



Time to Decide

The Ambivalence of the World of
Science Toward Education

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Summary

The twenty-first century will be characterized to a large degree by humanity's collective success or failure in solving global scientific challenges: developing solutions to devastating diseases and disorders, managing spiraling energy requirements, reversing ecological destruction, and innovating new techniques to ensure sustainable methods for producing food, clean water, shelter, and sanitation despite a growing worldwide population.

Although the current pace of scientific discovery is inspiring and often breathtaking, we must not assume that this pace will continue. Scientific progress is dependent upon a complex range of factors—the availability of a skilled and diverse workforce, adequate funding for research and for commercialization of research, high-level political will, open global communication and collaboration, broad-based commitment to a critical mindset, and broad consensus about humanitarian values, among others—all of which can be transformed for better or worse by political, social, and economic events within a matter of decades. These factors are certainly too complex to be reduced to a single root: there is no panacea that by itself can stimulate great scientific advancement. Yet there is a common thread running through the many conditions of progress that, though not sufficient to ensure the prosperity of science, is necessary to it. That thread is broadly available, high-quality science education, in the absence of which funding, governmental will, and professional collaboration lack the raw materials necessary to achieve their fullest impact.

In particular, there are two critical objectives that science education systems must achieve. First, today's young science enthusiasts must be nurtured and educated so they may become the highly qualified, productive scientists of tomorrow. Second, students who are interested in pursuing non-science career paths must be well educated in the basics of how science works and why it matters to society so that they will create the broad financial, social, political, and cultural conditions necessary for research to flourish. Unless both goals are met, the pace of scientific progress worldwide will eventually slow, leaving the answers to pressing global problems unsolved. Are we as a global community prepared to meet these goals? If we are not—and there is widespread evidence and opinion that suggests this—what are the causes of inadequacy? What are the potential solutions?

In June 2009, Nature Publishing Group (NPG) initiated a sustained, multi-stage effort to explore these issues. For the first phase of the project, we decided to investigate an important but too rarely discussed factor in the equation of postsecondary science education: the attitudes that scientists themselves hold toward teaching. Years of dialogue with practitioners and thought leaders in science education have suggested to us that education is a charged and troubling topic for scientists at institutions of higher learning. Despite their personal feeling that education is important, many academic scientists eschew teaching in favor of research. Most top-level universities—despite having a publicly stated mission of education—direct more funding, awards, and job security to outstanding researchers than to outstanding teachers. This ambivalence—if it is truly as pervasive it appears—creates a divide between the professed values of the science community and our decisions, between the educational outcomes we hope for and the

ways we allocate time and resources. How widespread is this ambivalence? Where does it stem from?

To better understand the answers to these questions, NPG conducted a survey of university-level science faculty from June through December 2009. All of the faculty members included in the survey had both teaching and research responsibilities. The survey asked probing questions to learn how academic scientists regard the quality of science education in their areas, as well as to zero in on the contradictory feelings and forces at work in the academic world of science. Do scientists value their teaching responsibilities, or do they consider them an inconvenience? Do they feel their institutions value their teaching? What do they regard as the key educational challenges to be addressed?

The results of our survey, discussed in more detail below, present a troubling reality: although scientists personally value education as much as research, they frequently align their decision making, both for themselves and on behalf of their departments, with the needs of research rather than those of education. Interviews with a number of prominent educators and scientists were conducted in late 2009 to obtain expert opinion and commentary on this result. In this position paper, we synthesize the data from our survey with ideas gleaned from teachers, researchers, and university administrators in order to confront the dichotomy that currently exists between teaching and research in the international academic science community. We suggest several reasons why today's scientists align their decision making with research. We make numerous recommendations for structural changes that academic institutions, funding agencies, and scientific corporations can implement to close the gap between the benefits and investments that accrue to education and research in the academy. Finally, we call for individual scientists in high-impact positions—whether they are department heads, decorated researchers, or policy makers—to take active steps toward finding real-world solutions that bring research and teaching within their orbit into closer balance.

PART I: BACKGROUND



The Twenty-first Century: A Century of Scientific Challenges for the Global Community

As the second decade of the twenty-first century begins, it has become clear that this century will be characterized in large part by our collective success or failure in addressing the many critical scientific challenges that humankind is facing

worldwide. These challenges include developing treatments or cures for devastating diseases and disorders—cancer, Alzheimer’s, Parkinson’s, HIV/AIDS, malaria, tuberculosis, cardiovascular disease, addiction, and diabetes, among others. Added to this is the quest for ever-increasing productivity and power in medical, information, defense, and agricultural technologies. Then there is the challenge of sustainability. The world’s human population today has reached 6.7 billion, and by 2050 it is expected to reach nearly 9 billion.¹ How can we, as a global community, meet current and future human demand for food, clean water, shelter, health care, and energy, while still preserving the environment and the natural resources needed by future generations?

