Mathematics Departments in the 21st Century: Role, Relevance, and Responsibility

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It is a great privilege to be asked to give a lecture named for Jim Leitzel. Jim and Joan were both members of Ohio State's Department of Mathematics for 25 years. They left Ohio State in 1990, but their influence on our mathematics department and university is still felt in significant ways today. Joan's leadership of the University of New Hampshire and, more generally, in higher education, is a source of great pride for Ohio State.

Jim Leitzel is well remembered at the university and throughout the mathematics community for his deep interests in students, his concern with teaching undergraduates, especially future mathematics teachers, his incredible work ethic, his outstanding scholarship, and his dedication to mathematics education reform. After seeing too many ill-prepared students coming to college, Jim accepted the job of coordinating Ohio State's master's program for teachers of mathematics. And in 1994, to improve the teaching of mathematics at the college level, he co-founded the outstanding Project NExT (New Experiences in Teaching). Among other things, this program links mathematics professors from across the country as a way to form support groups and share information about mathematics education. What an incredibly rich and *balanced* career Jim had!

Balance. That's a concept to keep in mind as we consider the external forces bearing down on today's mathematics departments and the actions departments must take in order to survive in anything like the form they enjoy today.

It may seem a bit extreme to use a word like *survive* in talking about mathematics departments, which tend to be among the largest on most college and university campuses. But I don't think so. With declining enrollments at all levels in many departments across the country, it will be increasingly difficult to justify their size. Mathematics departments must find new ways to contribute as the Information Age places new demands on our universities.

Before proceeding with this topic, I want to offer two disclaimers. First, my experience as a mathematician has been exclusively at research-intensive universities. So, my comments are skewed toward this environment. This happens to be where, I believe, we have some of our greatest challenges. So, I apologize in advance to those who work in teaching-oriented departments if my comments seem less relevant to your circumstances.

Second, I still have a great love for mathematics and for the company of mathematicians. But I have been removed for too long from the world you live and work in on a day-to-day basis. From that perspective, it's a bit presumptuous of me to be offering advice to you. On the other hand, sometimes an outsider—in this case a very empathetic outsider—can foresee issues, problems, and opportunities from a fresh perspective that can be helpful.

One of the challenges for a university president is the following two-fold assignment: First, understand the larger societal forces that will affect higher education in the next few decades. And second, work with faculty to adapt to these changes and use them to advance the purposes of the university.

[1]The James Leitzel Memorial Lecture at MathFest, University of California, Los Angeles, August 4, 2000.

I liken my role in today's environment to being at the helm of a ship in turbulent weather—trying to minimize the effects of the ill winds, while attempting to catch the favorable breezes and move the ship along its true course. This is a very tricky business. Historically, universities have not been good about understanding and responding to the larger societal forces. The metaphor for universities as ivory towers is not without merit. In the past, our relative isolation has even been thought of as an asset. It enabled us to maintain a sense of purity and independence in our mission.

Back in the days when I did honest work as a professor of mathematics, before I crossed over to the dark side as an administrator, I was amply supported by the National Science Foundation to do research on topics of intense interest to me and—truth be told—only a few score associates sprinkled around the world. This relative isolation from the outside community also enabled a culture to grow up within the department that allowed us to invest vast resources to educate relatively few of our students, and few resources to educate the vast majority of our students. For this latter group, we largely served as a fine filter, determining whether they could pursue a career in engineering or the physical sciences.

Contrast this situation—which I believe describes many mathematics departments even to this day—with the message in the recent publication *Toward Excellence: Leading a Doctoral Mathematics Department in the 21st Century* [**1**]. This book was produced under the auspices of the American Mathematical Society by a group of department chairs from some of our nation's leading research universities. If you haven't read it, I urge you to do so.

The opening line of the book is, "We have a simple message: To ensure their institution's commitment to excellence in mathematics research, doctoral departments *must* pursue excellence in their instructional programs." A few pages later, the authors say: "No single issue is more important than undergraduate instruction in determining whether research universities, especially public research universities, will receive strong support from alumni, legislatures, business leaders and the general public." They go on to say: "We can debate endlessly whether the criticism that higher education has been getting is fair, but the fact remains that universities do not have the public support they once had and that they certainly need."

What has caused this shift? Why in only a few short decades have we moved from a culture in which undergraduate education was almost an afterthought at many universities, to one in which respected leaders from some of our most distinguished research-intensive departments offer a clarion call for a new departmental paradigm—one that places undergraduate education at the very center of departmental concerns? Why are these leaders so concerned about what the alumni and public think?

