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ABSTRACT

The "Academic Excellence" (Research Corporation, 2001) study contains quantities of interesting data. The findings of this study make it apparent that all institutions profess undergraduate research as a value, and that all institutions put resources into research. Science activity has increased in the 1990s. In general, institutions tend to fund startup and facility costs, while the government and foundations fund equipment and research projects. Many of the conclusions reached by this study might have been predicted before the study was done, but others were somewhat surprising. One item that was a pleasant surprise was than 25% of the published papers included student coauthors. Another surprise was that there are no clear, unambiguous trends in the perception of what is most needed in funding. Also surprising was that the presence of graduate programs does not generate significantly more research grants or lead to great enhancements in faculty publication profiles. Data from the study make it possible to calculate such things as the average cost of producing a paper or the productivity of different academic ranks. The study leaves unanswered many questions, but overall is a thought provoking and useful examination of faculty roles and research at predominantly undergraduate institutions. (SLD)

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The Environment for Scientific Research by Undergraduates: Some Thoughts on Reading the "Academic Excellence" Study

Research Corporation

April 2002

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Research Corporation SPECIAL REPORT APRIL 2002

ACADEMIC EXCELLENCE

A study of the role of research in the natural sciences at undergraduate institutions

The Environment for Scientific Research by Undergraduates: Some Thoughts on Reading the *Academic Excellence* Study

Research matters

Early one evening I was engaging in that always satisfying experience of walking across a college campus. The campus was not my own and it is not my purpose here to be a booster for my own institution (no matter how deserving it is!) So, while strolling across this anonymous college campus, I happened to overtake a group of three undergraduate students talking animatedly to each other. While one would not wish to eavesdrop, if one did, and if one had any expectation concerning the subject of such a student conversation, the prediction might be inclined towards the Super Bowl, Olympics, or local sporting event; an upcoming dance or concert on campus; or the relative merits of Britney Spears *vs.* N'Sync. Anticipating such cross currents of American popular culture, I was pleasantly surprised to hear them discussing—research! And while student excitability can generally be counted on for modest restraint and tactful understatement, at least in the presence of faculty, deans, or presidents, this group was talking with high enthusiasm, bordering on the giddy. Each had spent the afternoon doing research in a science laboratory and their sharing of the uninhibited pleasure they felt at the experience, made complete my otherwise unremarkable day. What better way to turn students on to the pleasure of learning, to open their eyes to the prospect of thinking thoughts no other human being had before, or—is it possible?—to find the answer to a question that has evaded all previous pursuers. Research!

The story (and it's a true one) makes clear why we care about the environment for scientific research for undergraduate students, and why five foundations expended their most precious resource—money—to assess "academic excellence." Also clear is why busy faculty members would expend *their* most precious resource—time—to complete a comprehensive and rather laborious questionnaire on their academic habits and habitats. Simply put, research matters. It matters because research liberates students to reach more imaginative levels of thought than they might otherwise achieve when choosing among the many, varied, and worthy diversions of four years of college life. And who needs to wonder whether research matters to faculty? The answer to that query can be provided in one of the many minimalist utterances that will be familiar to anyone who works with young people—"Duh!"

Research matters, not because we expect all students to become researchers or professors—although this prospect has a certain delightful appeal—but because, at its core, research is about problem-solving, and no matter what their calling in life, be it business, law, medicine, the arts, public service, or education, people will be called upon to solve problems. And so a habit of mind, formed in a college laboratory over many a late night or long weekend, is a superb preparation for a spirited life to follow in "the real world."

Some selected observations on the study

The *Academic Excellence* study contains scads of interesting data. I actually read it from cover to cover (placing me, no doubt, in a very small group) on a long flight from Paris to Chicago. My seatmates exhibited modest curiosity about the thick volume occupying my attention, but none asked to borrow it, possibly dissuaded by my copious note-taking in the margins.