The global community’s twentieth-century record of making significant advances against complex scientific problems was impressive. It was just over 50 years ago, for instance, that James Watson and Francis Crick (with help from Rosalind Franklin) proposed the double helix structure of the DNA molecule; today, scientists are tackling the idea of creating artificial life from man-made chromosomes.² Creative minds are at work around the world, and the pace of discovery is remarkable. For this pace of innovation to continue, there are, in our opinion, two key conditions that must be met. One is a continually replenishing pool of well-trained scientists who can ask novel questions and perform the original research we need to tackle our many scientific challenges. The second is a scientifically literate public. These two groups are profoundly interdependent. While the former personally drive scientific discovery or take up positions in business, law, and

government that have direct impact upon scientific discovery, the latter become the science teachers, journalists, voters, and parents who indirectly create the societal conditions within which discovery can flourish. With a few exceptions, it is only in the context of a public that understands the basic principles, value, and benefits of science that state policy, funding, and social priorities will all be fully aligned in support of researchers.

As we look toward the future, we must ask whether we, as a global community, are sufficiently positioned to satisfy these two conditions. Are young scientists being adequately prepared to perform innovative research? Is the public at large being adequately educated about the value and principles of science? In this position paper, we argue that both of these goals—along with our global ability to respond to tomorrow’s scientific challenges—are at risk.

Science Education and the Next Generation

It is the mandate of science education systems—from the primary level through postsecondary and postdoctoral training—to turn today’s young science enthusiasts into tomorrow’s highly qualified and productive scientists, and to effectively educate the more general student body about the basics of how science works and why it matters to society. If both aspects of this mandate are not met to a sufficient degree on a global scale, the state of scientific progress in our world will decline over the next generation.

Is this two-part mission being accomplished? In some nations, it is. In many others, it is not. We can consider the case of secondary-level science education in the United States as a revealing example of the latter. The U.S. has the largest single-nation economy in the world,³ and spends about 2.7% of its GDP on scientific research and discovery, a figure second only to Japan among the G-7 nations.⁴ Logically, one would assume that the U.S. would be a global leader in the quality of its science education programs and the resulting level of student achievement. The reality, as most of us are aware, is quite different. The state of secondary science

education in the U.S. is a recognized matter of national concern. Beginning in the year 2000 and continuing every third year, the Organization for Economic Co-operation and Development (OECD) has conducted the Programme for International Student Assessment (PISA) to evaluate the knowledge and critical-thinking skills of 15-year-old students in mathematics, reading, and science. In 2006, over 400,000 students from 57 countries took part. For the U.S., the results were grim. High school students in the U.S. scored an average of 489 out of 1000, which is less than the overall global average of 500 and far below the scores of most other developed countries (Table 1). Overall, the U.S. earned a ranking of only twenty-ninth for science performance.⁵

science students are effectively “caught up” and engaged at the undergraduate level, one of three things will happen. First, students who major in non-science fields will not gain the basic scientific literacy they need to become informed voters, journalists, teachers, policy makers, or parents, leading to a gradual erosion of public support for science. Second, many students who enter their undergraduate studies with a professional interest in science but a subpar prior education will leave the field. This, we believe, reduces the diversity and overall size of the talent pool of future scientists. Third, many under-prepared students who do remain science majors will become under-prepared graduate students and eventually find their professional options severely limited. Over time, the aggregate impact of these losses will be significant. The state of scientific research will suffer; the pace of discovery will slow.



Arguments have certainly been made against this point of view. There are scientists who believe that the students with the greatest potential as researchers will be tenacious and resourceful enough to thrive even in an inadequate undergraduate context. Many go so far as to say that an attitude of “benign neglect” toward undergraduates performs a necessary role in separating the “wheat from the chaff,” ensuring that only the most talented students make it through the system to apply for the all-too-few research jobs available. We firmly disagree with this point of view. While it is true that benign neglect selects for some talented potential researchers, it surely stifles many more, particularly those who begin their undergraduate career with unusually inadequate prior preparation or who experience social hindrances due to gender and race, among other factors. This is science’s loss. Benign neglect also clearly has only a negative impact on the many students who pass through science classes to become teachers, policy makers, voters, and parents, robbing them of the opportunity to develop their lay scientific interests to a fuller degree. Surely the role of teaching is not to filter students, but to transform them through active, supportive engagement. In our opinion, if the scientific community wants the level of public scientific literacy as well as the pipeline of well-trained emerging researchers to keep pace with global

| | |
|----------------------|------------|
| Hong Kong-China | 542 |
| Canada | 534 |
| Japan | 531 |
| Netherlands | 525 |
| Korea | 522 |
| Germany | 516 |
| United Kingdom | 515 |
| Czech Republic | 513 |
| Hungry | 501 |
| France | 495 |
| Croatia | 493 |
| United States | 489 |
| Spain | 488 |
| Russian Federation | 479 |
| Israel | 454 |
| Bulgaria | 434 |
| Mexico | 410 |
| Indonesia | 393 |