The recommendations in *Toward Excellence* are a wise response to a fundamental shift in society that has altered our nation's socioeconomic ethos and higher education's relationship to it. As creations of society, our universities cannot help but be influenced by the forces at work in the larger outside community. These forces will change over time, but the change will be evolutionary and on the time scale of decades, not years.

Focus, accountability, responsiveness, and relevance have become the new national mantra. IBM and other companies that had long heralded their corporate version of academic tenure, now accept the need for massive layoffs to become leaner, more consumer-focused organizations. It's important that universities understand these forces, for it is unlikely that any university can succeed unless it takes these new socioeconomic dynamics into account.

The point I want to make is captured in a recent article about Ford Motor Company [**2**]. It described how that icon of the old economy was reinventing itself. The old

Ford manufactured most of what went into its cars, and management decided about 24 months in advance what models and colors they would push onto the public. But the new Ford is radically different. It will now make only about seven percent of what goes into Ford cars. A network of business-to-business suppliers will serve the company, and Ford will let its customers—the public—determine what models and colors will be produced, with delivery on demand. Similar changes are under way at virtually all companies and many governmental agencies across the country.

I offer this example in order to emphasize two points. First, the larger social context within which we operate is fundamentally different from the one many of us grew up in—and this context is not likely to change any time soon. It's unrealistic to think that in such an environment, universities can be successful if they proceed with business as usual. The second point is that many at universities do not seem to grasp this reality. In fact, I'm constantly amazed at how often my colleagues think that the changes universities are considering, and in some cases implementing, represent a sinister plot conceived in isolation by a devious gaggle of unenlightened presidents and provosts.

"If you would just tell the legislature how important what I'm doing is, they'd get off our backs and give us more money," is the kind of refrain I hear often. Indeed, only the *resistance* to change exceeds the *need* for change within our universities. I'm reminded of a bumper sticker I saw recently that said: "Change is good; you go first."

Now, I don't mean to imply that we in higher education are merely pawns of external forces we cannot influence. Clearly, we must actively and forcefully explain the importance of our fundamental mission to policy leaders and the general public. We must openly champion the value of a liberal as well as a professional education and the dangers inherent in under-funding the arts and humanities. We must be strong advocates for the essential role of basic research. And along with enlightened trustees and other friends, we can and should significantly influence the public policy decisions that impact our universities. But we must also understand—and work within—the larger sociopolitical context, because it, too, will greatly influence our success.

What are some of the implications of this new order for higher education? The good news is that the body politic sees much of what we do as vital to our nation's continued well-being. Never in my lifetime have I witnessed such a pervasive public focus on the quality of education at all levels. And never have I witnessed such public support for research, when that research is tied to a public benefit. Clearly, the light has dawned on the private sector. Industry now recognizes that *its* success depends upon *our* producing an abundance of well-educated graduates and intellectual property to fuel our knowledge-based economy.

The bad news? There continues to be an aversion to tax increases and growth in government. This suggests that we can anticipate only modest increases in funding, except in targeted areas of our budgets where there is a clear and obvious connection to economic growth or some other societal need, such as K-12 educational reform. In sum, it's quite likely that we will face continued financial constraints, if not austerity, in the years ahead.

Another phenomenon that will affect our university lives is an increasing demand for accountability in the use of public funds. With stiff competition for a limited pool of public resources, every allocation will receive heightened scrutiny. Governors and legislators will feel forced to document the impact of state funds. We can expect to be asked regularly about faculty workload, retention and graduation rates, time-to-degree, course availability, and measures of the "value added" by a college degree. There's no place to turn for relief from these demands, because the general public thinks that these are reasonable things to measure. We can and should engage in the process to ensure

that accountability measures we actually use are meaningful and appropriate for the aims of the university.

If you accept my premise, even partially, that we now live in an era in which the public will demand that universities be more responsive to the needs of the larger society—that we be more consumer-focused; if you accept my observation that the years ahead will be characterized by fiscal constraints, increased competition for resources, and heightened expectations for accountability, how then should universities and, in particular, mathematics departments, respond? What are the areas of opportunity in which—faithful to our discipline and traditions—we mathematicians can expand our activities and increase our centrality to the university's expanded responsibilities?

To try to answer that question, let me describe briefly three issues that I believe mathematics departments must be especially attentive to.

The first is the K-12 reform movement that is sweeping the nation. Every state is engaged in this issue. New standards, new curricula, new means of assessment, and new teacher preparation programs have captured the attention of governors, legislatures, and the general public as never before. A survey that I read recently asked people to name the number one problem facing our country. By a wide margin, it was the quality of K-12 education—not social security, not healthcare delivery, not crime, but K-12 education.

