The MIT Faculty Newsletter

Vol. VIII No. 3 **March/April 1996**

ROTC Task Force Reports

Faculty to Vote at Next Meeting

Samuel M. Allen

In response to a request by the Faculty Newsletter Editorial Committee for this issue, Secretary of the Faculty Samuel M. Allen has graciously provided the following synopsis of the ROTC discussion taken from the minutes of the March 20th faculty meeting.

President Vest stated that because of the variety of roles that he would ultimately play after the faculty reaches a decision on this issue, that he should not take an active role in the discussion of the topic or the motion. He noted that he was very proud of the civility displayed by the MIT community in debates on this potentially divisive topic prior to the meeting. He commended the Task Force for promoting openness and high-level discussion. He reminded those present that the Task Force's motion, to be placed on the floor at this meeting, would be voted on at the April meeting [April 17].

The members of the Task Force took seats at the front of the room and were introduced by Professor Graves, who thanked them for their contributions. Professor Graves reviewed the charge to the Task Force, and the various phases of its work. Since reporting to the faculty at the February meeting, the Task Force has met frequently to formulate its recommendation. In the coming month leading up to the April meeting, the Task Force will seek and evaluate additional community input.

Three principles have guided the Task Force as it wrestled with this complex issue: First, that of *inclusion*, the desire for an open and honest environment on campus; second, the desire to promote the *citizen soldier* concept, in which the country's military is composed of a representative group of

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Learning to Teach:

A Day in the Life of the New Teacher Education Program

Jeanne Bamberger, Crispin Miller, Brian White

Fall semester '95 marked several milestones in the new Teacher Education Program (TEP). The first graduate of the program and the first recipient of the Noyce Prize, Sally Buta (Course 3, '94), joined the teaching staff at Cambridge Rindge and Latin High School (CRLS) where she is teaching physics. (The Noyce is a $10,000 prize awarded to the outstanding graduating senior who has chosen a career in teaching and who has completed (or will complete) certification requirements to teach math or science in a public school.) Ricardo Campbell (Course 10 '95), the second winner of the Noyce Prize, is teaching 8th grade science at the Longfellow School in Cambridge while completing his certification in the Wellesley Fifth Year Program. And the TEP introductory course, 11.124, Introduction to Teaching and Learning Math and Science, had 25 students this semester, up from 8 the first year and 14 the second year. Of the students enrolled last year, 6 will complete certification requirements in June 1996.

To qualify for Massachusetts State Certification in math or science at the middle and high school levels, students must complete a major in the subject they expect to teach, and also take the following Education courses at MIT: *Introduction to Teaching and Learning Math and Science* (11.124); *Observation and Analysis in Classroom Settings* (11.125 - optional); and *Developmental Psychology* (9.85). [11.124 and 11.125 are HASS elective subjects. These two together with another Course 11 class can make up a HASS concentration.] These are followed by two subjects taken at Wellesley (often

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Editorial

Where Are We Going?

Reductionism has its limits, and can actually be misleading if extrapolated beyond the proper domain.

Independent local optimizations do not necessarily result in a global optimization.

The Institute seems to have little difficulty in applying these precepts to the study of the physical world and to the study of other organizations. In fact, MIT is noted for its interdisciplinary laboratories and its promotion of systems studies. Nonetheless, we have not taken the lesson to heart in the process of determining our own future. It is clear that MIT will have to change in response to changes in its external environment. Our funding sources will certainly change, the level of funding will probably change, and our role in society will be redefined. The administration's response to the need for change has been the separate "reengineering" of various subsystems. It is not clear that this reengineering is succeeding even in the narrow domains of application. [See Prof. Kirtley's discussion of the mail system in the October issue of the *Faculty Newsletter*.] More significantly, there is no way of knowing whether it is making things better or worse in the long run because we do not know what we are trying to accomplish.

If the MIT of the future is determined by a series of short-term responses to short-term stimuli, it is unlikely that we will end up with an optimized system. Optimized or not,it is quite likely that we will not like what we get. What we should be doing is trying to formulate a vision of the MIT we would like to see 10 and 20 years from now and then determining what we must do to achieve that vision. This may well entail changing the external environment as well as our internal structure. It may be an impossible task but we will surely regret it if we do not attempt to take responsibility for our own future.

It is the administration's task to develop, promote, and promulgate a goal, a vision of the MIT we would like to see at the start of the next century. This is a harder task than the simplistic application of techniques developed for the business world but it is much more important. We have not seen the vision, we have only seen separate domains rejiggered so they are somewhat cheaper and somewhat less efficient and less convenient. Is the MIT of the future to be like the MIT of today but a little smaller and a little less fun? It will be if the administration continues to be literally ministerial at the expense of being imaginative.

The provost's appointment of four Institute-wide councils to "help MIT set its course for the future" is a recognition of the problem but not likely to be a solution. For one thing, there are *four* committees, focused on four separate domains. More to the point, however, is the observation that committees rarely, if ever, frame bold new ventures even if this is what the situation demands. We would far rather see the President or the provost ennunciate a vision for us all to discuss, criticize, modify, improve, and maybe even adopt than to see something slowly evolve out of the deliberations of four committees. There will be time enough for committees when we figure out what we want to do.

If we don't know where we are going, how can we be sure we are going in the right direction?

If we don't know where we are going, how will we know when we get there?

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Parking Redux

Let's see if we've got this straight:

a) Parking at the Institute used to cost $20/year;

b) Now it costs $300/year (well, actually, $400/year, because we have to pay taxes on the $300 since the administration didn't arrange to have the parking charges deducted before taxes);

c) The complexity of handling the new $300 fee and the magnetic card-activated gates was too much for the Institute to handle, so a third party was hired (a.k.a. "outsourcing");

d) Now the third party (Standard Parking) gets our $300, the federal and state governments get the other $100, and we get to spend an extra half-hour getting into and out of the garage each day because the cards/gates don't work properly. [Assuming that we are able to get into the parking lot at all, as more parking stickers have been sold than there are spaces.]

Is that about it?

Editorial Committee

A new lunch program for faculty members and their guests began operation Monday, April 1, in the renovated Blue Room on the second floor of Walker Memorial. The service will be similar to the faculty lunchroom in Building 9, which will continue to operate. The Provost's Office, which sponsors the program, hopes the Walker location will attract faculty members from the east side of the campus. The experiment will run through the remainder of the academic year.