Although disturbing, these results were not surprising. In both 2000 and 2003, U.S. high school students earned a below-average score on the PISA, ranking the U.S. as number 14 out of 31 in 2000 and 22 out of 39 in 2003.^{6,7} The incongruity between these rankings and the potential scale of U.S. investment in human capital has served as a wake-up call to U.S. politicians and secondary school administrators and educators. But the U.S. is far from

Table 1: Selected mean scores by country on the OECD PISA in 2006. Overall OECD PISA mean score is 500.

alone in this crisis. There is plenty of room for improvement in the scores of secondary level students in many other rich and poor nations.

The quality of postsecondary science education around the world is more difficult to quantify, because there are few widely implemented standardized measures. Yet we believe that the data we have about shortcomings in secondary level education are also vitally relevant to scientists at the university level. When secondary science education underperforms, postsecondary education must aim not just to be adequate but to excel, in order to compensate for inherited challenges. Unless underprepared high school

scientific challenges, then it must take decisive steps to ensure that postsecondary science education systems deliver a consistently excellent learning experience.

Postsecondary Science Education: A Closer Look

In June 2009, Nature Publishing Group (NPG) began a sustained, multi-stage project to explore issues of quality in science education worldwide. This paper is the first of several to present our findings and recommendations. We chose to focus for the initial stage of our work on postsecondary rather than secondary education. This was decided for four reasons. First, as already discussed, wherever secondary science education is inadequate, we believe that postsecondary education bears an extra responsibility for actively ensuring that talented students of all backgrounds have a genuine opportunity to achieve their professional goals. Second, there are a large number of government-sponsored initiatives to address the secondary sector in many countries, whereas there are fewer aimed at the post-secondary sector. Third, although systemic improvements at the secondary level are difficult to bring about due to the overlapping influence of a broad number of factors, including local and federal politics, funding restrictions, and labor unions, we believe that a significant number of postsecondary institutions are comparatively free to set and implement transformational policies provided they have the will and commitment. Fourth, although it is at the primary and secondary levels that students first become engaged by science, it is at the tertiary level that they either learn the skills necessary to understand and perform original research or acquire the sophisticated layperson's knowledge of science that will serve them well throughout their lives as teachers, voters, and parents. The postsecondary level, therefore, is a crucial conversion point that must be "got right."

Our first challenge in exploring issues surrounding the quality of worldwide undergraduate science education was establishing whether in fact it is succeeding or failing relative to its goals. Because there is little reliable standardized international testing at the undergraduate level, we decided to poll science instructors' opinions about the quality of education in

their region. From June through December 2009, we conducted a survey of 450 university-level science faculty from more than 30 countries; all of the faculty members included in the survey had both teaching and research responsibilities. The results of our poll, discussed in more detail below, indicate that the majority of scientists consider the quality of tertiary education in their region to be mediocre or poor.

Building on this, our second challenge was to explore the causes of underperformance. Several potential causes have been well discussed in policy literature, including the poor preparation that many incoming students receive at the secondary level; a lack of widely available student support services such as tutoring and counseling; inadequate laboratory infrastructure; the prohibitive cost of educational resources; and the continuing prevalence of "transmission-of-information" styles of teaching over hands-on, inquiry-based approaches.⁸⁻¹⁰ We chose to focus in this first stage of our project, therefore, on investigating a cause that is widely acknowledged by scientists in private but too rarely discussed in a public forum: the ambivalence of scientists themselves toward education. Years of discussion with both practitioners and thought leaders in science education have made clear to us at NPG that education is a charged and troubling topic for scientists, particularly those in institutions of higher learning. Despite their personal feeling that education is important, many academic scientists eschew teaching in favor of research. Scientists at leadership positions at top-level universities—despite the university's publicly stated mission of education—direct more funding, awards, and job security to outstanding researchers than to outstanding teachers. This systemic ambivalence—if it is truly as pervasive it appears—creates a divide between the professed values of the scientific community and our decisions, between the educational outcomes we hope for and the ways in which we actually allocate time, prestige, and resources.

