUTION

Most university administrators claim that their faculty must be outstanding at both research and teaching to qualify for tenure and promotion. However, very few professors have the ability and the time to do everything required to excel at both activities; most must therefore give priority to one activity and content themselves with doing an adequate job of the other. Under the existing academic incentive and reward system, the only viable priority for most professors is research. The result is that much undergraduate teaching is done by professors who either have little interest in it or cannot afford to take the time to do it well, and much research is done by professors who would rather dedicate themselves to education if they had the choice. The quality of both teaching and research consequently suffers.

**What won't work**

What is the solution? It is not for chancellors and deans to proclaim yet again the supreme importance of undergraduate education, perhaps creating one or two new teaching awards as demonstrations of their sincerity. Such proclamations are hollow as long as professors who do outstanding teaching and merely adequate research are fated to be denied tenure, or if they are tenured, to be relegated to second-class citizenship. In the words of William Arrowsmith, *"At present the universities are as uncongenial to teaching as the Mojave Desert is to a clutch of Druid priests. If you want to restore a Druid priesthood you cannot do it by offering prizes for Druid-of-the-year. If you want Druids, you must grow forests."*

Neither should we drop most academic research and go back to undergraduate teaching as the primary business of the university. While this solution holds some attraction—particularly considering the amount of relatively pointless research now being done—it is regressive. Much of the basic research that provides long-range benefits to American industry is done at universities, and the future of American science and technology depends on its continuation. From a less exalted but equally critical perspective, most universities, engineering schools, departments, and professors now rely heavily on research funding for most of their necessary operations. Research funds support graduate research assistants, teaching assistants for undergraduate courses, work-study students, laboratory maintenance, professional travel, postage, telephone calls, photocopying, and so on. If the research support dried up, the quality of the entire educational program would suffer until an alternative funding structure could be put in place—a doubtful prospect in any case, an extremely long-range one at best.

No, we must continue to strive for both outstanding research and undergraduate teaching programs, and the ideal faculty member will always be the rare individual who can manage to do it all well—carry out world-class research, win outstanding teacher awards, and do his or her full measure of service. When we find such individuals, we should accord them full recognition and reward. But what we need is an incentive and reward system not based on the myth that there are enough of these people to go around.

**What might work**

The key to a solution is provided by Ernest Boyer in his splendid monograph, *Scholarship Reconsidered* (8). Boyer observes that the professoriate has four vital functions, or *scholarships: discovery* (frontier research intended to generate new knowledge), *integration* (interpreting and applying new knowledge to existing problems, multidisciplinary research), *application* (applying specialized knowledge to socially consequential problems), and *teaching*. He argues that while each of these functions is critical to the continued well-being of both academia and society, the present academic incentive and reward system values only the scholarship of discovery. He then proposes establishing an alternative system that makes it possible for professors to concentrate on any of the four functions at different points in their careers.

One possibility for such a system is to establish two broad pathways for faculty advancement: a research pathway and an education pathway. The system might work as follows.

*The research pathway would involve activity in fundamental research (discovery) and/or applied research and multidisciplinary studies (integration) and/or socially important research, e.g. in areas such as safety and environmental engineering (application).*
*The criteria for advancement on this pathway would be those in effect now at all research institutions.* Professors concentrating on research would be expected to exhibit superior research performance, as measured by external grants received, publications of articles in refereed journals, research monographs, review chapters and books, citations by other authors (an excellent and currently underused criterion), and peer evaluation. They would also be expected to teach both graduate and undergraduate courses and to perform at a satisfactory level in their teaching, although they might in some instances buy themselves out of undergraduate teaching with release time.

*The education pathway would be characterized by different expectations and different criteria for advancement.* Professors on this pathway would be expected to

1. Develop and utilize innovative teaching methods, problems, projects, experiments, and case studies, and report these developments at meetings and conferences (e.g. annual and regional ASEE meetings) and in publications in the engineering education literature;

2. Write undergraduate textbooks;

3. Implement measures to increase the relevance of the undergraduate curriculum to engineering practice;

4. Carry relatively heavy undergraduate teaching loads, including teaching undergraduate laboratories and design courses unless research faculty specifically request those courses;

5. Demonstrate superior teaching performance, as measured by end-of-class student evaluations, retrospective senior and alumni evaluations, and peer evaluations.

*Of all full-time faculty slots in a department, 75–85% should normally be allocated to research-pathway positions and 15–25% to education-pathway positions.* The cost of this policy to the department would therefore be minimal. Moreover, as discussed below, the long-range effect of the policy could be an increase in both research productivity and departmental revenues.