ROTC Task Force Reports

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the populace; and third, the perceived *value of ROTC to MIT students*. These principles are in direct conflict with current DoD policy, which excludes gays, lesbians, and bisexuals from full participation in ROTC and the military.

Professor Graves briefly reviewed some ways that other universities have attempted to resolve this issue, ranging from exclusion of ROTC from their campuses, to exemption of ROTC programs from university nondiscrimination policies. The Task Force is recommending a distinctly different approach: to continue ROTC at MIT, but to make concerted efforts to create a "model" ROTC program that is both inclusive and nondiscriminatory. The program advocated by the Task Force would have the following features:

- An ROTC program that is open to all students, that will be receptive to "constructive engagement" with MIT in order to bring about essential changes in the current program.
- A program by which MIT will "reinsure" cadets who lose ROTC scholarship support because of their homosexuality.
- Formation of an MIT committee whose mission is to advocate national policy changes, particularly the federal statute that prohibits homosexuals from service in the military.

Professor Graves reviewed these attributes of the recommended model program in some detail. He emphasized that the Task Force views its recommendations as interim steps toward the long-range goal of an inclusive and nondiscriminatory ROTC program. Professor Graves concluded his presentation by mentioning several areas of concern, and how the Task Force views them:

- The 1990 Faculty Resolution on ROTC stated that inadequate progress toward eliminating DoD policies on sexual discrimination would result in termination of the ROTC program at MIT. While the Task Force finds that progress is inadequate, it does *not* recommend termination at this time.
- The Task Force ignored the potential impact of legislation that could result in loss of DoD funding to universities that adopt anti-ROTC policies.
- Some critics of the "model ROTC program" at MIT have questioned its feasibility, because some of the recommended changes are in conflict with current DoD regulations (for instance, uniforms for all students, and participation in the summer ROTC program). Some specific recommendations of the Task Force can be implemented with concurrence of the local commanders of the ROTC units.
- The Task Force recommends an annual process of review by two committees, for assessment and reporting of progress. A future finding of inadequate progress could result in recommendations to modify MIT's relationship with its ROTC program.

A discussion of the Task Force's recommendations, lasting about one hour, followed Professor Graves' presentation. A large number of persons spoke on various issues, some at length and with notable eloquence. The discussion was collegial, candid, and thought provoking. A large fraction of those who spoke praised the Task Force for their process, particularly because it engaged such a wide spectrum of input from the community. Some who spoke had specific questions about the Task Force Report; these were fielded by the entire Task Force.

Two specific areas of concern about the recommendations of the Task Force were voiced in a number of remarks. The first was that the inquiry process by which a cadet's sexual orientation might be investigated would involve MIT faculty and administration members, and that this would effectively mean that MIT was an active participant in the discriminatory policies of DoD. Furthermore, it was argued that the faculty and administration of MIT should not be engaged in investigations of its students' sexual orientation. A member of the Task Force countered that it is highly desirable for an MIT representative to participate in any inquiry process, in order to protect students' rights.

The second area of concern was that the proposed model program does not represent a significant step toward elimination of discrimination within the ROTC program at MIT. Critics of the proposal believe that by virtue of having two groups of ROTC students, those planning to be commissioned and those ineligible for commissioning, the model program will be discriminatory. Also, because DoD policy does not allow commissioning of openly gay, lesbian, or bisexual individuals, the model ROTC program will remain in violation of MIT's nondiscrimination policy.

Several speakers voiced support for the recommendations, seeing the model program as an effective way for MIT improve its ROTC program and to remain engaged with DoD on elimination of current discriminatory policies.

Professor Graves read the proposed resolution, and it was seconded. A Task Force member pointed out that it is important to keep in mind the intention of the proposed resolution, vs. the application of proposed changes. The member elaborated that some vagueness in the report can be tolerated, as it provides flexibility for future actions; however, the Task Force tried to avoid vagueness that would allow for unintended interpretations of its recommendations.

Professor Bacow noted that the faculty meeting marked the start of a conversation on these issues, not the end of it. He encouraged the faculty to take up further discussion in order to prepare for the April meeting at which the issue will be voted.

President Vest concluded the discussion by expressing his heartfelt thanks to the Task Force for its work.✣

From The Faculty Chair

Collegiality, Community, and Trust at MIT

Lawrence S. Bacow

Institute faculty meetings are not known for being good theater. While it pains me to admit it, it is an effort to keep the routine business of the faculty from descending into tedium. Most of the important work of the faculty is done in committee where real differences on policy are thrashed out. By the time issues make it to the monthly faculty meetings, there is little left to discuss. Spirited debate is rare except in those cases where the administration's antennae fail them, and the faculty turns out to voice strong disapproval of an action taken without adequate faculty input. Fortunately, we have avoided such problems for close to two years. In fact, virtually every vote taken this year has been unanimous, which is either a sign of our remarkable ability to generate consensus, or our ability to bore people into submission.

The March faculty meeting stands in sharp contrast to our norm. Attendance was good – about 125 people turned out to hear the report of the Task Force on ROTC. The discussion was lively, with sharply differing opinions expressed. A number of people spoke passionately and eloquently about the recom-mendations of the Task Force. Some of these comments were favorable, some critical. Others spoke about what it is like to be a gay faculty member at MIT. Many of these statements were quite moving. If you did not attend the meeting, I urge you to read Sam Allen's summary of the discussion that appears in this issue of the *Newsletter* (Page 1), or Bob Di Iorio's excellent longer review of the meeting that appeared in the April 3 issue of *Tech Talk*.

As I sat through the ROTC discussion, I realized yet again what an extraordinary institution MIT is. Unlike virtually every other group that has taken up the question of gays in the military, our discussion was totally without rancor. Those who spoke felt comfortable enough to voice deeply felt personal sentiments. People listened carefully, thoughtfully, and respectfully to the views expressed. Where opinions diverged, motives and good will were never questioned. My sense is that the discussion was truly informative – those in attendance left the meeting with a better understanding of the issues and their colleagues than when they walked in. Perhaps even more importantly, instead of dividing us, I believe the ROTC discussion so far has actually brought us closer together. Diverse elements of our community have gained a better understanding of each other through this process. This is a remarkable achievement. We have developed a capacity to discuss this issue that I do not recall from our 1990 meeting. This is true not just for the faculty discussion, but for the student forums as well.