In order to better understand the extent and origins of this ambivalence, our survey included probing questions meant to tease apart the contradictory feelings and forces at work in the academic world of science. Do scientists value their teaching responsibilities, or do they consider them an inconvenience? Do they feel

their institutions value their teaching? What do they regard as the key educational challenges to be confronted? Once the survey was completed, interviews with a number of prominent educators and scientists were conducted in late 2009 to obtain expert opinion and commentary on the results. In this position paper, we synthesize

the data from our survey with ideas gleaned from teachers, researchers, and university administrators in order to confront the dichotomy that currently exists between teaching and research in the international academic science community.

PART II: RESULTS



Scientists' Ambivalence Regarding Education

In theory, providing truly excellent science education at the undergraduate and graduate levels should be a straightforward task for colleges and universities. Nearly all scientists across the world would agree that education is deeply important for the future of science and declare their personal support for it. The results of

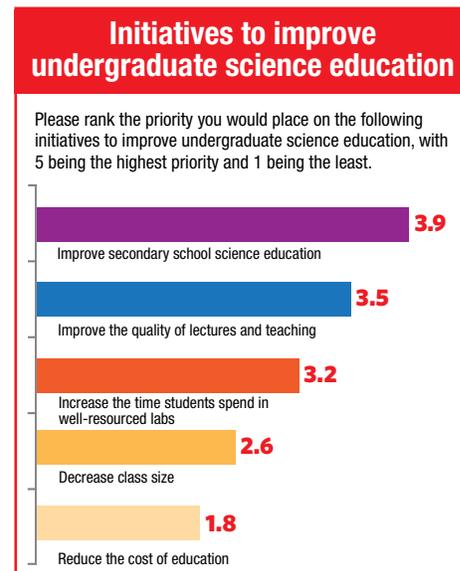
our survey, however, present a troubling reality: although scientists personally value education as much as research, they tend to align their decision making, both for themselves and on behalf of their departments, with the needs of research rather than of education. The survey results, along with selected commentary from the educators and scientists whose opinions we solicited, are summarized below.

1. Scientists Consider Postsecondary Science Education in Their Countries to Be Mediocre or Worse

According to the survey results, more than half of all scientists surveyed in Europe, Asia, and North America consider the quality of tertiary science education in their country to be mediocre, poor, or very poor. Only 6% of respondents in Asia, and 4% each in Europe and North America, consider the quality to be very good. This survey did not intend to form an objective measure of the quality of education in these regions, only to solicit the opinions of scientists, so the data alone cannot be used to assess the degree to which respondents' attitudes are correct. What is of primary interest about these results is the attitudes themselves. Scientists on the whole tend to believe that the science education ecosystem underperforms.

2. Secondary Education Is Seen as the Chief Problem, but University Teaching Is Seen as a Potential Solution

When the survey respondents were asked for their opinion of the relative importance of five commonly accepted potential solutions to the challenge of improving undergraduate science education (on a scale of 1 to 5, with 5 signifying the highest importance), a significant majority of respondents ranked the solution "Improving the secondary science education that feeds students into undergraduate programs" as most important (overall average of 3.9). It is clear that the respondents feel—rightly or wrongly—that they are to a large extent dependent in their success as educators on factors beyond their control. Yet the solution "Improving the quality of undergraduate lectures and teaching" was ranked a close second (overall average of 3.5). The respondents appear to acknowledge, therefore, that they have the power as an undergraduate teaching



community to redress their inherited educational challenges.

3. The Majority of Respondents Consider Themselves Effective Teachers

Although more than half (52%) of respondents felt that the students who enter their class at the beginning of the term are poorly prepared for the material to be covered, well more than half (77%) feel satisfied or very satisfied with their students' level of understanding when they leave their class at the end of the term. In other words, respondents in general feel that they are successful, effective teachers who produce a satisfying result. More explicitly, 85% of respondents feel that they have a positive or strongly positive impact on their students' ability to pursue science as a career, and 79% feel they have a positive or strongly positive impact on their students' desire to pursue a career in science.

There is an interesting potential contradiction between these data and the first result. It can't be true that the majority of faculty members are above-average teachers. If the respondents feel that the quality of education in general is low, yet also feel that they personally are successful teachers, then there are two possible interpretations: either the people who responded to our survey were skewed toward successful teachers, or they have cultivated too high an opinion of their own teaching impact.