The study has enjoyed considerable discussion and extended analysis at a meeting at Fermilab of the participating institutions, and at the AAAS meeting in February 2002. I'd like to add a few observations of my own (Figure 1). All of the 133 participating institutions profess that conduct of undergraduate research is a value they hold. All engage in it, albeit to greater or lesser extents. Nobody is publicly willing to stand outside the universal sentiment that teaching and research are tightly linked, inseparable, and not

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Figure 1

Academic Excellence: Some Observations

- **All institutions profess undergraduate research as a value**
- **All institutions put resources into research**
- **Science activity increased in the 1990s**
- **Institutions fund startup and facility costs**
- **The government and foundations fund equipment and research projects**

to be viewed as in competition with each other.

All institutions put money into undergraduate research. The confidentiality of the study does not allow the reader to discern who puts more, who less, although one assumes that the expenditure of treasure is some reflection of the amount of treasure one has. The proportion spent on various aspects of the research enterprise is also hard to discern. This is an interesting question as the way one assigns resources is a measure of one's priorities, and the choice of priorities is expected to contribute to the eventual outcome. More on this later, too.

The numbers of science degrees awarded over the period of study (roughly, the decade of the '90s) increased, as did the number of science faculty. The number of students doing research also increased, but it is hard to discern with statistical accuracy whether this is proportional to the overall enrollment increase occurring during the same time period. Interestingly, the increase in science and research activity grew more slowly over the period than did the increase in total institutional budgets. This was a very good financial period for most colleges and universities, but it appears, at least from this study, that a higher fraction of new resources went elsewhere than science.

As to where the money for research comes from, the answer, at least at a macro level, is that institutions fund faculty start-ups and facilities while foundations and the government fund equipment and research projects. While not an absolute division of labor, this state of affairs nonetheless makes sense to me. Whether one finds it palatable or not, colleges and universities are in competition with each other to attract the best faculty. Since provision of funds to launch a scientific career is one of the enticements colleges can offer, they, rather than the public agencies, would seem responsible for such funding. This is not an insignificant sum. Although it will vary widely, my guess is that a typical start-up package offered by a research-committed PUI (primarily undergraduate institution) will be in the vicinity of six figures; the top research-intensive universities may be in the upper register of these six figures. Facilities—bricks, mortar, and buildings—also seem the province of individual institutions, driven at least in part by the eagerness of grateful alumni to erect campus edifices bearing their names.

The historical compact between educational centers and the government—usually described as emanating from Vannevar Bush's *The Endless Frontier*—is that the public will pay for a public good. Since the public appreciates both the accumulation of knowledge and the application of new knowledge to the betterment of life, it seems a fair deal that the government will sponsor the lion's share of individual research projects and the equipment needed to conduct them. Not that we couldn't productively use more money—no self-respecting scientist would ever make such a case—but I think this general sharing and division of funding responsibility is working rather well.

Specific aims

Everyone who has ever written a grant application knows that you have to have Specific Aims. The *Academic Excellence* study as originally conceived had two (Figure 2). The first aim was to assess the environment for research in the natural sciences at primarily undergraduate institutions (PUIs). Virtually everyone who has studied the results agrees that the research enterprise is decently healthy. There are aches and pains here and there to be sure, but no fatal diseases were uncovered; the patient can legitimately be diagnosed as middle-aged, reasonably fit, and certainly not in need of a low-fat diet.

Figure 2

Academic Excellence: Specific Aims

- **Assess the environment for research in the natural sciences at primarily undergraduate institutions**
- **Gather evidence on the pace of faculty research grant proposals**