Only time will tell whether we are able to resolve this issue in a way that can gain the support of broad segments of our community. At this point, I am optimistic. The members of the Task Force have done yeoman's work on behalf of MIT, and we are all in their debt. I hope the faculty will come out in numbers to the April 17 meeting to hear the final recommendations of the Task Force and to continue the extraordinary discussion that began at the March meeting.

It is difficult to predict where the ROTC issue will settle. The Task Force is using its time wisely this month to gather additional reactions from the community, and to refine its recom-mendations. Students, faculty, and staff have provided helpful input. Only time will tell whether we are able to resolve this issue in a way that can gain the support of broad segments of our community. At this point, I am optimistic. The members of the Task Force have done yeoman's work on behalf of MIT, and we are all in their debt. Their process of fact-finding, issue framing, soliciting student and faculty reactions, and thoughtful analysis is a model for other faculty committees to emulate. I hope the faculty will come out in numbers to the April 17 meeting to hear the final recommendations of the Task Force and to continue the extraordinary discussion that began at the March meeting.

Civility and collegiality are in short supply on many university campuses these days. Our experience with the ROTC discussion illustrates the value of these assets in addressing difficult problems. Good will, trust, respect, and communication permit us to address differences without being divisive. They allow people to hold sharply divergent views and still function as a community. Unfortunately, this type of social capital is extraordinarily hard to create, yet easily destroyed. In these difficult times for research universities we need to protect that which is unique about MIT. We should not take for granted the collegiality and trust that permits us to find solutions to tough problems that might test lesser institutions.✣

TEACH TALK

Setting Up the Content of Recitation Sections

Brian T. White

The TAs say:

"My students never talk in section!"

"It's so hard to tell what the students will need in section."

The students say:

"I just draw a blank when I look at the problem set problems; I don't know where to start."

"You have to be sure to get a good TA, otherwise you'll never learn the material."

These are frequent problems in large lecture subjects. In the Biology Department, we have found a very successful solution: create a curriculum for recitation sections that parallels and supports the lectures, problem sets, and exams.

In Introductory Biology (7.012, 7.013, and 7.014), the section curriculum grew out of a collection of recitation practice problems which were designed to give the students practice working problems similar to those on the problem set. It soon became clear that the students loved the practice – since problem-solving is a very important component of our subjects – and that it made the recitation sections more lively and interactive. Having these problems makes it easier for the TAs to focus their attention on the topics where the students need the most help.

We have found that these section problems are more than just a little classroom exercise. They help the TAs to do a better job, they give students practice with problem-solving skills, and they improve the interaction that is a unique and vital part of recitation section. Over several semesters, the collection of practice problems has evolved into a complete curriculum where we have one or more problems for each section meeting and a set of notes and hints on how best to use them.

A Common Situation

Jennifer is a TA who teaches recitation sections in the large lecture subject *Introduction to Transportation: How to get from here to there without a car*. The lectures covered the prices and schedules of various modes of transportation and the students had just received a problem set which asked them to explore their options and find the best route for getting from Central Park to Disneyland. Jennifer went over the material covered in lecture and then asked, "Do you have any questions?" Although Jennifer was sure that they would, the students didn't ask any questions and she ended section early. A few days later, as she graded their problem sets, it was clear that the students had missed many important concepts. If they had only known what to ask....

If the content of recitation section were organized in advance, Jennifer could have gone over the lecture material briefly, highlighting what previous semesters had shown to be the most troublesome points. She would then have handed out a problem something like this:

You are planning a trip from MIT to Provincetown, MA and you have only $100. Plan your trip given the attached MBTA, train, bus and commuter plane schedules.

Jennifer could then let the students work together in small groups to play with the problem and develop their own strategies. This would give the students practice starting a problem and getting past "drawing a blank." Jennifer could then ask, "How would you start looking at this problem?" If the students understood the material, then she and the class would assemble a solution together. If they did not, the students would then have a concrete example on which to base their questions; these questions would show Jennifer what topics she needed to go over.

Or, if it made more sense to show the students a particular way to solve the problem, she could work the problem step-by-step, asking the students for information all along the way: "What form of transport does our $100 budget rule out?" "Since we have to take the bus, where is the closest bus station to MIT?", etc. These questions could either be parts of the problem handed out or could be in the notes given to the TAs with the problem.

Either way, the resulting discussion would take advantage of the close contact possible in section to bring out the relevant issues, allow the TA to correct misconceptions, fill in missing details, and explore multiple solution strategies. Rather than depending on the students to generate questions in a vacuum, the problem focuses their attention and shows them whether or not they understand the material at the appropriate level.

(Continued on next page)

Setting Up the Content of Recitation Sections

White, from preceding page

Creating A Curriculum For Recitation Sections

It is easiest to start with a collection of problems, one for each section meeting, and then develop notes on how to use them over several semesters of use and revision. In Biology, we have hired TAs from the previous year to write the problems over the summer. We decided to use TAs because they often have the best sense of the topics with which the students had the most trouble. We divided the semester's section meetings among the TAs and had them either write new problems or adapt existing problem sets or exam questions. They then exchanged drafts with each other for one round of editing. Following that, the instructor reviewed the edited drafts and made a final edit. The problems were then distributed to the new TAs the following semester.

As the problems were used, we collected comments and suggested revisions. We also collected notes from a few of the TAs to pass on to future TAs as a teaching guide. As a result, we are able to progressively develop the curriculum as the class continues.

Helping The TAs To Use The Curriculum

It is much harder for the TAs to get "down in the mud" and work with the students in a discussion of how to solve a problem than it is to give a lecture. While working through these problems in Section, I have found that students often come up with seemingly bizarre answers which are not clearly articulated, and it is difficult to make sense of them on the spot. It is also difficult to know in advance how long a discussion should take or which of the students' strange questions will lead in a productive direction. But through this messy interaction, the students have to grapple with the material and ask relevant questions, and therefore have a more solid understanding of the subject matter. Seeing how the false starts and dead ends don't work, as well as how the most productive strategies do work, will prepare them for the variety of problems they'll face outside of section.