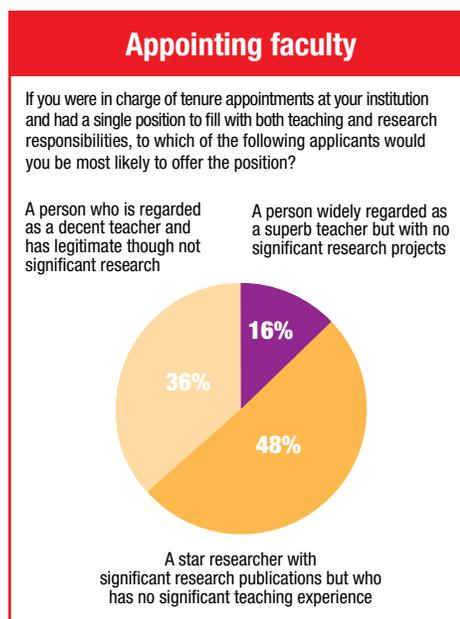
In our opinion, the latter interpretation is not unlikely; the cognitive bias of illusory superiority (often called the "above-average effect") is well understood in the social psychology literature.¹¹

"There have been many objective studies done that show that the majority of people feel that they are better than the majority," comments George Church, Professor of Genetics at Harvard Medical School, Professor of Health Sciences and Technology at Harvard and MIT, and Director of the Lipper Center for Computational Genetics at Harvard Medical School. "You can even tell subjects in advance that this is a statistical error that people often make, yet the majority will still rate themselves better than average." Could some scientists' overstated opinion of their own teaching effectiveness be one of the reasons why the quality of classroom education is too often inadequate?

4. The Heart of the Matter: Respondents Value Education More Than Research, but They Would Appoint a Skilled Researcher over a Skilled Teacher for an Open Tenure Spot

When survey respondents were asked about the relative importance of teaching and research responsibilities to the future of science worldwide, a substantial majority (77%) said they considered teaching responsibilities to be equally as important as research responsibilities. Of the remainder of the respondents, a clear majority (16%) considered teaching responsibilities to be more important than research responsibilities. In fact, only 7% of respondents considered teaching responsibilities to be less important than research responsibilities. Therefore, at least on paper, the scientists who responded to our survey consider teaching to be just as important as or even more important than research to the future of science. This is their own professed belief.

Yet our respondents' hypothetical actions did not agree with their professed values. The respondents were provided the opportunity to appoint a hypothetical candidate to an open tenure position in their department. The survey specified that the selected candidate would be expected to both teach and perform research once appointed. Respondents were



given the choice of three hypothetical candidates: a star researcher with no significant teaching experience, a star teacher with no significant research experience, and a decent teacher and decent researcher who is not a star in either discipline. Despite their assertions that teaching is equally as important as research (if not more important than research) to the future of science, the plurality of respondents (48%) said they would appoint the first candidate—the star researcher with no significant teaching experience.

No one who has observed tenure appointments at universities would doubt the respondents' sincerity in their answers to this question. Anecdotally, priority is very clearly given in tenure appointments at most institutions to star researchers over star teachers, even though scientists themselves apparently place an equal or greater personal value on education. Why is there such a discrepancy between scientists' values and their decisions regarding education? We believe that this is a crucial question that must be answered in order to make a material impact on the state of science teaching.

5. Respondents Believe That Student Talent and Work Ethic Are More Important Than Teaching for Driving Student Success

One part of the answer may be found in another result from the survey. When asked to rank five commonly accepted drivers of student success in order of the role they feel they play in student success (with 1 being least important and 5 being most important), respondents felt in extremely large numbers that the students' native talent and work ethic are the most important (overall average score of 3.9), followed by lectures nearly a full point behind (overall average score of 3.0). Perhaps because scientists feel that student ability and drive is the most important determinant of success, they do not consider it of preeminent importance to appoint superb teachers to valuable open tenure positions. Is this view supported by data?

In their book, *Talking About Leaving: Why Undergraduates Leave the Sciences*, Elaine Seymour and Nancy Hewitt¹², sociologists at the Bureau of Sociological Research at the University of

Colorado in Boulder, present data to the contrary in a U.S. context. Seymour and Hewitt interviewed hundreds of undergraduate students across the U.S. whose high school SAT math scores were at least 650 out of 800 and who had started their college careers in natural science, mathematics, or engineering. The interviewees were randomly selected for the authors by the participating colleges and universities from a much larger pool of students whose academic profiles matched the authors' research design. Seymour and Hewitt found that approximately half of the students interviewed had switched out of their science, mathematics, or engineering program by senior year ("switchers"), while the other half remained in their initial major and planned to graduate with a degree in science, mathematics, or engineering ("nonswitchers").



Although science, mathematics, and engineering faculty members often cite a lack of native ability and willingness to work hard as among the major factors that cause students to become "switchers," Seymour and Hewitt found that this was not the case. Their data showed that classroom climate and faculty pedagogy are the two major factors that contribute to the choices undergraduate students make about pursuing science majors and their satisfaction with science as a choice of major. Competitive class climate, strict grading, overpacked curricula, and the overt "weed-out" attitude of some faculty were the most-cited reasons for abandoning a science major. Of note, the authors emphasize that, in these studies, the "switchers" and "nonswitchers" are not identifiably different populations of students, and academic ability is not a reliable predictor of who stays and who leaves. They therefore conclude that science classroom environments, instructor teaching styles, and the process of instructional selection is unintentionally causing the loss of able, interested students from science professions.

