The MIT Faculty Newsletter

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Annals of Reengineering

A Dell of a Deal

Theodore A. Postol

MIT's reengineering activity is delivering another triumph of innovation in its unerring quest to bring greater efficiency to our community. It is now possible, with the knowledge of the MIT administration, to purchase Dell laptop computers at a special price to MIT and MIT affiliates. The special price is between 10-15 percent *above* the street price. This bargain was explained to me in a brilliant explication of the market process by MIT's Program Manager for Reengineering and Vice President for Information Systems, Prof. Jim Bruce:

...it appears to me that much of your concern has to do with differences between the model you have for how computers are sold and how the marketplace actually works. Far from being monolithic and having only a single way to sell each product, each computer company sells through many different sales channels...This often leads to discontinuities in the market where one product will be available in only one sales channel, or where very similar products will have different prices in different channels.

(Continued on Page 3)

Faculty Survey Results Offer Some Surprises

Lydia Snover

The most important professional goals of MIT's faculty, in order of their importance, are: to be a good teacher, engage in research, and be a good colleague, according to the results of the 1995 Higher Education Research Institute (HERI) Faculty Survey.

Distributed to 951 MIT faculty in the fall of 1995 with a second mailing sent to non-responders in the spring of 1996, as of this May 337 faculty had returned surveys to HERI. The responses came from 290 men and 47 women. This represents a 35% return for the total faculty and a 37% return for women faculty.

The four most important/essential personal goals of our faculty are: to become authorities in their own fields, raise a family, obtain recognition from their colleagues, and develop a philosophy of life. Raising a family is less important to the female faculty than the male and developing a philosophy is less important to the men than the women.

The faculty perceive that the issues that are the highest priority at MIT are: the promotion of intellectual development, enhancement of MIT's national image, and hiring faculty "stars."

(Continued on Page 18)

Restructured Dean's Office Prepares for the Future

Rosalind H. Williams

On 1 October, 1997, President Vest announced a major restructuring of the Office of the Dean for Undergraduate Education and Student Affairs. Before that date, offices directly concerned with student services had been separated into three reporting lines:

1. The existing dean's office, reporting to Provost Joel Moses: this included Central Administration, Undergraduate Academic Affairs, Residence and Campus Activities, Counseling and Support Services, and the Office of Minority Education.

2. Two offices responsible for operations in residential and campus life, reporting to Senior Vice President Bill Dickson: Housing and Food Services and Campus Activities Complex.

3. Offices dealing primarily with student financial and academic information, reporting to Vice President for Administration Jim Culliton: Admissions, Bursar, Career Services and Preprofessional Advising, Registrar, Student Financial Aid, and Student Information (MITSIS), as well as Athletics.

(Continued on Page 5)

Integrating Biomedical Science into the Engineering Curricula: Two Perspectives — Pages 6 & 7

Teach Talk — Page 8

Also: Outgoing Mail Service Explained; Classroom Videotaping; M.I.T. Numbers

Contents — Page 2

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Contents

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Annals of Reengineering

A Dell of a Deal

Postol, from Page 1

As a *re*-engineered member of the MIT community I decided to *re*-test the implications for MIT purchasers of Professor Bruce's *re*-engineered concept of "market model," and his concept of different "sales channels."

Reengineering an experiment derived from an earlier incident with Dell, I asked an individual from MIT to phone Dell's educational marketing division and attempt to obtain a price quote for a notebook computer advertised in the 1996 September *PC-World* for $2,699. The price quote to the MIT purchaser for this computer was a whopping $3,526! In this price quote, a $259 PCMCIA modem card was added to the quote and listed with other items at a cost of $0.00. The quote also listed at no charge an item described as a "3 Year Limited Warranty with years 2&3 NBD Parts and Delivery." This item added a hidden charge of between $250 and $300 to the purchase price that the customer was not informed about. However, even with this information obtained from other sources, the math still did not add up!

I continued the experiment by obtaining more than a half dozen additional quotes using different individuals. All the resulting price quotes were in excess of the magazine-advertised street price. At the end of this process, I, who have no idea what Reengineering is about, personally phoned Dell and asked them explicitly for a price on the "bare" advertised computer. The quote I received for the computer was for $2,798. Minutes after obtaining the special "Dell Deal" for MIT, a colleague made a phone call at my request to Dell Direct, the *public* marketing arm of Dell, and exactly the same computer was purchased for $2,630. Thus, it seems that the steady hand and vision of Reengineering is delivering to the MIT community – yet another *Dell of a Deal!*

This recent experience, of course, has not been the first Dell of a Deal I have gotten with the aid of MIT's highly oiled and reengineered administration. In February of this year, I attempted to call Dell's shenanigans to the attention of Barry Rowe, MIT's director of Purchasing, who I naively thought would be an avid supporter of Reengineering, and would thereby jump at the chance to make our community a yet more finely honed engine of economic progress. At that time I had received a price quote from Dell of $3,629 for a machine that was at the same time being advertised on Dell's bulletin board for $400 less than the "special" price to MIT. When I asked the Dell representative about the price discrepancy, she explained that I was "mixing up apples and oranges."

Although I was humbled by the knowledge that I had no idea what Reengineering is, I nevertheless felt that I had climbed far enough out of the primordial sludge to be able to understand the difference between apples and oranges. So I persisted in seeking an explanation of the subtle secrets of life; the secrets that could explain the difference between the birds, the bees, the millipedes, megalosours, and, of course, the $400 price discrepancy. Unfortunately, the Dell representative could not provide an explanation that my simple un-reengineered mind could grasp.

Hat in hand, and seeking the greater wisdom of a reengineer, I turned to MIT's head of Purchasing for help. After a good bit of foot-dragging on Mr. Rowe's part, followed by a good bit of foot-prodding on my part, a reluctant Mr. Rowe claimed that he had looked into the matter. This claim culminated in the following dazzling running commentary, which Mr. Rowe was good enough to put in writing to me, and in copy to his collaborating reengineer, Prof. Bruce:

Dell Marketing is the sales arm that deals with educational, government and health care customers. Dell Direct is the mail order part of their business which deals with individuals.

[MIT has] a "reseller agreement" ... with Dell (Marketing)...which was used by the MIT Computer Connection for the purchase, markup (to offset expenses), and sale of Dell computers to Institute departments and labs and personally to faculty, staff, and students. [Note: The machine that I purchased at a "street price" of $2,630 was at the same time being offered by the MIT Computer Connection (MCC) for $3,175. The MCC machine had a larger hard drive (1.3 GB rather than 810 MB), which according to Dell's published price schedule results in a price adjustment of $200. Thus the "special" price to MIT offered by the MCC is $2975 for the same machine I purchased without affiliation for $2,630.]

...Dell's policy [is] to extend Dell Direct pricing to Dell Marketing customers if the buyer and/or the Dell Marketing sales representative [is] aware of a Dell Direct advertised price that [is] lower than Dell Marketing pricing less educational discount of 2%. If Dell Direct pricing [is] lower it would not then be subject to the 2% educational discount.

Dell Marketing and Dell Direct are separate corporations with separate pricing strategies. Dell Direct prices are not automatically provided to Dell Marketing. However, Dell Marketing sales representatives are encouraged to be aware of Dell Direct advertised

Annals of Reengineering

A Dell of a Deal

Postol, from preceding page

pricing. This is not a fool proof arrangement and Dell Direct pricing is capable of frequent and rapid change.

Sales to the Government are handled in the same manner by this division, although the Government probably has GSA discount arrangements which provide deeper discounts probably in the range of the discounts which the MIT Computer Connection gets. However, for certain deeply discounted Dell Direct "bundles" which the sales rep is not aware of, I suspect the Government pays the higher price.

In your case you were aware of a lower advertised price, but your sales rep was not. Evidently you did not inform her of this as she quoted higher prices to you for the XPi 120 and 75 on February 8.

Dell Marketing standard pricing includes one year standard no cost warranty and second and third year parts only NBD warranty at a cost of $199 for the XPi, which the customer can buy or not.

Dell Marketing's written quote (#6912104) of 2/8/96, for $3,629 including discount for a XPi 120 with 1.2 GB and one year standard no cost warranty and second and third year parts only NBD warranty was from Dell's standard price lists and was not correct. A bundled price for the XPi 120 was available, but was not extended to you because of an oversight on the part of the sales rep or because she was not aware of the bundle price. In that the cost of the second and third years warranty was included in the sell price as indicated on Dell's price list, the $.00 indicated on the quote for this feature should be interpreted as "no additional charge."