Because leading a discussion can be challenging for the TAs, we make an effort to prepare them for this interaction. First, we have a TA training session where we explicitly go over the details of how to lead a discussion including classroom climate, asking good questions, and interpreting students' answers. Second, we have a TA manual which has notes and guidelines on how to work through the problems, useful explanations, and some questions to expect. Finally, the instructor meets regularly with the TAs to discuss the week's section problems and how best to use them. We began with a collection of problems and detailed solutions; this was enough to cure many of the typical section difficulties. The rest we developed over time.

The Payoff

Having an organized curriculum for recitation sections has made a big difference in the biology subjects where we have assembled one: Genetics (7.03) and Introductory Biology (7.012, 7.013, and 7.014). The TAs now have a starting point on which to base their own lesson plans rather than guessing what the students might need and scrambling to make up problems at the last minute. The TAs also have the benefit of an "experience transplant" from previous semesters both in terms of good problems to use and advice on how best to use them. The problems are designed to get the students talking, which leads to a more effective and enjoyable section than in the past. The students now get practice confronting, starting, and solving problems with the help of an experienced TA. In our case, a little work each semester has accumulated to produce an important component of a strengthened class.

If you would like to find out more about the section problems and notes that are used in Biology, contact Brian White, btwhite@mit.edu.✣

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M.I.T. Numbers

Comparison Of Annual Research Revenues By Area ($000)

	Fiscal '92 Actual	Fiscal '93 Actual
School of Architecture & Planning		
TOTAL	9,632	11,472
Less: Major Sub-Contracts	317	117
Net Research Volume	9,315	11,355
School of Engineering		
TOTAL	91,491	109,793
Less: Major Sub-Contracts	5,343	15,700
Net Research Volume	86,148	94,093
School of Humanities		
TOTAL	2,251	3,621
Less: Major Sub-Contracts	0	0
Net Research Volume	2,251	3,621
School of Management		
TOTAL	5,107	6,765
Less: Major Sub-Contracts	0	0
Net Research Volume	5,107	6,765
School of Science		
TOTAL	105,398	116,634
Less: Major Sub-Contracts	5,121	8,887
Net Research Volume	100,277	107,747
Whitaker College of HST & Mgt.		
TOTAL	16,871	19,353
Less: Major Sub-Contracts	3,226	3,676
Net Research Volume	13,645	15,677
Total Academic Departments		
TOTAL	230,750	267,638
Less: Major Sub-Contracts	14,007	28,380
Net Research Volume	216,743	239,258
Interdepartmental Labs		
TOTAL	88,234	90,532
Less: Major Sub-Contracts	2,044	4,661
Net Research Volume	86,190	85,871
Other Departments & Special Labs		
TOTAL	3,283	3,184
Less: Major Sub-Contracts	1,072	686
Net Research Volume	2,211	2,498
Total Campus Research Volume		
TOTAL	322,267	361,354
Less: Major Sub-Contracts	17,123	33,727
Net Research Volume	305,144	327,627

Note: Figures **not** adjusted for inflation.

Source (and thanks):
Robert M. Dankese
Assistant Director of Finance

Fiscal '94 Actual	Fiscal '95 Actual	Fiscal '96 Forecast	% Change '95 to '96	**Preliminary** Fiscal '97 Forecast	% Change '96 to '97
12,167	12,324	12,000	-2.6%	13,284	10.7%
247	90	200	122.2%	0	NA
11,920	12,234	11,800	-3.5%	13,284	12.6%
103,569	98,136	100,000	1.9%	104,000	4.0%
10,882	7,877	6,000	-23.8%	5,686	NA
92,687	90,259	94,000	4.1%	98,314	4.6%
3,070	3,113	3,300	6.0%	2,285	-30.8%
0	0	0	NA	0	NA
3,070	3,113	3,300	6.0%	2,285	-30.8%
7,446	8,564	8,100	-5.4%	7,997	-1.3%
0	0	0	NA	96	NA
7,446	8,564	8,100	-5.4%	7,901	-2.5%
117,372	125,329	124,000	-1.1%	114,430	-7.7%
7,317	11,005	9,800	-10.9%	5,586	-43.0%
110,055	114,324	114,200	-0.1%	108,844	-4.7%
20,976	21,221	22,000	3.7%	16,819	-23.6%
4,116	2,724	2,000	-26.6%	1,503	-24.9%
16,860	18,497	20,000	8.1%	15,316	-23.4%
264,600	268,687	269,400	0.3%	258,815	-3.9%
22,562	21,696	18,000	-17.0%	12,871	-28.5%
242,038	246,991	251,400	1.8%	245,944	-2.2%
92,133	89,177	90,000	0.9%	94,185	4.7%
6,932	7,572	19,000	150.9%	20,270	6.7%
85,201	81,605	71,000	-13.0%	73,915	4.1%
3,034	3,825	2,600	-32.0%	2,000	-23.1%
500	543	0	-100.0%	0	NA
2,534	3,282	2,600	-20.8%	2,000	-23.1%
359,767	361,689	362,000	0.1%	355,000	-1.9%
29,994	29,811	37,000	24.1%	33,141	-10.4%
329,773	331,878	325,000	-2.1%	321,859	-1.0%

A Day in the Life of the New Teacher Education Program

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in the Wellesley Fifth Year Program): *Educational Theory, Curriculum, Evaluation* (Education 300); and *Supervised Practice Teaching*. (Education 302- 303). (Working with mentor teachers at CRLS and observing in their classrooms is an essential part of the program.)

The TEP is currently funded by the National Science Foundation under their program, Collaborative for Excellence in Teacher Preparation. The grant of $5,000,000 over five years has been made to the TEAMS-BC Collaborative (Teacher Education Addressing Math and Science in Boston & Cambridge) which includes Harvard, UMASS Boston, Wheelock College, MIT, and the Boston and Cambridge School Systems. The program has three primary goals: to improve teacher preparation in mathematics and science, to interact with math/science undergraduate courses at the participating universities, and to increase the number of underrepresented minorities and women teaching and learning mathematics and science in the public schools.