The second major factor is the changing demographics of our nation. According to a study by the Hudson Institute, by 2020, there will be 10 percent fewer whites and 30 percent more non-whites in the workforce. And according to the U.S. Census Bureau, by 2050, the non-Hispanic white population in this country will decline to about 50 percent. The Educational Testing Service reports that in the next 15 years, college enrollment will grow by more than 2 million—and African-American and Hispanic students will account for nearly 80 percent of that growth. For our nation to continue to prosper in this Information Age, it's clear that vastly larger percentages of these minorities and women must be attracted to mathematically related disciplines.

The third trend is the nature of the nation's research agenda. Today, much of the most exciting work being done, and the best funded, is interdisciplinary research. Neural networks, angeogenisis, data bases, and other new fields that cross traditional department boundaries are where we now find a disproportionate amount of exciting results—and funding.

Given these factors, what opportunities exist for mathematics departments to create their enrollments and their role in the larger agenda of our universities? I think this is a very important question—one that deserves the serious attention of every department in the nation. For, like a sequence of comets striking the Earth, external and internal factors are combining to alter the environment in which mathematics departments operate. Under these new conditions, we can either meet the fate of the dinosaurs, or we can adopt new strategies and thrive in the coming decades.

Unfortunately, we don't have a very good record of adapting to the outside world. If a university is an ivory tower, then mathematics departments are too often at the highest window in the tower. And if we peek inside that window, the current view is not a pretty one. Recent data show:

- A significant decline in overall enrollment and a vanishing number of majors;
- A precipitous drop in graduate enrollment (In fact, between 1994 and 1998—the last year for which we have numbers—graduate-level mathematics enrollment across the country is down more than 18 percent.);
- And close to 60 percent of course instruction at the level of first-year calculus or lower.

Yet, at the same time, there has been essentially no decline in the number of tenured faculty, and there has actually been a rise in the number of non-tenured teaching faculty. It's impossible to imagine that these trends can continue much longer. In this era of constrained resources and increased accountability, either enrollment will go up, or the number of faculty positions will go down.

But the outlook isn't all bad, and mathematics has some important assets. Along with English, it is still seen as one of the two core disciplines upon which an educational foundation is built. As a result, mathematics is still a requirement at most colleges and universities. Also, mathematics always has had—and undoubtedly always will have—the potential for strong connections to other disciplines, especially in the physical sciences and technology, and increasingly in the biological and social sciences. These connections occur at both the educational and research levels. Moreover, mathematics is singled out with special importance in the push to improve the quality of K-12 education. In fact, both major presidential candidates have stressed mathematics education as a critical national issue.

The question we face is how to draw upon these assets:

- As we address the challenges of the new academic environment;
- As we adapt in order to survive;
- And, as we attempt to broaden the role and mission of our departments.

In thinking about the issues we're facing, I tried to imagine myself as the chair of a mathematics department today. I asked myself, what would I do? How would I begin to address these challenges? Here are five steps I would take.

First, I would try to persuade my colleagues to adopt the recommendation of *Toward Excellence*, to make the quality of undergraduate education a central mission of the department—not just rhetorically but through the allocation of the department's human and fiscal resources.

What would this commitment to undergraduate education entail?

- A call for a reshaping and restructuring of the curriculum, with greater emphasis on active learning at all instructional levels and on the connections mathematics has to other disciplines;
- A commitment to changing the department's role from an instructional filter to an educational pump;
- A commitment to develop joint majors and upper-level service courses in partnership with other departments;
- A commitment to develop and reward faculty who can deliver high-quality mathematics instruction to a diverse audience of non-majors;
- The creation of a departmental track to prepare K-12 teachers;
- And direct involvement in the state's K-12 mathematics reform efforts.

My second action as chair of this virtual mathematics department concerns graduate education. I'd want my department to revamp its graduate curriculum to better reflect changes in employment opportunities and the needs of the discipline. For too long, we've ignored the reality that many of our master's and doctoral students pursue careers outside academia. In fact, a recent study conducted by researchers from the University of California, Berkeley, examined where Ph.D. graduates from tier-one institutions were working 10 years after receiving their doctorate. Nearly 30 percent

of the mathematics Ph.D.s were working somewhere other than academia. I am convinced that this percentage will grow in the coming years, as both the public and private sectors face technological challenges that mathematicians can help them solve—in expanding areas such as data encryption, data management, computer modeling, genetic mapping, and the study of large, complex systems. Even more telling, the Berkeley study showed that a relatively small fraction of these Ph.D.s from tier-one schools were working at doctoral-producing universities. It is imperative that we change our outlook and better prepare tomorrow's Ph.D.s for the non-academic and non-research university career options that most of them will pursue. We owe it to them—and we owe it to the organizations and institutions that need them.