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Based on all of the above ... I consider Dell's explanations reasonable, though not to my liking. I would prefer an arrangement where Dell Direct bundle pricing was automatically transmitted to Dell Marketing. However, [MIT Purchasing is] not in a position to dictate how Dell runs its businesses.

I'm sorry, but I will be retired by the time you receive this....

If anyone understands Mr. Rowe's explanation, please call me at extension 3-8077.

Anyone wishing a copy of the quoted correspondence and the materials referred to in this column, including the numerous inflated price quotes to MIT, please call my secretary, Lynne Levine, at extension 3-0133. Anyone wishing to discuss the matter with me directly can call me at my office, 3-8077.✣

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Outgoing Mail Service Explained

Following is an excerpt from a memo by Mail Services Manager Peggy Guyer (x3-6000; pguyer@mit.edu) distributed at the beginning of the semester.

In order to clear up any misunderstandings, I thought all of you might like to hear what the procedures are for having your outbound mail handled by Mail Services. It's actually a pretty simple system.

First, we are taking the outbound mail on incrementally, as we add Distributed Mail Centers, and as departments' postage meter leases expire....

The procedure is as follows:

The departments sending out their mail deposit it, unstamped, in a box designated either "US Mail to be Processed" or "Int'l (international) Mail to be Processed." The mail should be bundled either with a laminated barcode card (supplied by Mail Services) or simply with a sheet of paper indicating your department and account number.

We pick up the outbound mail starting around 2:30 in the afternoon. We pick up again around 5:15 pm. ALL OUTBOUND MAIL IS SENT OUT THE SAME DAY IT IS GIVEN TO MAIL SERVICES.

We are encouraging you – strongly! – to give your mail to us for that earlier pickup if at all possible, because that is mail that we process and then send out to be barcoded and sorted by ZIP, before it is given to the Postal Service that night. This mail not only saves the Institute postage, it moves much faster once it hits the Postal Service. Mail that we get at the later pickup is posted at full rate and not sorted. So if you have something to mail in the late afternoon, and it is not crucial that it be in the mail that night, give it to us the next morning.

*One small caveat about the early pickup – because the presort vendor turns the mail over to the Postal Service after midnight, we postmark our "presort" mail for the following business day. So if you have a letter that for legal reasons *must* be postmarked today, please flag it with a post-it note and we will meter with today's postmark and give it to the U.S. Postal Service directly.*

Your department will be charged postage on a monthly journal voucher. We can supply details of exactly how many pieces of mail sent, at what price, by date, on request but, please, only if you think have a severe problem. Those reports are humongous! Of course, we can't tell you where each letter went – we meter far too many to keep track of that!....✣

Restructured Dean's Office Prepares for the Future

Williams, from Page 1

Upon the death of Vice President Culliton last spring, it was necessary to reconsider the administrative home of offices that had reported to him. Moreover, there were compelling reasons to consider a larger reorganization of student services at that time.

First, the committee chaired by Linn Hobbs that had conducted the search for Dean Arthur Smith's successor had undertaken a deep, serious review of the dean's office. In the spring of 1995, the Hobbs Committee recommended that the two major wings of the dean's office – academic support, and support for residential and campus life – be more clearly distinguished, so that longer-range academic issues would not be forced into the background under the inevitable pressures of shorter-term events. More particularly, the Hobbs Committee recommended a "two-dean" model: a Dean for Student Life reporting to a Dean for Undergraduate Education. Each dean, the committee advised, should be accorded more authority and resources through the consolidation of fragmented reporting lines.

Since the Hobbs Committee issued its report, Student Services Reengineering has moved forward briskly – which is another reason why it made sense to reorganize student services more broadly. One of the major principles of Reengineering is to analyze work by processes rather than by offices. At MIT, existing organizational boundaries sometimes made it difficult to reorganize student services in this way. The consolidation of reporting lines was an obvious way to speed up and simplify the work of the Reengineering teams.

Certainly a primary purpose of this new organization is to provide more efficient, effective delivery of services to students and faculty alike. Another benefit, while more subtle, is at least as important. Now that a wide variety of activities have been brought together into a common administrative framework, all of us at MIT become more aware of their common purpose: to enhance the overall educational experience of MIT students. In its very existence, the new organization articulates the message of a shared educational mission. Where students eat, where they sleep and study, how they make arrangements for events and activities, how they get advice about academic and career choices, how they find help when they are in distress, how they find advice about financial matters, how they participate in athletics, what they do over IAP – the new dean's office impels us to view all these activities through a common lens, that of education.

To turn this vision of integration into a robust administrative unit will take some time. While all of us in the new office will be involved in this, a central role will be played by the new director of Administration and Operations, Steve Immerman. Integration will happen more quickly if the "new dean's office" is not thought of as an "old office" core around which some new offices are now clustered. Instead, we have to think of a truly new office, one organized around overarching processes: the flow of student information, the sequence of academic experiences, and the provision of residential and campus opportunities that are educational in the broadest sense.

In fact, we do not yet have a new dean's office; we have only a framework for establishing new connections and new ways of working. Building on this framework will not be easy, but at MIT we pride ourselves on our inventiveness – and one of our most significant inventions has been MIT itself. This is an unparalleled opportunity to create a new social invention based on shared information, collaborative working habits, and a common educational mission.✥

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Classroom Videotape Consulting

Most MIT schools and departments participate in the Classroom Videotape Consulting Program. This free service, offered through the Teaching Resource Network (TRN), provides faculty and other instructors the chance to have one or more of their classes videotaped, and to review the tape with a professional teaching consultant.

This service operates independently of schools and departments. The taping and subsequent review are not used as part of any evaluation process. Since the tape belongs to you, you can opt just to be videotaped. However, most faculty have found the consultation to be extremely valuable in providing objective and constructive observations of their own teaching.

To find out more about the MIT classroom Videotape Consulting Program, contact your department headquarters, TRN (x3-9419), or MIT Video Productions (x3-7603).✥

Multidisciplinary Education and HST: A Nexus for Health Sciences and Technology

Martha Gray

Have you ever known of someone who died suddenly – apparently of a heart attack? Every year, hundreds of thousands of middle-aged Americans die suddenly in their homes, cars, or offices from cardiac arrhythmias. In many of these cases, sudden death is the very first sign that the individual has any heart disease at all. Why does this happen? Can one predict who is most at risk? What kinds of questions need to be answered to get at this problem? What kinds of disciplines should be brought to bear in addressing these questions?

Health and medical problems like this are compelling to us on personal and intellectual grounds. They attract faculty and students in a broad array of classical disciplines. Furthermore, as reflected by the fact that health-related expenditures comprise one seventh of the GNP, these are problems that are of fundamental importance in our society. It is reasonable to presume that MIT should have a visible presence in the health sciences, but how does MIT marshal its intellectual resources to address problems like cardiac arrhythmias? Moreover, how does MIT educate its students so that they are able to address these kinds of problems? Health problems are complex and difficult to study, let alone solve, within the context of any given traditional department. They require the productive interaction of natural scientists, engineers, social scientists, ethicists, and experts in management, in brief, the resources of a university.

The Harvard-MIT Division of Health Sciences and Technology (HST) is a successful model of how the resources of a university (in this case two universities) can be brought to bear on education and research in an area which is fundamentally multidisciplinary. By design, HST has reduced the barriers that have long compartmentalized the three major cultures which potentially contribute to solving problems in health: science, engineering, and medicine. The experience of Prof. Richard Cohen, in addressing the problem of predicting sudden death, exemplifies the merging of intellectual resources from ordinarily separate disciplines.

Sudden death in adults, in the vast majority of cases, results from a disorganized pattern of electrical activity in the heart – ventricular fibrillation. In Richard Cohen's laboratory, M.D. and Ph.D. students and research fellows have worked together applying the disciplines of physiology, physics, mathematics, engineering, and clinical medicine to address two main objectives: to understand the underlying electrical instability giving rise to ventricular fibrillation and to develop new noninvasive electrocardiographic techniques for identifying individuals at risk. This research started with observations made from finite element computer simulations of electrical conduction processes in the heart. Animal studies were then conducted to test these observations experimentally. Finally, human studies were carried out which showed that the subtle pattern of variation in the shape of electrocardiographic waveforms observed in the computer simulations and animal studies could be detected in man and appeared to be predictive of susceptibility to lethal heart rhythm disturbances.