To assure that the MIT Teacher Preparation Program maintains high academic standards in connection with the first goal, an Oversight Committee has been appointed that includes 15 faculty members primarily from the Schools of Engineering and Science. Chaired by Professor of Biology Jonathan King, its purpose is also to address the second goal – i.e., to help integrate the Program into the Institute curriculum. To assist in addressing the third goal, we have the help of faculty in the Department of Urban Studies and Planning where the TEP is housed. Faculty from DUSP, including the chair, Bish Sanyal, also serve on the Oversight Committee.

Getting Started

Three years ago we set out to design an Education program that would fit MIT: it would need to meet the intellectual standards that MIT students expect as well as engaging students' sophisticated knowledge of math and science, their abilities to think analytically, and to confront and play with complex problems. But at the same time we needed to prepare teachers who would be effective in a public school such as CRLS where they could expect classes of 20-25 students who could be dramatically different from one another and also from the familiar MIT cohort – in life experience, in educational background, in interests and career goals, and also in the modes and media through which they would learn best. What did MIT biology or physics majors need to know that they didn't know already if they were to become teachers who could engage the curiosity and interest of such diverse student populations?

Starting from the assumption that all of our students knew the subject matter they were going to teach and thus would be able to deliver the necessary information, we focused on more educationally problematic issues: For instance, how could we prepare our students to cope with the inevitable situation where the canonical explanation, that seemed so obvious, fails – fails to be understood, or fails even to make contact with the pupils' diverse mix of previous schooling and worldly experience? Better explanations; more spiffy presentations; more relevant material? Still keeping in mind that the goal of teaching is to guide pupils towards a better understanding of the subject matter, we proposed a somewhat radical alternative: What if MIT students could get interested in understanding *their* students' intuitive ideas? What if, as teachers, they could learn to look for the nub of a potentially generative idea in an explanation that was otherwise odd and certainly different from the canonical one – *an idea that could be developed***?** Strategies such as these would help teachers and pupils understand one another and this, in turn, was an essential constituent if high school students were to become interested in gaining a meaningful understanding of science/math subject matter. On this view, we made it one goal of the TEP to help our students acquire just such teaching strategies.

But how to do that? Was there know-how that was already part of MIT students' repertoires that would help them see some value in taking seriously ideas that would seem at first to be just wrong? We hit upon a surprising confluence: To deal successfully with the complexity and uncertainty of problem sets, MIT students have necessarily learned how to *play with a problem situation* – to selectively shift focus among possible features and relations at different levels of detail, even to reconstruct what they take to be "the problem." This is an essential survival skill at MIT. What if this MIT ability to see a problem in multiple ways and to recognize a common principle in differing embodiments, could also become a means for finding potential reasonableness in another person's explanation? The analogy was not obvious. Our students would need help in making a connection between playing with the meaning of a physics problem and playing with the meaning hidden in a pupil's explanation.

If the strategy was going to work, and if pupils were to learn the material, it

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would be crucial for credibility and effectiveness that the canonical theory and its multiple possible representations be kept clearly in mind as active backdrop. Against this backdrop teachers could find emergent ideas while also challenging their pupils to account for differences between their proposed explanation and the accepted one. This approach, which at first seemed radical, was, in fact, reflected in the new National Science Education Standards just published by the National Research Council: "Teachers of science should engage students in conversations that focus on questions, such as "How do we know?" "How certain are you of those results?" "Is there a better way to do the investigation?" "Is there an alternative scientific explanation for the one we proposed?" Do we need more evidence?" "How do we account for an explanation that is different from ours?" [*National Science Education Standards*, National Academy Press, 1996, p. 74.]

A Hand-Tooled Approach To Teacher Education

As we designed the first course with these goals in mind, it was clear that for MIT students, the path from problem sets to people had to be traveled along specific content. To paraphrase Seymour Papert, you can only learn about learning by learning about learning *something*. So we organized the first education course, 11.124, into four content units: physics (simple machines), biology (genetics), nature of matter (weight and density), and math. For each unit we present students with hands-on problem situations. But to achieve our teaching goals, "hands-on" in itself was not enough. The value of the situations depends on the depth of the principles that must be engaged, the effectiveness of the task in encouraging students to interrogate their own understandings, and the potential of the task to generate multiple representations/explanations that the students, among themselves, need to confront. Of critical importance is allowing plenty of time for students to turn back – to trace their conceptual process, to develop and interrogate explanations for what worked and what didn't, and especially to think about and argue over differences in the explanations that emerge among the students, themselves. (We focus on the simple machines tasks, here, but the biology task, designed by Brian White, was also hands-on and embodied similar principles.)

Snapshots From A Class Discussion

To give the reader a feel for the class and how it works, we describe in detail one of the task situations involving simple machines, along with the students' discussion that followed their completion of the task. (Most of the classes were videotaped. We are using the tapes to critique our classes and eventually to make a single edited tape to be used by other educators who have expressed interest in this approach to teacher preparation. Names have been changed to protect the innocent.) The 25 students in this semester's class represented 12 different majors including 4 students in mechanical engineering (see box, next column).

The Task: Lifting 100 Pennies

The task (designed by Crispin Miller) was to make a machine from a small set of Lego parts – blocks, a standard Lego electric motor, assorted gears and shafts, and a small winding spool with string on it – that would be able to winch up a weight consisting of 100 pennies. For this motor and winch drum to lift this weight, the gearing ratio needed was greater than any single ratio offered by the gears available – any successful machine would have to use at least two stages of gearing.

The 24 students in class this day worked in groups of three – two builders and one observer in each group. The observer was charged with taking notes which traced the building process, particularly noticing changes in strategies, what triggered them, and how the changes related to the builders' reevaluating their original assumptions.

11.124: 12 Different Majors

Chemical Engineering	1
EE/Computer Science	2
Humanities (21S)	1
Urban Studies	1
Cognitive Science	1
Math	2
Biology	6
Mechanical Engineering	4
Chemistry	4
Environmental Engineering	1
Chemical Engineering	1
Political Science	1

For instance, several groups initially built a row of gears, small to large, all in a single plane (see Figure 1, next page). This strategy failed, because (as will be explained in a moment), no matter how many gears were used, this arrangement still amounted to a single-stage drive. But, characteristic of MIT students, when their strategy failed, the builders took it not as a defeat but as a challenge. Playing with the situation, they were ready to rethink their design and to interrogate the assumptions that generated it.