The second aim of the study was to gather evidence on the perception that faculty at PUIs were applying for fewer research grants and that this condition might negatively impact research quality and quantity. With respect to quantity of proposals, my reading of the various charts and tables in the study shows a bit of variability up and down, but proposal submission is essentially flat over the period examined. Combine this with the increase in the number of faculty members (approximately 20 percent over the period) and you come to the conclusion that application velocity has declined. True enough, but should we be worried about it? I'm not particularly dismayed by this for three reasons. First, applying for funding is not the *raison d'etre* of scientific existence. It may seem so, especially at medical schools and research universities, but there is nothing mythically important about being awarded a research grant. Doing the work *is* important, and the study contains no data suggesting that first-rate scientific work is not being done in the PUIs. The second reason I'm not worried about grant application numbers is that, while the data can't get at this, it is my sense that institutions are putting more of their own money into supporting research projects. This lessens the reliance on external funding. That this would be so arises from a fundamentally good reason: educators collectively believe in the centrality of research to a quality undergraduate experience, and are therefore unwilling to trust the vagaries of a 30% success rate in grantsmanship to fund a central priority. This in no way minimizes the importance of writing and submitting grant proposals—subjecting one's ideas to the rigors of peer review is critical to the refinement of one's thinking. And this argument foreshadows my third reason for a lack of anxiety over proposal submissions. Our faculty have been successful in producing the truly important measure of output of scientific labor: published papers. The composite result shows 0.54 publications per year per faculty member over the period of the study. As Donald Kennedy, past Stanford president and former editor of *Science*, put it at the Fermilab meeting (where the *Academic Excellence* study results were first discussed publicly), "A peer-reviewed paper every other year is pretty darned good."

A few surprises in the results

So far, nothing I've said is very surprising. Many of the conclusions I've mentioned might have been predicted even before the study was done. Don't get me wrong—just because your hypothesis was proven correct doesn't mean that the experiment never needed to be carried out. No scientist would display such a nihilistic attitude! But there are some findings in the data that I found a bit surprising, unpredictable, or, to use a phrase one often hears around a laboratory, "very interesting" (Figure 3).

Figure 3

Academic Excellence: Surprises

- **Distribution of faculty effort**
- **Publications with student coauthors**
- **Distribution of funding needs**
- **Role of graduate programs**
- **Environment for women**
- **Cost per publication**
- **"Associate Professor Syndrome"**

Considerable effort was expended to record and assess how faculty apportion their time among various activities, including: classroom and laboratory teaching; curriculum development; student advising; administrative and committee work; research; community outreach; and consulting. I was somewhat surprised to learn that the breakdown of effort among these categories was similar across the different types of institutions that participated in the study (private and public; small and large; liberal arts and comprehensive). Given the differing missions, histories, and types of campus ethos present among these schools, one might have expected much more variety in the way science faculty members spend their time. Understandably, the results are presented in a relative format, i.e., as fractions of effort rather than an absolute measure of work time. Because of this, the data do not reveal whether faculty members work 20 hours a week or 60 hours a week, but given the encompassing pleasures of scientific life, we would expect the higher figure might be closer to the mark. It also emerges that the amount of time spent on various activities has changed little over the decade studied, although a discerning eye, unconcerned with statistical validity, might detect a slight increase in time spent on research, with correspondingly less spent on teaching. If so, this will be cause for some rejoicing among

faculty. Most amazingly of all, at least to the jaundiced among us, faculty members and administrators had a very similar assessment of how faculty employ their time. Perhaps the campus cultural divide is not as wide as some would lead us to believe.

One item falling into the category of pleasant surprise was that 25% of the published papers included student coauthors. I'm actually surprised on both sides of this number—surprised that it would be this high when the technical demands of modern research might be expected to exceed the grasp of many college students, but also surprised that it would be this low on teaching-intensive campuses where scientific research probably wouldn't happen if it did not happen at the hands of students. The deeper meaning of this number probably requires more thought, but suffice it to say that one's first publication is generally the most thrilling, and large numbers of students are experiencing this thrill before they arrive in graduate school.