Effective treatment for individuals known to be at risk for sudden death currently exists in the form of the implantable defibrillator. Until now, the problem has been that it has not been possible to identify reliably the individuals at risk. MIT has licensed the diagnostic technology developed in Prof. Cohen's laboratory to a (now public) startup company – Cambridge Heart. Having begun with "simple" laboratory questions, a new technology has evolved that has the potential of saving the lives of many thousands of individuals annually.

Similar scenarios in which research culminates in having an impact in medicine could be written about many members of the faculty who have played central roles in HST. Looked at most generally, the research areas encompassed by HST faculty and students lie in several broad focus areas:

(1) Molecular, Cell, and Tissue integrative biology: the science of understanding how biological systems work at length scales ranging from molecules, to cells, to organs, to organisms and from genetics to function;

(2) Biomedical Engineering and Biomedical Physics: the development and use of engineering and scientific principles to understand functionality in living systems and to alter or assist functionality in living systems;

(3) Imaging Science and Technology: the establishment and use of technologies in order to view biological structures and processes;

(4) Biomedical Informatics: the

(Continued on Page 10)

A Modest Proposal for Biomedical Engineering Education

Linda G. Griffith-Cima

It was not long after I joined the faculty at MIT in 1991 as an assistant professor jointly appointed in Chemical Engineering and HST that I became acutely aware of the magnitude of unmet undergraduate educational needs in biomedical engineering. The mechanism was simple: every term *scores* of undergrads called, e-mailed, dropped by, left notes asking for advice on courses and applying to graduate school, seeking UROPs, trying to decide whether to go to medical school or graduate school in engineering, and wondering why there were not more courses in biomedical engineering available for undergraduates. It was overwhelming. And still is.

The number of students interested in biomedical engineering continues to increase, making the problems even more acute. Over 200 freshmen visited the Biomedical Engineering booth at Freshman Midway this year, seeking information about biomedical engineering activities on campus and the new Biomedical Engineering Minor degree. A poll of students in my junior-level chemical engineering course (10.302) showed that roughly two-thirds of the students are interested in biological applications of chemical engineering. Ten percent of the students who received a degree in Chemical Engineering last year double-majored in Biology. Students from several Engineering departments have worked together to start an MIT chapter of the Biomedical Engineering Society, and 65 students attended the inaugural meeting last month. Parents of high school students who are considering MIT call to find out about MIT's biomedical engineering programs, and the students themselves write directly, through the Internet, to find out about biomedical engineering at MIT.

The upshot of this tremendous student interest in biomedical engineering is an urgent pressure on Engineering faculty to address the professional development needs of these students. My experiences are definitely not unique, and my sense of desperation at coping with the magnitude of the problem is shared by many other faculty in the School of Engineering who interact on a daily basis with undergraduates.

A group of faculty from various Engineering departments began to meet informally in 1991 to discuss these issues, and by 1993 this group evolved into an *ad hoc* interdepartmental Biomedical Engineering Curriculum Committee, with members drawn from a broad spectrum of departments in the Schools of Engineering and Science, as well as HST. I have served as co-chair of this Committee since 1993, with Roger Kamm and Alan Grodzinsky alternating as co-chairs. A significant accomplishment of the Committee has been introduction of a Minor in Biomedical Engineering as MIT's first interdepartmental Minor degree. This BME Minor was lauded by the Institute curriculum committees as providing a standard to which future interdepartmental Minors must adhere, and was approved unanimously in May 1995 by a vote of the MIT faculty. More than 30 students have already enrolled in or completed the Minor. The Committee now additionally includes members of the School of Science (from Biology and Chemistry) and serves to coordinate BME activities within the School of Engineering and between the School of Engineering and School of Science.

Formidable administrative issues arise hand-in-hand with opportunities for enhancing biomedical engineering educational programs at both the undergraduate and graduate levels at the interface of engineering with biology. New course development is essential, especially at the undergraduate level, to synthesize approaches from these diverse disciplines, but no structure exists to provide faculty time necessary for creating these between departments. The educational achievements thus far have been made with negligible formal administrative structure or support. (In fact, the BME Minor is run at present by the Center for Biomedical Engineering, which is primarily an interdepartmental research center, with no funding for curriculum development, faculty time, teaching assistants, laboratory supplies, etc.)

The faculty who have been involved with the educational changes accomplished thus far are hoping for administrative changes which will strengthen MIT's ability to educate students in biomedical engineering, and which will allow us to retain a competitive position with other institutions in the future. This is essential because a growing number of top students are interested in combining engineering and biology in their education, and because a growing proportion of future technology will require combining these different disciplines.

(Continued on Page 14)

Teach Talk

When Students Learn

Lori Breslow

In the last "Teach Talk," John Belcher wrote about some of the exciting improvements that have been made in physics curricula and the ways in which physics is taught. Calling physics education "a lively field," Prof. Belcher described it as an area of inquiry "with a theoretical underpinning based on general research in education as applied to physics." Although Prof. Belcher was writing about his discipline in particular, the same thing could be said for mathematics or engineering education: Throughout the country innovations in curricula and classroom practice abound, fueled, in part, by what we know about how students learn. This "Teach Talk" expands upon Prof. Belcher's article to describe in more detail important research into learning styles, and what that research can tell us about how we can improve the way we teach.

Learning Styles: Should You Draw Pictures for an Extrovert?

The basic premise behind the most common notion of learning styles is that individual students have definite preferences in the way they learn; in other words in any given classroom, different students will have a variety of ways of receiving and processing information that are particularly comfortable and natural for them. Students may differ, for example, in whether they prefer to get their information through visual or auditory channels; whether they are more likely to process information actively by working with their hands or reflectively through introspection; or whether they comprehend ideas better if material is presented to them inductively or deductively. There are at least a dozen such classification schemes by which educational theorists have attempted to define and categorize students (probably the most famous of which is the Myers-Briggs Type Indicator). Educational researchers who subscribe to this notion of learning argue that instructors need to adopt teaching styles that are compatible with the ways their students prefer to learn.

To the extent that this way of looking at learning reminds us that our students are not a single mass, and that teaching is an interactive process that must take into account the characteristics and needs of those on the other side of the podium, it is a good thing. To the extent that that understanding leads us to develop and use a variety of techniques in the classroom – lectures with visual aids, small-group discussions, demonstrations, hands-on activities – the idea of learning styles also makes a valuable contribution to our teaching. But as with other attempts to put complex human beings into simple categories, this way of thinking about how students learn has its shortcomings.

Another Approach: "Deep" and "Surface" Learning

There is, however, another stream of research on learning that I believe contributes even more to our understanding of what happens to our students in the classroom (not to mention the library, the lab, and the dorm) as they grapple with the material we want them to know. This is the notion of "deep" and "surface" approaches to learning, a theory that comes from 20 years of research observing how thousands of students throughout the world in over 40 different disciplines actually go about the process of learning.

First put forth by Ference Marton and Roger Säljö working in Sweden in the mid-1970s, deep and surface approaches refer to the ways in which students engage material. They may work with material superficially, looking primarily for the facts they will be tested on or those they need to know to get an assignment done. Or they may work with material on a more complex level, trying to integrate it with other things they know so that their knowledge of a specific phenomenon, process, or idea becomes more sophisticated and expert. The distinction is not, these researchers explain, between learning just the facts or learning higher level concepts. The difference is between learning the facts in an unconnected, disorganized way for a narrowly defined purpose, or learning the facts in relation to concepts so that understanding is broadened. As researcher Paul Ramsden writes in *Learning to Teach in Higher Education*, "Surface is, at best, about quantity without quality; deep is about quality and quantity."

The idea of deep and surface learning is applicable to all disciplines, but the distinction does have different meanings in various fields. In more technical subjects, a deep approach is defined – at least initially – as a narrow concentration on details, but also an understanding of logical connections. As a mechanical

(Continued on next page)

When Students Learn

Breslow, from preceding page

engineering undergraduate recently explained in describing a course in which he was obviously learning in a profound way, "Before I was plugging numbers into formulae. Now I understand better how things fit together – how the calculations I do make sense in the lab, and how that works with the concepts we've been studying in class."

It's important to realize that some students aren't "surface learners" while others are "deep learners." Rather, students move back and forth between these two kinds of learning (or probably more realistically, they move along a continuum defined by these two extremes) learning content in a relatively more deep or relatively more surface way at different times. But if it's true that approaches to learning aren't something intrinsic to students but instead chosen selectively, then the next logical question is, what motivates students to select one approach over the other?