6. Respondents Feel Their Institutions Value Research More Than Education

A second part of the answer to why there is a discrepancy between scientists' values about

education and their decisions regarding faculty appointments reveals itself in another question from the survey. In this question, respondents were asked to characterize the value their institutions place on education relative to research. The plurality of respondents (41%) felt that their institutions value research more than education, although about 25% felt that their institutions value education and research equally.

This, we believe, is very near the crux of the matter. We believe that the most significant cause of the discrepancy between scientists' personal values and their actions during tenure decisions is their perception of what their institutions want and their desire to make the kind of decisions they feel their institutions want them to make.

Why do scientists believe that their institutions value research more than teaching? Tadamitsu Kishimoto, Professor in the Graduate School of Frontier Biosciences at Osaka University and former Dean, Professor, and Chairman of Department of Medicine at Osaka University Medical School, as well as former President of Osaka University from 1997 to 2003, cuts to the heart of the matter. "Research brings in prestige, grant money, and prizes. Everything in your career here at my university is evaluated by what you have done with your research," he notes. "Here, researchers in the prime of their careers must not teach. They do not have time for education."

We can see that with the way academic science functions now, many scientists have concluded that research and teaching are, in fact, set against each other in a "zero-sum" game—a game in which success in one area is entirely at the expense of success in the other. And it is clear which side of the game scientists feel holds the greater rewards, both financial and social. As a result, scientists naturally align their decisions—about both themselves and others—to promote contributions at the bench over those in the classroom.

Education and Research: A Zero-Sum Game?

Are scientists correct in thinking that research and education are set against each other today in a battle for limited resources? Of the thought leaders we interviewed, most felt that they are.

We have already seen Kishimoto's thoughts on the subject. Chao-Ting Wu, Professor of Genetics at Harvard Medical School, agrees: "I think many faculty would love to teach, but decide not to because they have to keep funding available so that their students and post-docs can stay at the cutting edge of research." David Asai, Precollege and Undergraduate Science Education Program Director at the Howard Hughes Medical Institute (HHMI), former chair of the Department of Biology at Harvey Mudd College, and former head of the Department of Biological Sciences at Purdue University, cuts to the chase: "[The conflict between research and teaching] is an important problem, and it has not yet been resolved."

Shirley Tilghman, Professor of Molecular Biology and President of Princeton University, has an intriguing dissent. She begins, "I think the appearance of tension between the two exists everywhere, from small liberal arts colleges to big research universities. We live with it because we are trying to accomplish two things at the same time." But she argues that teaching and research should actually be viewed as mutually beneficial. "I really believe—and it absolutely was true during my own career—that teaching informs your science and improves your science. Anyone who sees teaching as something that detracts from your science is not taking their teaching seriously. I don't even think you have to be teaching a graduate seminar for that to be true. Just the work of putting together an undergraduate course on whatever your field is will cause you to reflect about that field differently than if you stayed highly specialized in your own little area." Kishimoto also makes a pragmatic qualification to his general opinion: "My experience is that good teaching is an important tool for attracting people to my laboratory. I found that when I put the effort into giving good lectures, then the best medical students came to my laboratory!"

On the whole, though, the majority of the scientists we talked with are in agreement: today, research and education are, in general, pitted against each other in a zero-sum game. Those faculty who emphasize and succeed in research are rewarded in multiple ways; those who emphasize education may achieve personal

satisfaction but rarely reap society's most plum incentives—money, fame, and peer admiration. Yet, saying that research and education are

a zero-sum game today does not mean that they should be. They should not—not if science is to prosper throughout the twenty-first century.

PART III: CONCLUSION

A Realignment of Institutional Values Is Essential to Improving Science Education

No single project can provide a rigorous roadmap to the global effort to improve post-secondary science education. Still, single surveys can highlight clear and important ideas that must inform such a broad-based effort. We believe our survey and follow-up interviews throw into relief one clear and crucial reality: there is a misalignment between the science community's values in regard to education and the decisions it makes about allocating advancement, recognition, and material rewards, and this misalignment is an important reason why the quality of education is often inadequate. **In our opinion, the world of science must confront and resolve this contradiction of values.** The world of science must ensure that research and teaching are not a zero-sum game; that investing personal time and money in teaching is just as rewarding for scientists as performing research.