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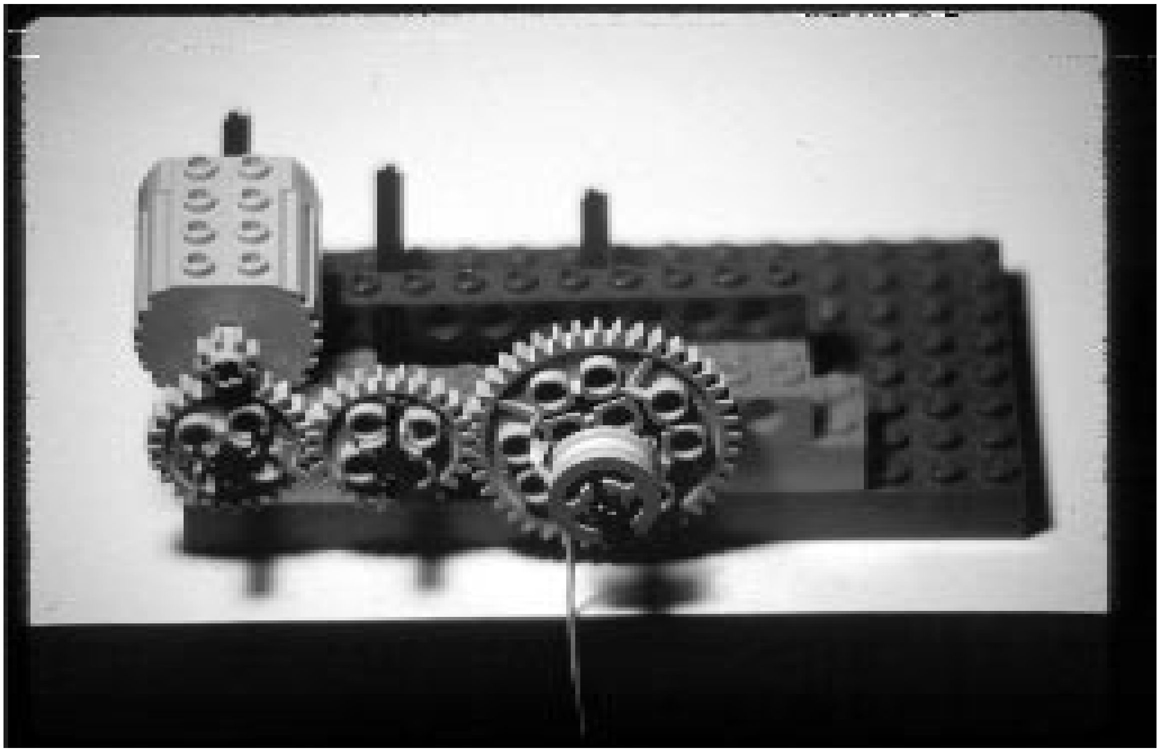

Figure 1

After a good deal of discussion within the groups, tinkering a bit, and often with some critical questions from Crispin, it became clear to most how they needed to redesign their machine if it was to do the job. To build the kind of multi-staged machine that would do the task, builders had to be able to move out of thinking in a single plane. They had to think back and forth between two different domains of physical work – translational motion, combined with force (at the teeth of the gears); and angular motion, combined with torque (at the shafts). With all the gears in one plane, every one of them will have its teeth moving at the same speed and with the same force as the first one (except for frictional losses); no number of intermediate gears will make any difference in the ratio between the first gear and the last gear. The machine that finally worked was a two-stage drive, where the motion of an intermediate gear is transmitted *as rotation* – not as tooth motion – to another gear of a different size *on the same shaft*, to create a different force and tooth speed. This transformed form of the work can then usefully be transferred, through tooth meshing, to the next gear (see Figure 2).

All but two of the groups eventually built successful machines in the 1 1/2 hour session, but explaining why the machines worked was another whole story. The discussion during the subsequent session was intense and revealing. As we had hoped, there were distinctly competing explanations with the proponent of each explanation feeling strongly about its "rightness," often considering another explanation simply "not intuitive."

The Discussion

We pick up the discussion somewhere in the middle. Nancy, who was an observer, is questioning the students' understanding of terms. She relates this to differences in the focus of students' explanations: "torque" or "force," which fails to convince her as a legitimate focus, in contrast to the ratio of gear revolutions which is clearly favored by her and her group:

Nancy (Biology major): I think the other thing is, though, some people are getting caught up in some of these terms that they don't completely understand. You use the term, "torque," and if you don't completely understand torque, how can you ever understand how it applies to this? I know when I was observing [the builders], when they were talking about it, they never even brought up *force or torque*. They were talking in language like, "O.K., for every revolution of the big one, the small one is going to go around 50 times." And we were talking about it more in those terms and trying to figure out the relations from that way.