In order to answer that question, Marton, Säljö, Ramsden, and others went back to the field. As James Rhem, executive editor of the National Teaching and Learning Forum, explains, "They approached students, observed their actions, and listened very carefully as they described how they actually went about studying in particular situations." And that work yielded in some ways a not-so-surprising result: Students make decisions about how well they are going to learn something from cues in their environment. To put it simply, students make decisions about how they will approach learning tasks quite pragmatically by assessing what will be expected of them in any given situation and then trying to fulfill those expectations. It is true, these theorists say, that how students learn will vary to some degree according to personal preference, habit, or personality, but, as Rhem points out, "[approaches] vary more in response to a student's perception of particular contexts and the intention the student forms as a result."

How Our Teaching Can Benefit

The last question, then, is what is it about the way we structure our students' "learning environment" (a phrase that is meant to encompass not only an individual course, but departmental and campus climates, as well as curriculum design) that encourages deep or surface learning.

Students take a surface approach to learning, the research says, when:

- There's too much material in the curriculum as a whole and/or course in particular;
- The messages about how a student is rewarded in the course aren't clear;
- Feedback on progress isn't given frequently enough or is of poor quality;
- Opportunities for independent learning aren't present;
- Methods of assessment stress surface learning.

Of all of the above, the experts point out that evaluation may be the most crucial variable. Instructors need to decide for themselves what level of understanding they want students to achieve (this can vary as different parts of any one course may demand different kinds of comprehension) and design methods of assessment that will lead students in the right direction.

Yet the experts also acknowledge that fostering deep learning is no easy matter. For example, they describe several experiments in which the instructor thought he/she had created assessments that asked the students to go beyond mere repetition of facts only to discover that students still found ways of providing the instructor with the answer they thought she/he wanted. Yet Ramsden underscores that "it's not so much the specific teaching and assessment methods you use that make the difference ...but the ways your students perceive them. The key to understanding approaches," he continues, "is that they arise from the students' *perceptions* of the teacher's requirements." [italics mine]

Finally, then, what techniques can we use – what signals can we give – to encourage deeper learning? Five ideas are suggested:

- To the extent possible, give students some choice in the content of the course and the method of study;
- Demonstrate your own commitment to the subject matter and stress how it is relevant to the student;
- Connect new ideas to the students' prior experience and existing knowledge;
- Use teaching methods that encourage "active learning" with students doing things with and learning from one another;
- Find ways to assess students that give them the opportunity to be actively engaged with the material.

While there's no doubt that some of these techniques can be labor intensive and time consuming to develop, others are fairly easy to implement (e.g., being explicit with students about your expectations and objectives). And the research indicates that the payoff is there. (Interestingly, students themselves report higher levels of satisfaction when they use deeper approaches in their studies.) Perhaps, then, the important thing to know about student learning is that it can be profoundly affected by the relationship between you and your students and by the messages you give them about the ways they are to learn from you.

Multidisciplinary Education and HST

Gray, from Page 6

archiving, analyzing, and dissemination of biomedical information; and

(5) Clinical Sciences: epidemiological risk and disease assessment, and the development and evaluation of therapeutic and diagnostic tools. Together, these areas form the foundation of efforts by HST faculty and students to solve health-related problems. Clearly there is much overlap among these areas. Moreover, there is considerable overlap with the "classical" disciplines represented by departmental units. Indeed, with few exceptions, all of HST's approximately 200 faculty members have primary appointments in a "classical" department at either MIT or Harvard. *The unifying theme, though, is that the fundamental objective of the research and education is to have an impact on health care, to bring the science or engineering "from bench-to-bedside."*

While the intellectual richness of the five areas listed above is part of the fabric of HST, the human and physical resources are deployed broadly across the Harvard and MIT communities. Probably the most important "glue" which holds the fabric together is the students. There are roughly 320 students currently enrolled in HST's educational programs. Although these programs lead to different types of degrees (some conferred by Harvard; some by MIT) there is a common philosophy that permeates all programs. All, by design, integrate information from several fields in a very substantive way and attempt to use to the best advantage the complimentary resources of both institutions.

• The Medical Engineering and Medical Physics (MEMP) program is intended for students who desire a career in the area of health sciences that builds on their engineering and physical sciences background. These students complete a fairly typical doctoral program with the following important addition: They take preclinical courses with the HST-M.D. students, and then participate in three clinical experiences: introduction to clinical medicine, where they learn how to take a history and physical examination, etc.; medicine clerkship, where they serve as medical students in a hospital medical unit; and preceptorship, where they go in-depth into an area of their choice that is at an interface of clinical medicine.

• The Speech and Hearing Sciences doctoral program was recently inaugurated through the efforts of its founder, Prof. Nelson Kiang, and a number of faculty at Harvard and MIT. The only program of its type in the country (and the only training program funded in this area by NIH) it seeks to prepare its students to be leading research scientists who can apply quantitative and biological methods to problems relating to speech and hearing. The highly multidisciplinary character of the program is reflected by the range of research projects undertaken by students and faculty and in the program's core curriculum.

• The Radiological Sciences Joint Program is a joint doctoral program with MIT's Nuclear Engineering Department. These students complete a fairly typical doctoral program within the Nuclear Engineering Department, but have in addition, a focused clinical experience composed of three basic biomedical courses and a one-month clinical practicum. The research and education of radiological sciences students typically revolves around radiation therapy or imaging (including magnetic resonance imaging, computer-aided tomography, positron emission tomography, and single photon emission tomography).

• The Medical Informatics Program is a collective effort of about 30 faculty from the Harvard and MIT communities who provide graduate and postgraduate research training opportunities. Three primary areas of study include: informatics as related to health and health care delivery (e.g., clinical information structures, decision

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Multidisciplinary Education and HST

Gray, from preceding page

making, etc.), biomedical science (modeling and simulation, data banks, etc.), and imaging (e.g., acquisition, processing, correlative imaging, etc.).

• The Medical Sciences (M.D.) program is oriented towards students who have a background in the quantitative sciences (40 percent have degrees in engineering or physics, most of the others in biology and chemistry). In the preclinical curriculum, taught by Harvard and MIT faculty, students are expected to develop some understanding of the scientific and engineering underpinnings of normal and abnormal human physiology and clinical medicine. All students engage in research (an experience which often includes a year of full-time research, and 3+ years of part-time research); 30-40 percent of them ultimately pursue a Ph.D. degree. (Students pursuing both degrees are automatically in the "M.D.-Ph.D. program.")

• The Clinical Investigator Training Program is devoted to the training of post-doctoral physicians from a variety of clinical disciplines in the techniques and processes used in patient-oriented research. The specific curriculum allows trainees to develop expertise in the performance of clinical investigation while taking courses covering computational and statistical sciences, biomedical ethics, principles of clinical pharmacology, *in vitro* and *in vivo* measurement techniques, and aspects of the drug development process. This is the fourth year of the program developed by Professors Robert Rubin and Alan Moses, and funded by an unrestricted grant from Pfizer, Inc. The home base for this program at MIT is in HST's Clinical Research Center.

The cross-cultural and cross-institutional mix of students and faculty associated with the degree-granting educational programs is, not surprisingly, also evident in the classroom teaching by HST faculty members in both HST and non-HST courses. For example, in the course entitled "Physiology of the Ear," one of the core courses in the Speech and Hearing Sciences Program taught by Prof. Dennis Freeman (MIT) and Dr. M. Charles Liberman (Harvard), students use approaches ranging from acoustics and hydrodynamics to the biology of synaptic transmission, to examine experimental observations, develop and analyze quantitative models, and assess clinical relevance – for example the efficacy of cochlear implants.

Throughout its 25-year existence, HST has been an unusual enterprise. At the outset, the organizational structure "broke the mold" of the traditional department-centered approach in order to optimally foster an interdisciplinary and collaborative approach to both research and education. The paradigm of HST has demonstrated that a multidisciplinary approach to education can be enormously successful.

Prof. Elazer Edelman's efforts in creating a teaching laboratory for tissue engineering and in developing modules for an undergraduate biomaterials course (3.081) provides an example of the infusion of biomedical concepts into the teaching of engineering students. The interface between living cells and a natural or artificial material is of fundamental importance to areas ranging from tissue engineering to implant design. One of the modules demonstrates this idea using the example of endovascular stainless steel stents (meshed tubes expanded inside a blood vessel and left in place to maintain luminal patency). These stents inevitably induce damage of the vessel wall, but this damage is minimized if the stents become coated with cells. To illustrate the design and biological issues, the students examined how the surface composition and roughness of the stainless steel corresponded with the ability of cells to adhere to the surface.