Tilghman agrees: "The balance between teaching and research is one of the most fundamental problems that an educational institution faces. The most important thing for a university to do is to be very clear about the expectations that it has for its faculty, and then to practice what it preaches. The second most important thing is to have reward systems that reflect what the university's values are. I continue to think that if we set up teaching and research in opposition to each other as if these were utterly different activities, and don't appreciate how intertwined they are, we are always going to be in the position in which they appear to compete."

How can scientists' values and decisions be realigned? A significant part of the lead, we believe, must be taken by the academic institutions that hold so many of the reins of power in the world of science. Institutions, as governing bodies, directly make many of the decisions

that have an impact upon the educational dynamics studied in this survey, and they strongly influence even the personal decisions that individual scientists make. Thus, we believe that academic institutions must make an honest appraisal of their own reward and decision structures vis-à-vis their stated missions. Community colleges generally do recruit, select, and reward excellent classroom teachers in keeping with their expressed mission. But universities classified by the Carnegie Foundation as R1 (first-tier research) and other four-year colleges, although they often claim to hold teaching as an essential part of their mission, do not always recruit and reward excellent teachers.

How, then, can universities worldwide change the alignment of their reward systems to reflect the importance of teaching as well as the importance of research? In our interviews, it was widely agreed that two things are necessary. First, a standardized system of evaluating teaching must be developed. The thought leaders we interviewed had many suggestions, ranging from a peer review system of teaching skills to the tracking of student outcomes to indicate successful teaching. Although the development of such a system presents a challenge, we believe it is a challenge that the global scientific community is more than capable of meeting. Indeed, the engineering community has begun to find solutions to their corresponding challenge. The National Academy of Engineering report *Developing Metrics for Assessing Engineering Instruction: What Gets Measured Is What Gets Improved* proposes using a combination of peer review, student evaluations, department chair review, and self-review to measure teaching quality.¹³ We are confident the international science community can similarly develop, calculate, and promote compelling metrics of educational merit until they are as highly prized as traditional metrics of research merit,



such as impact factor. We will explore potential approaches to evaluating science teaching quality in a future paper in this series.

The second necessary component for change at academic institutions is to tie the key drivers of prestige and financial rewards to teaching. If outstanding teaching were rewarded with the prestige and money that are showered upon outstanding research, scientists would be free to pursue either according to their desires and innate talents. In practical terms, many successful scenarios can be envisioned. For example, one scenario might be to directly compensate faculty financially for the time that teaching takes away from research and do so in a substantial way. Wu agrees: "If you take time off for teaching, you are less able to keep up with the literature, you are away from your laboratory, and the impact upon your research is humongous. How can the university address that? What I think can be done is to provide financial supplements for teaching, because one of the biggest time-sinks aside from teaching is looking for funding. A university can determine what teaching a course might equal in terms of research funding, and then compensate for that time with a sizable grant that can be used to support the scientist's laboratory. The funding for such a program could come from donor gifts. I feel sure that there is an untapped cadre of donors who remember good teaching and would be inclined to donate in support of teaching." Wu suggests that this type of giving could be encouraged by rewarding the donor with a course being named after him or her, such as the Joe A. Donor Introductory Biology Course. "The donor would be honored with the named course, and the teacher would be rewarded with funds for the laboratory, which would make the course something to vie for among faculty," she says. In another scenario, more academic institutions could earmark a number of tenure-track positions to have only teaching responsibilities, and award tenure to faculty in those positions purely on the basis of their teaching records, as has been done at Western Michigan University with the creation of the tenure-track "faculty specialist" category.¹⁴ This would create breathing room for faculty who are skilled at and passionately drawn to teaching but would otherwise feel obliged to give the "publish-or-perish" dynamic their main focus. It might also, as a knock-on effect, begin to raise the lower prestige and compensation borne by

faculty in non-tenure-track temporary teaching positions, who account for a significant segment of university and college teaching faculty (more than half of postsecondary faculty in the U.S., for instance).¹⁵

On the other hand, universities can also capitalize on particular tenured faculty members' zeal for research by financially rewarding their laboratories for participating in undergraduate research programs, which are well known for engaging students. Says Church: "In my opinion, some star researchers don't enjoy and will never be highly successful at teaching because it doesn't match their personality type. Rather than finding ways to move these stars into a classroom environment where they won't excel, why not find more ways to take undergraduate students into their environment and expose them to these scientists' infectious enthusiasm for research?"