*Education-pathway positions should normally be filled by known outstanding teachers or experienced engineers, and ideally by individuals who fall into both categories.* New Ph.D.'s with no industrial or teaching experience should not be permitted to enter the education pathway directly: allowing them to do so would defeat the purpose of the proposed system and could also seriously jeopardize their career development if things did not work out. They would be eligible to switch to the education pathway only after demonstrating their potential to meet the performance criteria listed above. If they have no industrial experience they might be requested to acquire some through industry-based sabbatical leaves or summer internships, either before or after the switch becomes official.

*No distinction should exist between the two pathways in status, perquisites, or expectations of departmental and university service.* Education-pathway professors should have the same opportunities for merit raises, tenure, and promotion to full professor as their research-pathway colleagues enjoy. The sole criterion for faculty recognition and reward should be quality of performance: no professor should ever experience second-class departmental citizenship because of his or her career focus on either education or research.

Consider the potential benefits of this policy:

*The quality of undergraduate education would inevitably improve.* Bordogna *et al.* (9) recently proposed a new paradigm for engineering education, with features that include a heightened instructional emphasis on design and manufacturing, experiential learning, integration of knowledge from individual courses and disciplines, dealing with ambiguity, problem formulation, teamwork, and the societal context of engineering problems. The faculty structure proposed in this paper would both accommodate and facilitate the changes Ernst recommends. New and better instructional materials, demonstrations, problems, case studies, and teaching methods would be developed and tested by the education-pathway professors. The results of these efforts could then be communicated to the rest of the faculty, who might not have the time to develop the materials and methods themselves but might be willing to use some of them in their own courses.

*The education-pathway professors could serve as mentors to other faculty members who wish to improve their teaching.* New assistant professors and instructors could co-teach their first one or two courses with education-pathway professors, seeing first-hand what excellent teaching looks like and being exposed to techniques they can later adapt to their own teaching styles.

*Vital departmental functions for which research credentials are irrelevant, including course and curriculum planning, coordinating undergraduate advising, and undergraduate program administration, would be done expertly by people who want to do them.*

*Research-oriented faculty members, with their lighter teaching roles and freedom from unwanted undergraduate administrative and advising responsibilities, should be able to increase their research productivity.* Between the revenue generated by this increased productivity, grants brought in by the education faculty for curriculum development and undergraduate laboratory expansion, and funds for endowed education chairs provided by industry (which often has more of a vested interest in high-quality undergraduate education than in graduate research), the school and departments could in the long run experience a financial gain.

*Faculty members on the education pathway could devote themselves to undergraduate education, free of the need to dilute their efforts with research for which they have little enthusiasm.* The results would include an increase in the average quality of engineering research and a decreased competition for graduate students and laboratory space in every academic department.

*The courses most closely related to engineering practice—the undergraduate laboratory and design courses—would be taught by people with both the background and the enthusiasm to teach them expertly rather than by professors dragooned into teaching them on a rotation system. More important,* *industry-bound undergraduates would gain teachers and advisors who would serve as role models of experience and professionalism.*

This proposal is neither radical nor unprecedented. At least one department at a major research university has a named full professor whose career has been devoted to engineering education, whose presence in that chair has greatly enriched our profession and the stature of his own department. Another major college of engineering with a strong research program uses a flexible evaluation system for determining merit raises: teaching, research, and service are given variable weights according to each professor's career emphasis, so that professors whose primary career activity is teaching and those who are more research-oriented have equal opportunities to advance.

In my own department, we brought on to our faculty several years ago a man with 30 years of industrial experience, who made it clear that he had no interest in research. It was one of the best things we ever did for ourselves. He has taken over, enthusiastically and expertly, many of the responsibilities from which most of us instinctively recoil, including administering the undergraduate program and transforming and modernizing the undergraduate laboratory. His technical experience has proved to be a rich resource for both his students and his colleagues, and his managerial background and skill have enabled him to do gladly and well what most of us would do reluctantly and, at best, adequately. He was recently promoted to full professor, with no dissent on any level, and the sky has not fallen.

In short, the system I propose would ensure that we are not requiring body repairmen on our faculties to fix transmissions or accountants to perform surgery. Both research and teaching would be done by individuals with the desire to do them and the enthusiasm and skill to excel at them. The quality of the education program, the quality and productivity of the research program, and the morale of the faculty would all increase, and in the steady state departmental revenues would most likely go up.

Why not try it? What could we lose?

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If I were to name all the friends and colleagues whose ideas have influenced mine, the list would be longer than the paper. I will limit myself to just four of them. First, this presentation in a sense follows the 1988 Phillips Award Lecture by Hank Van Ness, who made many of the same points more gracefully and less verbosely. Second, Armando Rugarcia's thoughts about the contrasts between research and teaching inspired my choice of the theme of the paper, and I have drawn heavily on those thoughts and many more of Professor Rugarcia's insights about engineering education when writing it. Finally, my thanks go to Rebecca Brent and George Roberts, whose comments on a preliminary draft of the manuscript led to substantial improvements in the final version.

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