The impact of these educational programs and teaching efforts is, of course, difficult to measure. But, by typical metrics, they have been outstanding successes. The M.D. and MEMP programs have been in existence for enough years to allow an assessment of outcomes. They each begin with a highly selective admissions process (<10 percent of applicants are admitted to each program). MEMP graduates have been

(Continued on next page)

Multidisciplinary Education and HST

Gray, from preceding page

Vignettes of HST Graduates

• ***Ed Cheal*** [MEMP, 1986], presently the director of Research and Development in the implant division at Johnson & Johnson Professional, Inc., manages the development of orthopaedic prostheses – a job which requires collaboration and coordination among a team of engineers and orthopaedic surgeons. His Ph.D. and post graduate research concentrated on the biological response of bone to an orthopaedic implant and the role of mechanical and material interface factors in eliciting that response.

• ***Dennis Choi*** [M.D., 1978] is chairman of the Department of Neurology at Washington University, St. Louis, and is the leading authority on the excitotoxic action of glutamic acid in injury to the central nervous system.

• ***Gilbert Chu*** [M.D., 1980] is associate professor in the Departments of Medicine and Biochemistry at Stanford. His research is concerned with how cells recognize and respond to damaged DNA and the roles of proteins that bind to damaged DNA in the repair and recombination of the nucleic acids, important issues in carcinogenesis.

• ***David Ho*** [M.D., 1978] is a professor of Medicine at New York University and the head of the Aaron Diamond Center for AIDS Research. He is an international leader in HIV virology.

• ***Karen Hsiao*** [M.D., 1982] is associate professor of Neurology at the University of Minnesota. She has made major contributions in several areas. She recently reported the development of transgenic mice overexpressing amyloid protein, associated with pathologic and biochemical abnormalities similar to those seen in human Alzheimer's disease.

• ***Bruce Rosen***, a graduate of both the HST MEMP and HST M.D. programs [1984] is currently director of the NMR Imaging Center at Massachusetts General Hospital. He is well known for his contributions in the area of "functional" imaging – that is, magnetic resonance images of the brain in which areas having some functional activity (e.g., visual cortex) are highlighted by virtue of the fact they receive increased blood flow.

• ***Mark Salzman*** [MEMP 1987] recently moved from his position as a full professor at Johns Hopkins University to play a leading role in the development of a Ph.D. program in Biomedical Engineering at Cornell University. He has done groundbreaking work in the area of drug delivery and tissue engineering. Recent examples include the use of polymeric drug delivery systems to administer drugs and natural biomolecules to specific organ sites to treat diseases such as brain tumors and neurodegenerative diseases, and to deliver vaccines for reproductive health.

• ***Cynthia Sung*** [MEMP, 1988] a member of senior staff of the Biomedical Engineering Program at NIH, has developed analytical and experimental models to address problems in effective delivery and clearance of therapeutic agents used in oncology. She has made major contributions to the planning and effective implementation of clinical trials of new chemotherapeutic agents with emphasis on brain and micrometastatic disease.

• ***Jose Venegas*** [MEMP, 1984] is an associate professor of Anesthesia and Bioengineering at Massachusetts General Hospital and has made many major contributions in pulmonary medicine, including developing a theoretical understanding of high-frequency ventilation techniques, and pioneering novel positron emission methods for evaluating the coordination of blood and gas flow in the lung. These techniques are being utilized in understanding and optimizing gas exchange associated with novel respiration therapies such as partial liquid and nitric oxide ventilation.

• ***Michael Weiss*** is professor of Medicine and of Biochemistry at the University of Chicago where he is a principal member of the Center for Molecular Oncology.

• ***George Wodicka***, a MEMP graduate [1989] who is now an associate professor of Electrical Engineering at Purdue, has had an active research program using sonic techniques to solve clinical problems. His projects range from developing a basic science understanding of the mechanisms responsible for breath sounds (generally heard through a stethoscope) to using this information for sleep apnea diagnosis and in the development of a patented approach to positioning and monitoring the patency of neonatal endotracheal tubes. Professor Wodicka was recently appointed a chair of their new Biomedical Engineering graduate program, which built on a model of HST, and is a joint effort of two universities (Purdue and Indiana University Medical and Dental Schools).

• Four HST graduates populate the ranks of MIT faculty: ***Richard Cohen*** [HST], ***Elazer Edelman*** [HST, Department of Medicine Brigham and Women's Hospital], ***Martha Gray*** [HST, EECS], and ***David Page*** [Biology].

Multidisciplinary Education and HST

Gray, from preceding page

very successful in winning the prestigious NSF PYI/NYI/CAREER awards (7 out of 25 given nationwide in biomedical engineering in the last 6 years) and in garnering faculty positions. Of the 42 MEMP graduates who have been out more than 5 years, at least 12 are in positions of leadership. About half of the MEMP graduates going on to academia do so in medical centers (12 percent of the graduates are faculty at Harvard Medical School) in a diverse range of departments. Their integration within the medical establishment is an essential step in establishing medical engineering and medical physics as an integral part of academic medicine and the health care delivery system. Similarly, M.D. graduates have obtained residency and, subsequently, faculty positions in leading medical schools and universities (25 percent at Harvard Medical School). The vast majority continue to be active in research, and some 30 percent of them have positions of leadership.

In thinking to the future, it is instructive to review how HST was created in the first place. In 1966 the National Institutes of Health urged MIT to create a medical school. At the same time, Harvard Medical School was being urged by some of its faculty members to develop a program in biomedical engineering. A joint Committee on Engineering and Living Systems was formed to explore opportunities in these areas. Their work ultimately culminated three years later in a resolution, passed by the full faculties of MIT, Harvard Medical School, and the Harvard School of Public Health to establish a Harvard-MIT School of Health Sciences and Technology to foster the development of health-related programs of education, research, and service between the institutions. Based on the success of the first seven years, the governing boards of the two universities decided to proceed with the development of a stable institutional structure which would be an integral part of the two universities. The term Division was chosen as a name for this academic structure rather than the original term "school" which has different meanings in each university. In 1977 the Harvard-MIT Division of Health Sciences and Technology was established by vote of the corporations of MIT and Harvard. The Division is by design multidisciplinary and without internal departmental structure.

Throughout its 25-year existence, HST has been an unusual enterprise. At the outset, the organizational structure "broke the mold" of the traditional department-centered approach in order to optimally foster an interdisciplinary and collaborative approach to both research and education. The paradigm of HST has demonstrated that a multidisciplinary approach to education can be enormously successful. (There are many examples of successful multidisciplinary research organizations at MIT.)

HST's success has not come without struggle. Because MIT is a strongly department-based organization, the institutional impulse is to focus on the core of the departments and not the edges where they meet. Furthermore, tradition has a strong grip on institutions and there is often great resistance to unusual organizational structures – particularly as they relate to education of students. The pressure to conform (e.g., to make the M.D. program look like other M.D. programs, or to make the engineering activities more department centered, or to ask would this student or faculty "make it" in a traditional discipline) has been the essence of the "discomfort" zone for as long as HST has existed. At the same time, being in the "ether" (as some have referred to HST) is a deliberate choice for most of its participants who, while able to "fit" in a traditional discipline, are most excited by a setting where the perspective is cross-cultural.

Let us return to the questions raised at the beginning of the article. The vision of HST is to provide the nexus for health sciences and technology at MIT, and to have an impact on health care through research which is carried from "bench-to-bedside." To get there, we will build in five main areas that form the foundation of health sciences and technology. As a platform, we have unique educational programs with strong track records in most of these areas and we have an infrastructure that includes the "bench," the clinical research center, and access to hospitals. And, we have been fortunate to have extraordinary human and intellectual resources in the form of faculty from Harvard and MIT who have been willing to devote considerable time and energy to building the programs.

It is our hope that you, our reader, will be sufficiently engaged to come visit us, and possibly help us build and realize our potential in seeking to achieve our goals.✣

A Modest Proposal for Biomedical Engineering Education

Griffith, from Page 7

Hence, the purpose of this article is to provide a view "from the trenches" of what the School of Engineering must do to provide for the programmatic needs of MIT students interested in biomedical engineering, and in the process to solidify MIT's position as a leader in engineering education into the twenty-first century.