Other scenarios for change involve using the rewards of prestige and honor. Tilghman explains, "At our Commencement ceremony, we honor four members of our faculty for their outstanding teaching. It is one of the highlights of our Commencement exercises. It's another way of emphasizing that teaching really matters to this institution . . . and the award comes with a check." Wu suggests that a university could establish named, funded professorships to be granted on the basis of teaching excellence, much as named, funded professorships are granted on the basis of research excellence today. Nancy Moreno, Associate Professor in the Department of Family and Community Medicine and Associate Director of the Center for Educational Outreach at Baylor College of Medicine, comments, "An increasing number of colleges and universities are creating education honor societies for faculty members. At my institution . . . we have an Academy of Distinguished Educators. In order to become a member, one has to receive a criterion-based education award (judged by a peer-panel)."

One unique idea was put forth by Kishimoto. He believes that retired researchers should be actively recruited by academic institutions to be teachers. "Students want to learn from great researchers, but mid-career scientists often do not have time for education. Maybe the best education can be given by those who are retired

from research. At that point, excellent retired researchers can take the time to become excellent lecturers and can pass on their knowledge.” How could this be brought about? Perhaps if a small number of prominent and accomplished researchers, such as Nobel laureates, were to dedicate their latter years entirely to teaching, the example would be sufficient to inspire a larger pool to do the same.

Eddie Lunsford, Biology Instructor at Southwestern Community College, suggests that not only should excellence in teaching be measured and then rewarded, it should also be facilitated by training science faculty members to teach well. “What I really wish for, although I fear that it will never happen, is that certification to teach at institutions of higher education be required, as it is with high school and elementary teachers. Many times university faculty go into a classroom to teach with absolutely no background in learning theory. Some type of formal certification process, perhaps not a two-year degree, but more than just a two-hour workshop, would benefit everyone.” We consider this idea crucial to improving of the overall quality of teaching, and will explore potential approaches to training and certification in a future paper in this series.

While one part of the lead in realigning rewards with values must come from universities, another significant part must be taken by funders of science, including government agencies and private foundations. As discussed earlier, even scientists who value and enjoy teaching more than research often feel obliged to prioritize research because there is far more funding available to support research than teaching. This is a changeable situation. By virtue of a simple but decisive shift in strategic priorities at the highest levels of funding, something approaching comparable amounts of money could flow into supporting excellence in teaching and supporting productive research. HHMI offers one encouraging example. Asai explains, “HHMI provides grants to individuals for science education. The individual grant recipients—called HHMI Professors—receive up to one million [dollars] over a four-year period to innovate in science education. This program has the goal of putting prominent scientists in a position to engage in education—developing and restructuring

courses, mentoring, designing new programs, engaging in research with undergraduate students, and more. To date, a total of 40 HHMI professors have been recognized; each is a distinguished, recognized scientist and creative scientist educator. I’d like this program to continue to grow and catch the national attention of professional scientists, showing them that there are terrific scientists doing very cool things with students, and that this is rewarded financially.”

Although universities and funding institutions need to be at the head of the pivotal realignment of values to rewards in science, other institutions must play a vital supporting role. First, media companies (including NPG) must apply their expertise to finding ever-increasing ways to turn talented science communicators and teachers into social and financial stars. Could there be a prize for education in the sciences that carries prestige comparable to the Nobel Prize? Such awards would go a long way toward closing up the disparity between the social rewards and prestige accrued by researchers and teachers today. Second, corporations that depend on science can use their financial clout to stimulate and reward exceptional teaching while simultaneously enhancing their public image. They can do this through grants to excellent teaching faculty in the communities in which they do business or by developing a pro bono culture, comparable to that in the legal profession, in which staff scientists donate part of their time each month to mentoring students or even teachers.

Finally, individual scientists in visible and high-impact positions have a major role to play as well. Rather than waiting for environmental drivers to realign around a balance between research and education, these scientists can begin to “vote their conscience.” They can consciously alter their decision making and implicit and explicit valuations in order to support talented young teachers as much as talented young researchers. Tilghman feels strongly that department chairs in particular already have a relatively free hand to set their departments’ agendas. If they send a clear message that teaching skill and commitment will be an important part of determining promotions and salary increases, then the members of their department will put considerable focus on the classroom.

A Call to Action

All of these ideas, while theoretically actionable, require deeper thought and analysis to become truly practical. Each demands profound change from a well-established academic culture. And none of them is sufficient to materially move the mountain by itself; a difficult-to-produce combination of more or less all of them will be necessary. Yet difficult is not the same as impossible. Transformation can occur. The key, we believe, is to begin by acknowledging as

a community that the problem of ambivalence is real and damaging. From the starting point of that consensus, solutions will follow.

It is time to decide. Do we, the world of science, care equally about education and research? If we do, then we must commit now to a broad-based and fundamental rebalancing of our community-wide dynamics. In a situation in which the first to move toward progressive goals will seem to lose ground against more traditional peers, all must move together.

We welcome you to join a follow-up online discussion on the ideas outlined in this paper at www.nature.com/scitable/forums/TimeToDecide

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