Another surprise—or perhaps relief is a better word—is that there are no clear, unambiguous trends in the perception of what is most in need of funding. Among a list of 14 categories of items requiring funding, the four at the top were: information technology; courses and labs for majors; research time; research facilities; and the three at the bottom: courses for non-majors; research support personnel; electronic and paper journal resources. Notice that research and teaching ambitions are not separated into different categories: faculty perceive them, correctly I believe, as inseparable aspects of a satisfying scientific life. And despite the ranking of funding needs into 14 categories, the differences are small, and there is no clarion call that one area is desperately starved for funding or that another is receiving too much largesse. Perhaps we have the balance of funding provided by the private and public agencies at about the right level. My own view is that if national circumstances caused a significant funding squeeze, investigator-initiated project grants are the heart, soul, and central nervous system of research, and need to be most resistant to inroads, even if other areas are also worthy.

Still on the hunt for surprises in the results, here's one to ponder. The presence of graduate programs doesn't generate significantly more research grants or lead to great enhancements in faculty publication profiles. This certainly flies counter to conventional wisdom, which contends that graduate students are the lifeblood of research. Perhaps so at research universities, but at the places surveyed, which emphasize undergraduate education, graduate programs may not materially boost the creative milieu for research.

A pleasing finding in the study was that women have made striking gains in employment at these institutions over the past decade. The percentage of tenure-track faculty who are women nearly doubled, from 21% in the '80s to 40% in the '90s. Interestingly, women outperform men in acquiring grant dollars in every field except environmental science, but lag behind men in publications in every field except neuroscience. Speculations on the sociological implications of such data are probably too reckless for public display; suffice it to say that all of us welcome the improvement in opportunity for women in the sciences.

And here is some more good news. The study contains very comprehensive data on both faculty publications and grant awards (and cross checking with agency records showed a very high degree of reporting accuracy by college faculty). Thus, one can calculate the average cost per publication—$36,000. Most people's first reaction will be to wonder if they've ever read a scientific paper that was worth $36,000 (aside from their own publications, of course!). But in context, this is a very impressive number. About ten years ago, when I was serving as a study section member for the National Cancer Institute, the agency estimated an average cost per paper of about $70,000, twice that of the institutions studied, and this does not add the intervening decade of inflation. I conclude that research at undergraduate institutions provides excellent value for the money.

Finally in the list of surprises is what I will call "the associate professor syndrome." The publication rate of associate professors is more similar to assistant professors than to full professors, and associate professors actually do worse than assistant professors in attracting grant dollars. While one might conjure up many explanations for this finding, my (tongue-in-cheek, of course) conclusion is simply to never promote people to the rank of associate professor. After the pre-tenure probationary period is successfully navigated, just make them full professors straight away, and we'll statistically avoid the productivity gap of the middle rank!

Imponderables

The study also ignites several thoughts that tweak my curiosity. Idle curiosity is dangerous stuff, doubly

so for college presidents. And answers to these questions are either unavailable in the data or perhaps are unanswerable by any survey instrument. Whatever the limitations, however, here is what I would like to know, perhaps best answered not in the aggregate, but on each of the campuses that participated in the study (Figure 4):

What is the intensity of commitment to intellectual pursuits? Some students may pursue research projects simply because they are required for a major or because a research credit may appear easier to obtain than in a regular course. Admittedly, these motivations will get students exposed to a research lab, but the resulting passive experience will not service as well as a student who comes at science from a genuine passion inspired by faculty and other students who share that passion.

What is the rigor and challenge of the research project? I once heard Bruce Ames, eminent professor at Berkeley, and creator of the widely-used Ames test for mutagens and potential cancer-causing agents, tell the story that marijuana, birth control pills, and beer have been tested and retested so many times by his students, that we can be ultra-confident that these are not actively dangerous carcinogens. The students undoubtedly learned some science in running the tests, but what they are doing, at least in my estimation, is not research. It may be a simulation of what real research is like, but it lacks the mystery, the depth, the frustrations, the confusion, the exploration of alternatives, and the demand of hard thinking about the unknown that characterizes research as it is truly practiced.

What is the role of the research group vis-à-vis individual faculty-student interactions? Because of the complexity of the most interesting problems, much of contemporary cutting-edge scientific research occurs in the context of large multi-disciplinary, collaborative research groups. The solitary, brooding, creative thinker is not a lost icon, however, so one wonders which type of experience most undergraduates have and which is better for their educational development.