MIT's radical position on biomedical engineering education

Biomedical engineering encompasses application of engineering approaches to solve problems in biology or medicine, and thus includes an incredibly rich and diverse spectrum of interactions between engineering and biology, along with engineering and medicine. It ranges across examples such as the use of robotics to improve rehabilitation of stroke victims, the invention of new noninvasive imaging techniques, development of novel drug delivery systems, and creation of bioartificial organs. Also, biomedical engineering as an applied field is a subset of the broader field of bioengineering, which is the intellectual combination of biological and engineering principles regardless of whether the applications are health care related. It thus differs from the historical chemistry precedent that led to creation of a single new engineering specialty to address the key problems.

Many universities have formed formal departments of biomedical engineering which confer both undergraduate and graduate degrees in biomedical engineering. Interestingly, none of the top 10 engineering schools currently have a full-fledged Biomedical Engineering Department (although some – including Berkeley, Michigan, and Cornell – are creating or considering new administrative structures for biomedical engineering with aspects of department-like function). Among these top schools, MIT is nevertheless prominently recognized as a strong contributor to biomedical engineering. This recognition is likely due to a confluence of several factors: the engineering departments at MIT are unusually rich in the numbers of faculty engaged in biomedical engineering research; faculty in the engineering departments at MIT tend to be leaders in their disciplines and thus highly visible generally; and, the faculty in the engineering departments have strong research ties to the conveniently-located Harvard Medical School and teaching hospitals and – increasingly – to the MIT Departments of Biology, Chemistry, and the Division of Toxicology.

At the same time, MIT has not parlayed its research riches into a correspondingly lofty reputation in biomedical engineering educational programs. By all rights it should be the unquestioned No. 1 program in the U.S.; for instance, MIT has 18 Founding Fellows of the American Institute for Biological & Medical Engineering, more than double the number of any other institution (Johns Hopkins has 7, Washington 6, Duke 5, Harvard and Pennsylvania 4 each). Yet in terms of program reputation, at best MIT has been listed No. 5, No. 4, or No. 3 in various rankings of BME educational programs. Obviously, there is a significant underutilization of the biomedical engineering faculty talent here in terms of BME education and programmatic impact, beyond the immensely successful individual research efforts.

> **Thus, the entire School of Engineering must continue to embrace biology and incorporate it even more fully into the engineering core. *Biology must be considered as a foundation science of engineering, along with chemistry and physics. Biomedical Engineering as a specialty is best treated as a Minor within a given field of engineering.* Our philosophy thus diverges significantly from the trends at other schools.**

Although biomedical engineering has a strong presence at MIT, does the fact that change is afoot in student interests mean we should now consider starting a formal department? I believe not. *The diversity of engineering itself prohibits a single cogent intellectual educational program of its applications*

(Continued on next page)

A Modest Proposal for Biomedical Engineering Education

Griffith, from preceding page

in biology and medicine to be developed. Even in developing the BME Minor, the BME Curriculum Committee felt that no single course in biomedical engineering could be defined for all students. Rather, students should be allowed to explore the ways their particular engineering skills can be applied to biological and medical problems. Moreover, it is crucial that students gain a solid foundational understanding in one of the traditional engineering fields before adding to that some degree of specialization in BME. Finally, isolating BME from its roots adds a layer of separation from cutting-edge advances in the engineering disciplines. Very few of the biomedical engineering faculty themselves see much advantage at MIT in forming a BME Department *per se* isolated from the traditional departments.

Thus, the entire School of Engineering must continue to embrace biology and incorporate it even more fully into the engineering core. *Biology must be considered as a foundation science of engineering, along with chemistry and physics. Biomedical Engineering as a specialty is best treated as a Minor within a given field of engineering*. Our philosophy thus diverges significantly from the trends at other schools.

We have a tremendous opportunity to remain at the forefront of engineering education by incorporating this new science and defining new industries for engineering to impact. A subtle consequence of MIT's approach to biomedical engineering is its effect on the future generation of biologists. Biologists have not traditionally interacted with engineers and often are not aware of what skills engineers bring to the table in developing therapeutic and diagnostic products based on key biological advances, or in analyzing biological phenomena. Many of MIT's Biology students will go on to work for, or even found, companies which address translation of biological discoveries into clinical realities, which will involve engineers just as much as the textile industry did at the turn of the century. An incorporation of engineering approaches into the educational experience of at least some Biology students – for example, through the BME Minor – can thus give them a unique competitive advantage in such careers. Thus, MIT again has the opportunity to influence the progress of industries in the U.S.

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MIT as a historical leader of intellectual change in science and engineering in America

In the late 1800s, the field of chemistry underwent a dramatic shift – led by scientists in Germany – from the description and ordering of chemical species to the development of general laws governing chemical change. Taking a cue from the way in which physicists approached problems, chemists began to focus on the quantifiable aspects of chemical phenomena and analyze chemical behavior in mathematical terms. Chemistry thus moved from a science of observation to one of prediction.

In the 1890s, Harvard had developed a substantial research base in chemistry, but "MIT had been chartered in 1861 to train engineers, it had grown and prospered doing exactly that, and administrators felt little desire to tinker in matters that were best left to rich institutions like Harvard. Consequently, MIT was rather slow to join the parade of schools that began to march to the tune of basic research and graduate education in the 1890s." [John W. Servos, *Physical Chemistry from Ostwald to Pauling: The Making of a Science in America.* Princeton University Press, 1990.] Several MIT

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A Modest Proposal for Biomedical Engineering Education

Griffith, from preceding page

graduates trained in German labs – notably, Arthur Noyes – returned to MIT as faculty and became leaders in a reform to make MIT known for basic sciences as well as engineering. Noyes incorporated a rigorous physical chemical approach into the chemistry curriculum, pushed the Institute to create a research center devoted to physical chemistry graduate education in 1903, and ensured that MIT developed the premier Department of Chemistry in the U.S.

Industrialization in the late 1800s had created a demand for engineers with a knowledge of chemistry. Course X, Chemical Engineering, was initiated in 1888 as a division in the Chemistry Department. It began to flourish in 1902 when William Walker began to revamp the field – and create a new discipline – by incorporating the new sciences of physical chemistry and thermodynamics along with the engineering sciences into the curriculum. Significantly, Noyes convinced Walker to require Chemical Engineering students to take a theoretical chemistry course, setting a precedent for chemical engineering curricula throughout the world. The Chemistry Department was split into separate Departments of Chemistry and Chemical Engineering in 1920.

The remarkable changes which occurred in chemistry in the late 1800s and the impact on engineering are paralleled in modern times by a similar revolution in biology. The advent of molecular biology has provided the tools to undertake mechanistic investigations of the behavior of cells and higher organisms, and, like chemistry 100 years ago, biology is rapidly moving from a science of characterization and categorization to one of quantitative analysis and mechanistic understanding. The MIT Biology Department had the early vision to focus faculty hiring in the exciting new area of molecular biology, building a premier department and winning world acclaim. And faculty in the Department of Applied Biological Sciences helped define the field of biotechnology, profoundly influencing industrial applications as diverse as pharmaceutics, agriculture, and synthetic chemistry.

Biology thus now stands poised to become a foundational science, along with physics and chemistry, for engineering. ...a course in modern biology was adopted in 1991 as a requirement for all MIT undergraduates at the urging of the Biology Department. One practical consequence of this requirement is that enrollment of undergraduates in the Biology Department has skyrocketed, paralleled by a similar explosion in student interest in the interface between engineering and biology.

Biology thus now stands poised to become a foundational science, along with physics and chemistry, for engineering. The Biology Department has given the MIT School of Engineering a strong start in this direction. Just as at the turn of the century theoretical chemistry was adopted as a sound basis for an educated (chemical) engineer at the urging of the Chemistry Department, a course in modern biology was adopted in 1991 as a requirement for all MIT undergraduates at the urging of the Biology Department. One practical consequence of this requirement is that enrollment of undergraduates in the Biology Department has skyrocketed, paralleled by a similar explosion in student interest in the interface between engineering and biology.

This analogy is not perfect, however, to that of the development of chemistry and its strategic role as one of the foundations of chemical engineering: advances in chemistry took place at a time when the engineering disciplines were struggling to define themselves; in contrast, advances in biology take place when the distinct engineering disciplines are strongly established. MIT again is poised to play a leading role in determining the direction of

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A Modest Proposal for Biomedical Engineering Education

Griffith, from preceding page

how a scientific revolution advances the field of engineering, and the future of MIT as leader depends on the willingness of the MIT School of Engineering to take responsibility for determining the direction.