My third action has to do with the department's research agenda. More than ever before in our history, much of the most exciting research is happening at the boundaries where two or more disciplines overlap. For example, with the completion of the human genome project, researchers are combining data management and biomedical initiatives to develop pharmaceutical breakthroughs, and researchers from biotechnology, material sciences, mathematics, and computer science are collaborating to develop amazingly powerful biological computer circuits.

This explosion in interdisciplinary research should have a significant impact on faculty recruitment and development strategies, so my virtual mathematics department's third action would be to support the retraining of faculty who wanted to move into one of these interdisciplinary areas. I would insist that the department reallocate positions in order to hire researchers in fields such as computational sciences, neural networks, and string theory, as well as in the teaching and learning of mathematics.

Let me give you an example. This past year, the University of Oklahoma's mathematics department collaborated with its electrical engineering department to offer a master's degree in the growing field of signal processing, focusing on wavelet technology. They also graduated their first Ph.D. in that field, and that graduate received job offers both in and out of academia. Programs like this are creative responses to job market realities.

Oklahoma's mathematics department also instituted another new program last year to attract new graduate students. They now invite college seniors from across the state and the region to a three-day mathematics jamboree, where they can meet with faculty and grad students and hear stimulating talks. Following this program, and additional recruiting, Oklahoma more than doubled the number of new graduate students admitted into its program this year.

The fourth action I would take is a direct response to declining enrollments and the demographic changes in our population. In order to succeed in this new era, we must attract a more diverse population of students and faculty to our mathematics departments—just as we must in science and engineering. Overwhelmingly, most of our mathematics graduate students are male and are either white or foreign-born. And even their numbers are shrinking: Overall enrollment in graduate-level mathematics programs fell more than 18 percent between 1994 and 1998, with steady declines each and every year. Moreover, the number of African-Americans and the number of women enrolled in graduate-level mathematics programs each shrank about 9 percent between 1994 and 1998. African-Americans are now about 5 percent of mathematics graduate students, and as late as 1997, the total number of African Americans receiving a Ph.D. in mathematics during the entire year was *seven*. Yes, seven in the entire nation. As for women graduate students in mathematics, men currently outnumber them almost two to one; only 260 women received mathematics doctorates in 1997.

We must do a better job at improving mathematics education for under-represented groups of students in their early years and encouraging them to continue their studies

in mathematics. It's not an impossible task. In fact, the University of Nebraska has set an outstanding example for making an extra effort to attract women into its graduate mathematics program. During the decade of the 1980s, the University of Nebraska Mathematics Department did not award a single Ph.D. to a woman. They had awarded only six in the school's entire history. The numbers were unacceptable to them, and they took action.

Almost 10 years ago, Nebraska initiated mathematics summer camps for high school girls, weekly seminars on women in mathematics, and a decade of targeted recruiting and focused mentoring. The results: Nebraska can now boast that about half of its mathematics graduate students are female. And in the past few years, about 40 percent of its mathematics Ph.D.s have gone to women; the national average, by the way, is about 22 percent. According to their department chair, Jim Lewis, this influx of female graduate students has also qualitatively improved the department. In fact, the department's first NSF postdoctoral fellowship went to a female graduate in 1997.

According to those involved, the most important element of this success at Nebraska is the effort and commitment of its faculty—and the confidence they have that they will be rewarded for their efforts. The University of Nebraska's mathematics department received a Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring in 1998.

My former department, the mathematics department at the University of Maryland, has had comparably dramatic success with African-American graduate students. Under the leadership of its chair, Raymond Johnson, the department began an active recruitment effort, with an individualized admissions process, and a highly effective mentoring program. The result? The department has attracted some 25 African-American graduate students to its Ph.D. program over the past six years. Incidentally, the program at Maryland follows closely the recommendations in a recent MAA report about diversity in the discipline.

To indicate the appropriateness of the MAA recommendations and the success of the University of Maryland's efforts, let me point out that their 25 African-American mathematics graduate students represent between 10 percent and 15 percent of all African-American mathematics graduate students in the nation. Several of these students have already received their Ph.D.s. Next year the department expects five more to complete their degrees. Remember that in 1997 only seven African-Americans in the entire nation got a Ph.D. in mathematics. Like the University of Nebraska, the University of Maryland is showing that we can create greater diversity in our nation's mathematics departments.