Are the lights on?

The *Academic Excellence* study cannot directly address these or many other equally interesting or transcendent questions. Please don't interpret this as a call for more studies—I actually think our faculty and students should spend more time *doing* what they do than *justifying* or *categorizing* what they do. So next time someone wants to assess the vitality of the research environment at colleges and universities, I suggest that they use the following methodology, which is simple and cheap and probably as reliable as anything else: walk by the science labs at 11:30 p.m. on various nights. Count the number of lights on. If it's high, all is well. If the building is dark, perhaps research needs a bit of stimulus on that campus.

Figure 4

***Academic Excellence*:**
It would be nice to know...

- **Intensity of commitment to intellectual pursuits**
- **Rigor and challence of research projects**
- **Research group vs. individual faculty-student interactions**

THOMAS R. TRITTON
President
Haverford College

(Presented in the symposium entitled "Academic Excellence: The Role of Undergraduate Participation in Research" at the 2002 AAAS Annual Meeting in Boston, Mass., February 14–19.)

Errata

The numbers for ratios A, B and C for the College of St. Benedict/St. John's University in Table 2.10, Number of Doctorate Alumni in Astronomy, Chemistry, GeoSciences, Physics, and Biological Sciences by Baccalaureates Produced Six Years Earlier in the Same Disciplines (p. 50 of The SourceBook; *p.4 of the* Academic Excellence Special Report *of February 2002) should read: ratio A, 6.2; ratio B, 7.2; ratio C, 6.0.*

Thomas R. Tritton

President of Haverford College since 1997, Thomas R. Tritton is a cancer chemotherapy research expert who has published over 100 articles, reviews and books.

A 1969 chemistry graduate from Ohio Wesleyan University, Dr. Tritton was awarded a National Science Foundation predoctoral fellowship as a graduate student at Boston University. In 1973 he completed a Ph.D. degree in biophysical chemistry from Boston University and went on to do postdoctoral work in the chemistry department at Yale University. From 1975 to 1985 Tritton was a faculty member in Yale's pharmacology department and the recipient of a research career development award from the National Institutes of Health.

Dr. Tritton joined the University of Vermont in 1985 as a professor of pharmacology in the university's College of Medicine and, in 1991, was appointed vice provost for the university.

A member of the American Association for Cancer Research and the American Society of Biological Chemistry and Molecular Biology, he serves on the board of the Fox Chase Cancer Center in Philadelphia and has served on the editorial boards of several scientific publications dealing with cancer research and pharmacology, and on NIH and American Cancer Society advisory groups.

Dr. Tritton is also a former deputy director of the Vermont Comprehensive Cancer Center, and served on the board of directors of the Vermont Technology Council which developed a comprehensive science and technology policy for the state.

ACADEMIC EXCELLENCE

Results from a comprehensive study of the environment for research in the natural sciences at predominantly undergraduate colleges and universities have been published in *Academic Excellence: The SourceBook*—539 pages of data and opinions which constitute an important resource for defining the current status of the natural sciences at the 136 surveyed institutions and in the broader universe of undergraduate institutions. These schools have served as a national resource for a significant proportion of students who undertake professional careers in the sciences, and a primary reason cited for their output has been the research experiences of undergraduate students with faculty mentors.

However, prior to this study there was a growing perception that resources and productivity were declining. Concern over these perceived trends by five private foundations with interests in the natural sciences (Research Corporation, the M. J. Murdock Charitable Trust, the W. M. Keck Foundation, the Welch Foundation, and the Camille and Henry Dreyfus Foundation, Inc.) prompted the intensive data collection and analyses for *Academic Excellence: A Study of the Role of Research in the Natural Sciences at Undergraduate Institutions.*

Copies of *The SourceBook* are available from Research Corporation. Orders must be prepaid by check or money order; $50.00, includes priority rate postage.

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