Administrative structural organization is needed within the School of Engineering

Given the pressing need for developing appropriate educational programs in BME, and the opportunity for MIT to provide leadership in this field, how can we move forward? What is needed is an administrative structure whose mission is to foster biomedical engineering programs, to effectively translate its outstanding faculty and student resources into programmatic impact. Since educational programs must integrate successfully with existing curricula in the engineering departments, and with MIT's philosophy that biomedical engineering is best pursued by bringing biology into the fundamental engineering disciplines (just as chemistry and physics have been previously), I and many of my colleagues are convinced that the School of Engineering – with close ties to Biology and the rest of the School of Science – is the natural home for this structure. The partnership between engineering and biology can be fostered this way – just as it has been for decades between engineering and physics, and between engineering and chemistry.

Unfortunately, the urgent educational needs in the School of Engineering have been coupled in an unnatural way to the future of the HST program, and this entanglement severely impedes progress in the School of Engineering. The mission of HST is to offer joint graduate educational programs with Harvard Medical School focused on the practice of clinical medicine. Biomedical engineering intersects only a piece of this mission, as is reflected in the facts that by far the largest program offered by HST is an M.D. degree and that the major number of HST-associated faculty are Harvard M.D.s. Moreover, clinical medicine applications of biomedical engineering are only a small part of bioengineering more broadly. Hence, a suggestion that biomedical engineering education, or research, at MIT be run by HST is inappropriate – it would be an abdication of the School of Engineering's responsibility for its own students.

Much has changed in the world of research and education since the HST program was started, and the HST program is struggling to redefine its identity in response to these changes. With respect to research, 30 years ago interactions between physicians and engineers were relatively rare, and HST could serve as an important conduit for developing research collaborations. This is no longer the case, as virtually every professional meeting my colleagues and I attend is typically populated by an interactive mix of scientists, engineers, and clinicians from academia and industry, making initiation of collaborations quite easy. Not surprisingly, then, there are endless examples of productive MIT/HMS collaborations that have been initiated and maintained without any participation of the formal structure of HST. Much has also changed with respect to education. Attraction to the clinically-oriented MEMP program remains for students primarily interested in medical practice (as evidenced by the many MEMP students who transfer into the M.D. program), with an extra economic driving force arising from receiving three terms of MEMP fellowship support from MIT for taking HMS classes. But there is also a growing new generation of prospective students more interested in the engineering/bioscience interface with aims of going out into biotechnology, pharmaceutical, and medical device companies for the health care application of their training. The needs of this generation naturally put a central focus back at MIT with its fundamental engineering and science departments.

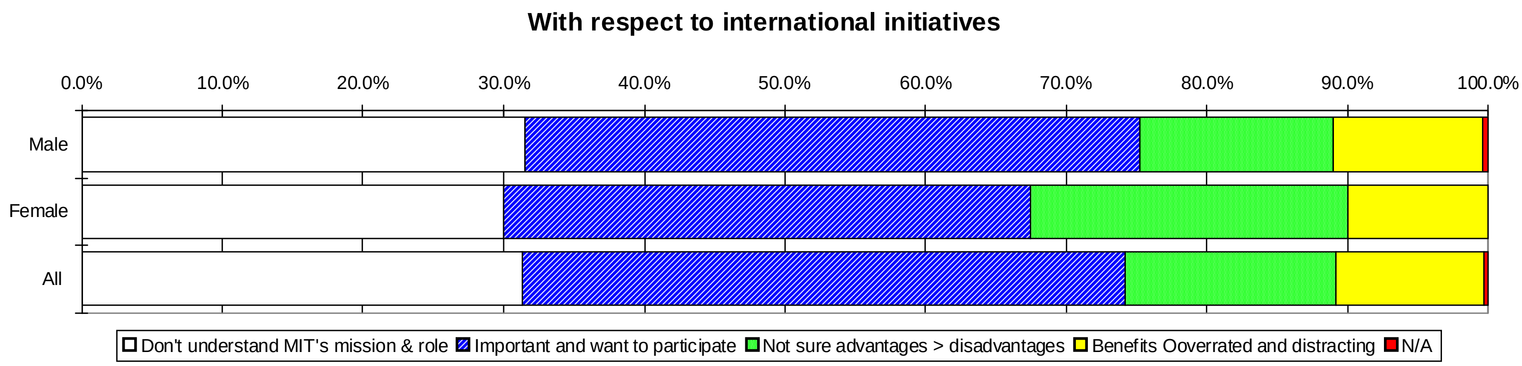
Thus, while it is important to maintain the successful clinically-focused HST programs, it seems inappropriate and ineffective to saddle the biomedical engineering faculty at MIT with an administrative structure that requires them to report to the Harvard Medical School in order to provide the education of their own engineering students.

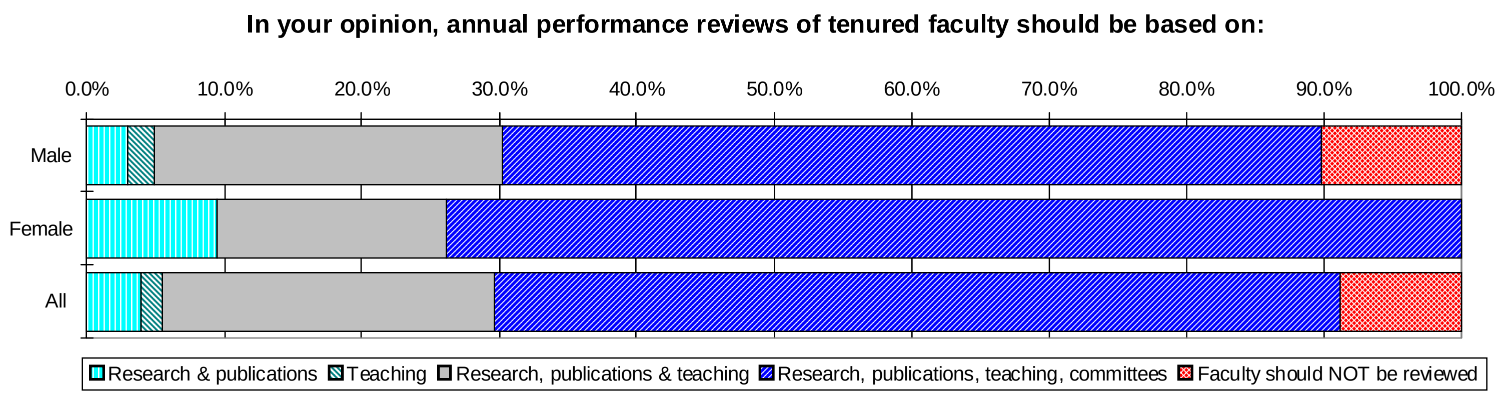
Conclusions

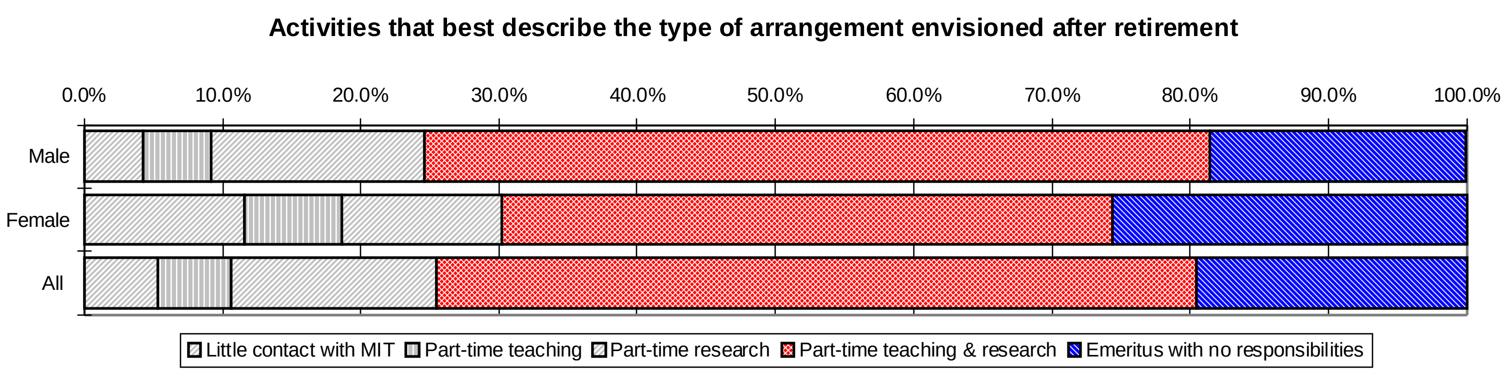
The need is urgent, and the opportunity is tremendous, for MIT to create a world-leading biomedical engineering program. This can, and should be, accomplished by forming an administrative structure in the School of Engineering responsible for providing programs we Engineering faculty know our students need, at the modern interface of engineering and biology.✣

Faculty Survey Results Offer Some Surprises

Snover, from Page 1







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Faculty Survey Results Offer Some Surprises

Snover, from preceding page

Non-tenured faculty are over-represented in the responses. Although women are slightly over-represented, younger, non-tenured women have a higher over-representation rate than men. This is particularly evident when data on levels and sources of stress are examined. Once the data is available the next step is to assemble tables and charts for tenured and non-tenured faculty by gender. In addition, it will be important to examine teaching and evaluation methodologies by discipline.