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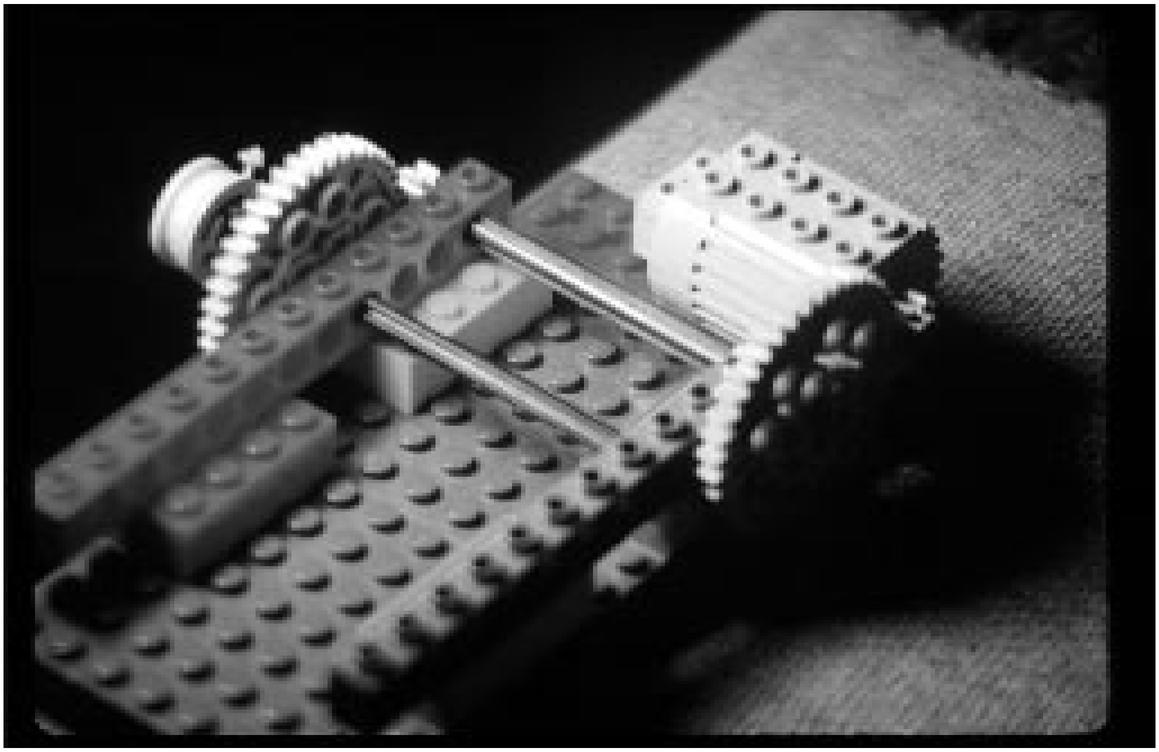

Figure 2

Jay goes on to question the effectiveness of the strategies of Nancy's group. Fred, who was in Nancy's group, explains in response to Jay's questions, how he was thinking about it. Fred uses the directly observable evidence (ratio of revolutions between big and small gears) that Nancy talked about, but goes on from there to focus on speed as the critical factor in why he thinks their machine worked:

Jay (EE/CS): I'm just curious, did your group discuss it completely in terms of revolution and teeth and stuff? I mean, how did you....

Fred (Biology): How did we get it to work from there?

Jay: Yah.

Fred: Well, basically, I had a goal that I wanted to *slow down the last gear*.

Sue (Chemistry): Why?

Fred: Why? Because the way I thought of it was that the slower it's going – like I had no idea whether it was correct – but what I thought was, there is *x* amount of power and if – this isn't right but this is the way I thought about it – was that power was in a way divided by the speed that the last gear was moving at. So, since I wanted to generate as much power as possible, *I wanted the last gear to be moving as slow as possible*.

Terry favors "distance" as the critical explanatory factor:

Terry (Biology): I guess the way I think about it is if you had the spool directly attached to the motor, the motor would not be strong enough to lift the pennies. And every time the spool spins around, it's going to lift the pennies *a certain distance*. And so if one turn of the motor is not enough energy – is not strong enough, whatever – turning the wheel is not strong enough to lift the pennies to that height, you need to make it so that one turn of the motor is lifting the penny less *height*. And so you need to change the gears in that way. I mean, I think we set up basically the same mechanism that they built – with the smallest gears to biggest gears.

Taking off from Terry's comment about "smallest to biggest gears," Joe, who was observing Laura, describes Laura's machine and explains what motivated her to use gears that went from large to small; Jeanne checks in to clarify:

Joe (Mech. Eng.): Laura built it bigger gears to smaller gears because she had an idea of "gearing down." And gearing down to her meant big gear to a small gear, not necessarily the velocities of the gears.

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Jeanne: That's something else, here. Laura, have I got it right, you're thinking about "down" in terms of big to small?

Laura: Yeah. I was hearing about "gearing down" and I was trying to figure out what that meant.

Tod favors force or torque as necessary for explaining how the machine works and he finds speed irrelevant for his understanding:

Tod (Chemistry): I really don't see where this speed thing comes from. It's not intuitive that in order to lift this object you need this gear to turn faster than that gear. For me, it's *force* that's...in order to lift this, we need a greater force than this motor can supply.

Jeanne: So all this stuff about distance and fast and slow is garbage for you as far as the gears are concerned.

Tod: As far as when I'm sitting down to think of, "How am I going to build a gear train to lift an object...." I don't consider angular velocity. I don't consider speed at all. I think about torque. I think about force.

Judy agrees:

Judy (Chemistry): Yeah, when you [Jeanne] came up to me and said, "Maybe you need to slow it down," it actually just aggravated me because I wasn't even considering speed. I don't know if I even said speed. Anyhow, my big problem was the difference in force and torque on the inside to the outside. And I couldn't get that. And then when you brought up speed, it just thoroughly confused me even more....

Jeanne brings the conversation around to teaching:

Jeanne: O.K., but what are you and Tod going to do with Nancy and Fred who want to think about....I mean, here's your students, Nancy and Fred, they're thinking in terms of gear revolution and fast and slow while you're talking about force and torque; what are you going to do with them?

Don, who was the MIT straight man in the class, interrupts to bring another whole ploy into the conversation, generating some quick responses from others:

Don (Mech. Eng.): The reason I think I get confused is because "bigger" and "smaller" doesn't relate to me. *I want to see the equations!*

Jeanne: Why do you want to see equations?

Don: It's like "bigger," "smaller," or "feels faster/slower," it doesn't mean anything – I want to see the numbers!

Nancy: It's not like they're vague terms, though. I mean they're qualitative and not quantitative, but they're pretty specific.

Don: Because the thing is, like, when you talk about "force," "torque," and then "speed" and stuff, they're all alike. You don't need to talk about speed at all to do this problem. But I think you can. You don't need to talk about torque at all to do this problem. But I think if people start combining those ideas you just get confused. In fact, you learn about these things in different courses. So I just made the model as simple as I can, and just worked through it like that. If it goes faster, it goes faster, it doesn't matter to me.

Jeanne: But the question is, can you get from one way of explaining it to another?

Don: Sure, but why? Because if you want to solve it using one way, you go straight through and solve it, you have a solution. And then you go back and try to figure it out. The intermediate steps just confuse you.