This brings me to my final and perhaps most controversial action. It's the concept of individualized faculty workloads. And it has a direct or indirect effect on each of the other four actions. I think there is no area in which universities are more subject to valid criticism than in the way we utilize our human resources. I'm certain the situation has improved somewhat from when I was a chair—but surely not enough. In my day, we had a uniform teaching load regardless of whether faculty were actually engaged in research. Indeed, we perpetuated the myth that *everyone* was doing research. God help the person who tried to take on some special assignment involving undergraduates. Rumors would start to buzz in the hall: "What's wrong with old Joe? His career must be on the skids." Such attitudes were never justified, but with the issues facing our departments and universities, they can no longer be tolerated.

We *do* need a new reward structure—one more in tune with current reality. And presidents, provosts and deans alike need to lead the way for the change. Mathematics departments are wonderfully suited to help support this effort. The demands on our department are perhaps more varied than those of any other department in the univer-

sity, and there are faculty in most departments whose talents are under-utilized. I'm confident that a department coming forth with a creative strategy in this area would gain enormous favor with the administration. I know it would with me.

In advocating responsibilities tailored to the interests and talents of individual faculty—which will vary over time—I want to stress one point very clearly. At research-intensive universities, we have every reason to expect that each candidate for tenure will demonstrate a research mastery of his or her field. In mathematics, this would almost certainly mean research published in major peer-reviewed journals. But, as Ernie Boyer pointed out in his brilliant book *Scholarship Reconsidered* [**3**], careers in academia are long, and few sustain an uninterrupted, 40-plus-year career of important research activity. As we all know, this is especially true in mathematics.

Let's accept and take advantage of this fact. Let's make it possible for faculty whose passion for research may be cooling to switch gears and focus on teaching, curriculum development, and outreach to the K-12 sector. And let's make it possible for individuals to gain promotion from associate professor to full professor if they excel in scholarship related to the learning of mathematics or in other areas of the department's primary responsibilities.

That's the plan of action I would try to implement in my mathematics department. And I'm sure that my wise, generous, and insightful president would see fit to provide me with the abundant resources I'd need.

In conclusion, one final word on perspective. I don't want to leave the impression that everything being done in mathematics departments today is deficient. Sometimes our rhetoric can get away from us, so let me state for the record that I don't feel that way. Many good and valuable things are happening in our field—many things that James Leitzel would be proud of. For example, I believe that our Ph.D. recipients over the past several years are generally better and more dedicated teachers of undergraduate mathematics than graduates in any previous generation. And, of course, the high level of research at mathematics departments across the country is producing remarkable advances in our discipline.

Department chairs obviously must concentrate on identifying and nurturing bright young talent—and supporting established, productive researchers. Any suggestion that this is not the case is misguided and is most definitely not what I'm advocating. What we do need so desperately at this time can be summarized in one word I put forth at the beginning: balance.

We need balance in the department's mission, reflecting our multiple responsibilities. We need balance in the allocation of resources to meet these multiple demands. We need balance in the diversity of our students and faculty. And we need balance in the allocation of people's time and responsibilities.

Achieving this balance will require insightful, forward-looking, and courageous leadership.

Certainly, this is not an easy time to be a mathematics department chair, so I'm glad that my duty as a chair is only for one day and only for a virtual department. Nevertheless, I'm confident that by facing the challenges ahead of us and taking bold actions to adapt, our departments can not only survive; they can flourish. Engagement in such an agenda may represent the most appropriate and effective way we mathematicians can use our talents to serve society's needs and our discipline's future.

In James Leitzel, we have an outstanding model for such efforts. And, by following in his footsteps to improve mathematics education across the board, we will undertake what could be some of the most rewarding experiences of our lives—and among the greatest contributions of our careers.

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Mathematical Detachment

A series of creatures might be constructed, arranged according to their diminishing interest in the immediate environment, which would begin with the amoeba and end with the mathematician. In pure mathematics the maximum of detachment appears to be reached: the mind moves in infinitely complicated pattern, which is absolutely free from temporal considerations. Yet this very freedom—the essential condition of the mathematician's activity—perhaps gives him an unfair advantage. He can only be wrong—he cannot cheat. But the metaphysician can. The problems with which he deals are of overwhelming importance to himself and the rest of humanity; and it is his business to treat them with an exactitude as unbiased as if they were some puzzle in the theory of numbers.

Contributed by Herbert Kalf, Mathematiches Institut der Universität München. The quotation is from the opening paragraph on Hume in Lytton Strachey's *Portraits in Miniature and Other Essays*, Chatto & Windus, London, 1931, p. 141.