Following are some other results from the survey.

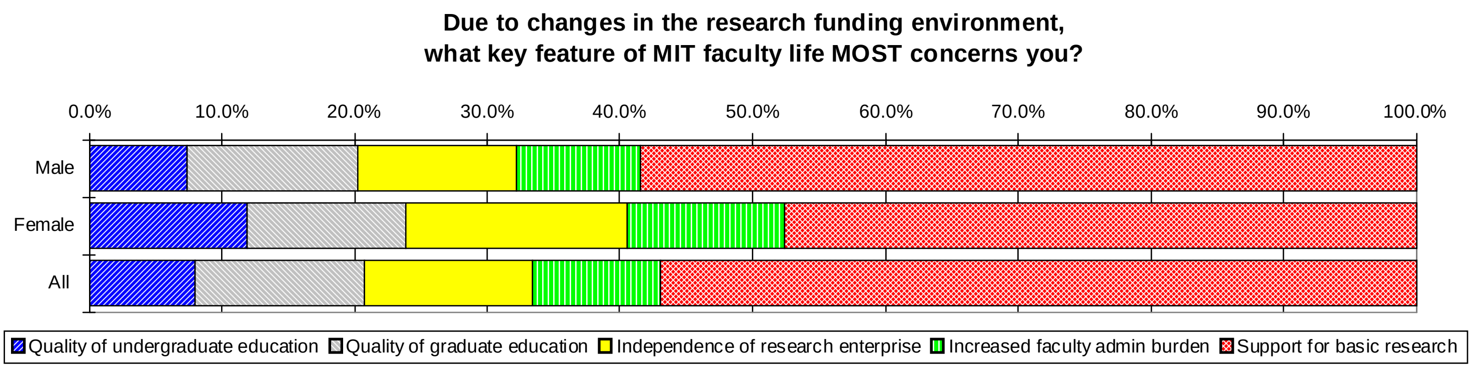
• In the last two years, 17% of the faculty considered early retirement and almost 50% plan to work beyond the age of 70.

• As a whole, the faculty reported experiencing moderate to extreme stress over the last two years, with two-thirds of the women reporting extreme stress. The four highest sources of stress for the faculty as a whole were time pressures, lack of personal time, research/publishing demands, and household responsibilities. Almost 61% of the women reported that the promotion and tenure process was a source of stress, compared to 34% of the men.

• The primary interests of the majority of MIT's faculty are oriented toward research.

• The primary reasons that our faculty have pursued academic careers are intellectual challenge, intellectual freedom, freedom to pursue their own interests, and opportunities for research.

• In terms of their jobs at MIT, the majority of faculty appear very satisfied or satisfied with all aspects of their position. The least satisfying aspects are social relationships with other faculty, relationships with the administration, and salary and fringe benefits.



• The faculty see as their four most important goals for MIT undergraduates: to develop the ability to think clearly, to increase their self-directed learning, to prepare for graduate education, and to prepare for employment.

• The faculty employed a variety of evaluation methods with almost 60% relying on competency-based grading and 42% on quizzes.

• Over 70% of the faculty use extensive lecturing in most or all undergraduate courses along with teaching assistants and class discussions.

• Almost 43% of the faculty felt that MIT was *not* doing well in reducing administrative burdens on the faculty. At least two-thirds felt that MIT is doing an adequate-to-excellent job in preparing graduate students to teach and helping students to understand the world they will enter. Over half think MIT is doing above average or very well in preparing undergraduates for professional practice and developing and delivering professional education. 13% of the faculty feel that they do not have access to adequate teaching facilities.

• As the research funding environment changes, MIT faculty are most concerned about support for basic research.

• 43% of the faculty find international initiatives important and want to participate.

• 62% of the faculty feel that post-tenure performance reviews should be based upon research, publication, teaching, and committee participation.

• 75% of the faculty plan to do part-time teaching and/or research at MIT after they formally retire.

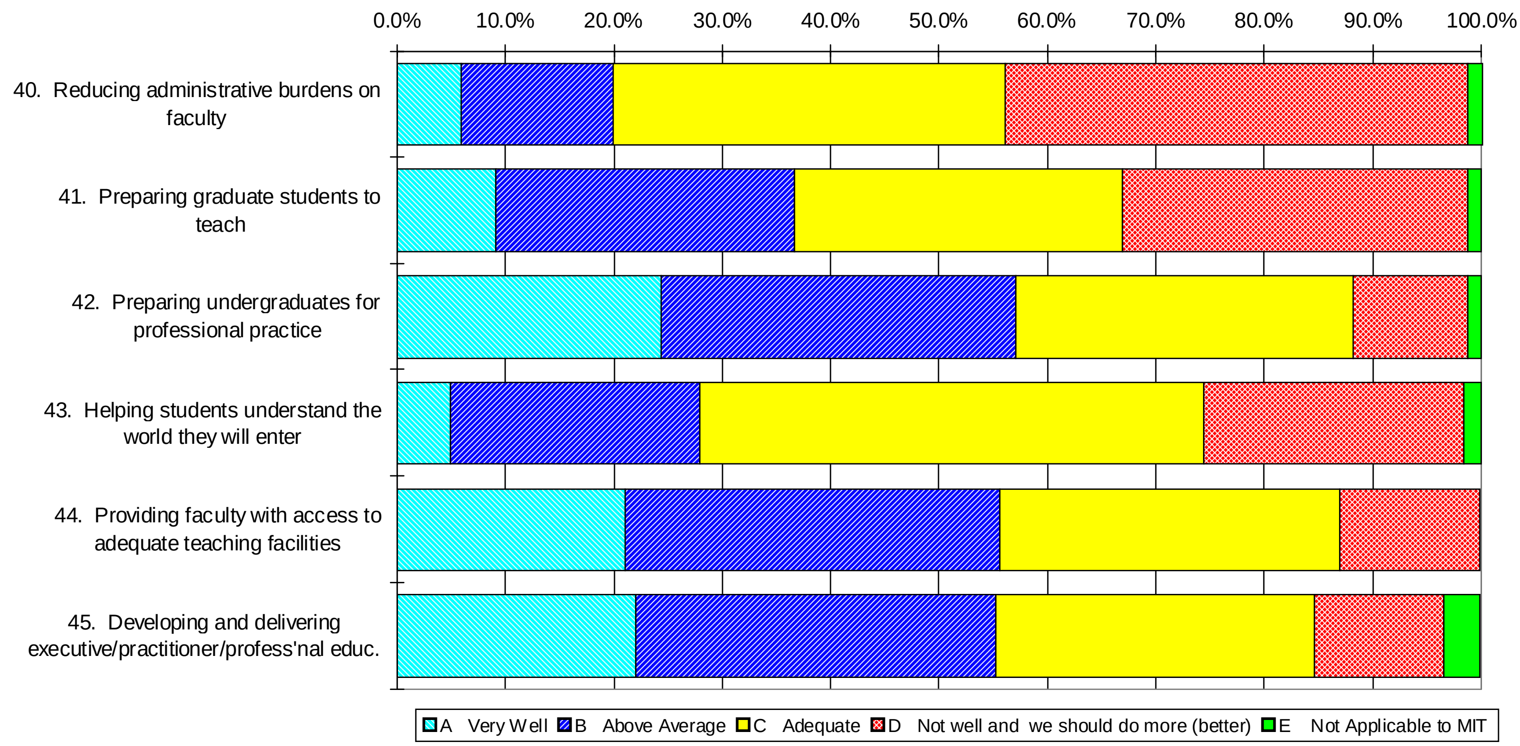
For complete survey results, as well as a variety of statistical breakdowns (e.g., by department) contact me at the Planning Office (x3-5838; snover@planning.mit.edu).✥

M.I.T. Numbers

from the

1995 Higher Education Research Institute (HERI) Faculty Survey

Overall, how do you feel MIT is doing in the following areas?



Source: MIT Planning Office
See article, Page 1