Jeanne: I guess what it comes down to is what do you want to *use an explanation for*? If you want to use it to try to help other people understand, then you're going to have to rummage around in your own understanding in order to find lots of different ways to make contact with people who aren't you.

Don: Right. But the goal of this was to solve the problem, not to learn. Wasn't it?

What Was That All About?

Don's comments, especially the last, were met with rather astonished laughter. Yet, as he probably intended, he did raise provocative questions:. What *was* "the goal of this?" And if it was "to learn," what was being learned that was different from "solving the problem?" We took it as a mark of a particularly successful session that these and other questions like them had even been raised. Looking back, we saw the process which we had hoped to provoke actually materializing: The task was compelling and sufficiently complex so that the students were drawn into

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seriously interrogating their own understandings. The subsequent reflections succeeded in generating a real confrontation of views. However, at this point no one, least of all Don, wanted to make a connection between them, to see "reason" in someone else's explanation. And yet, the session had successfully "modeled" the kind of classroom that we believed could work in settings where the understandings of the student body are much more overtly diverse than this one. Hearing one another's views as the students "rummaged around in their own understanding" was a lesson in itself.

Further, the session had been, in part, the kind of teacher preparation we are aiming for. The students had been obliged, through their own work, to interrogate their practical as well as theoretical understandings and to make the results of that inquiry explicit. That was a necessary first step. But it would take more time for students to take the next steps – to develop an interest in the controversies among explanations as a topic for investigation, as well. As the National Science Standards suggest, they still needed to get interested in the question: "How do we account for an explanation that is different from ours?" Holding these multiple explanations in mind and learning to see their possible intersections (despite Don's comments) could result in coming to a deeper understanding of the principles involved. In turn this deeper understanding would help them make the moves towards what we saw as important goals of the TEP.

It is well known that you only learn how to be an effective teacher when you are actually there, on the job, alone in the classroom with 20 students. That being so, we see the TEP providing generative rather than strictly structured, didactic preparation – a dynamic base from which to foment interest, controversy, inquiry, reflection, and the potential for continuous learning.

Teaching With Understanding

"Teaching for understanding" is a current catch phrase; we would prefer "teaching *with* understanding." The session addressed, if only obliquely, what that might mean: First of all, holding the canonical explanation/ theory clearly in mind as a necessary prerequisite for designing a task situation that would meet our criteria – the depth of the principles that must be engaged, encouraging students to interrogate their own understandings, a potential to generate multiple representations/explanations. Second, in the light of both practical and theoretical understanding, the importance of seriously considering alternative explanations, along with the importance of searching for the critical differences among them: How does the canonical representation of the situation differ (in focus, in kinds of entities named, relations built) from the alternatives; when (under what circumstances) could one representation be more useful/apt than another? Third, teaching with understanding means learning to differentiate between an explanation that probably cannot be rescued and one that holds the nub of a powerful idea even though it may be partly wrong (like those of some of our students). And finally, learning how to work with these generative ideas to develop their emergent potential.

These are the kinds of ideas and experiences that we would like our prospective teachers to carry with them into the classroom along with their knowledge of math, physics, biology, or chemistry. It is well known that you only learn how to be an effective teacher when you are actually there, on the job, alone in the classroom with 20 students. That being so, we see the TEP providing generative rather than strictly structured, didactic preparation – a dynamic base from which to foment interest, controversy, inquiry, reflection, and the potential for continuous learning.

Six students from last year are completing certification in June, 12 more from this semester's 11.124 are applying to graduate schools of education or to Wellesley's Fifth Year Program to complete their teacher certification, and 4 will be teaching in private high schools. With this cadre of MIT students out there teaching, we look forward to hearing back from the field on whether we are getting it right or not.✣

Letters

To The Faculty Newsletter:

I wish to comment on a key sentence in the editorial in the January/February issue. The sentence states: "Thus the early retirement plan is an effort to reduce the number of faculty." I have been involved with the retirement incentive plan since its inception, and I have never connected the two concepts of a retirement incentive plan and an effort to reduce the size of the faculty. The goal of the retirement incentive plan is to encourage intellectual renewal by making room for junior faculty when there is no longer a mandatory retirement age. The Institute stands to save money from an incentive program if retiring faculty are replaced by junior faculty, one for one.

As you may recall, in 1993 President Vest and then-Provost Mark Wrighton announced a plan to balance MIT's budget. This plan included, among several elements, the goal of slightly reducing the size of the faculty, and discussions have been held with selected departments (Nuclear Engineering, Ocean Engineering, and Physics) where such reductions, taken over a ten-year period, might make programmatic sense. Actually, at this time, there has been no significant change in the size of the faculty over the last few years.

The faculty reduction plan of 1993 and the retirement incentive programs are independent of each other. It is our intention to eventually replace each faculty member electing to retire under the incentive program. I hope this clears up a misconception that your readers may have obtained from the editorial.

Joel Moses
Provost

The "key sentence" referred to by Prof. Moses was a rhetorical flourish that survived into the final draft by editorial oversight. We believe that sentence to be erroneous and regret its inclusion in the editorial.

Editorial Committee

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To The Faculty Newsletter:

The comments on reengineering in the January/February 1996 issue of the *MIT Faculty Newsletter* were especially interesting to me. When I learned some time ago that MIT was to embark on re-engineering, I wrote to the Chairman of the steering committee and asked, "When you re-engineer, are you going to do it in a quality way?" The point of this question was that I had worked with W. Edwards Deming for the last 15 years of his life and, through industrial consulting in quality management, had seen first hand what happens when the principles of quality management are ignored as a company attempts to reorganize itself. The reply I got was simple, "MIT is not yet ready for quality management."

The Institute faces a number of daunting challenges. It seems inevitable that in the next few years there will be decreases in funding. If the leadership of the Institute were to learn about quality management methods, and then apply what they had learned, perhaps the passage through these difficult times can be made without great harm. On the other hand, if they do not, the costs in both human and financial terms will be very great.

A consortium of companies, including Ford, Motorola, Xerox, Procter & Gamble, and others, has banded together to bring these ideas to universities. They have put up 9 million dollars for NSF to use to attract academics into research on quality management. They have undertaken to 'adopt' various universities and give them financial assistance as well as instruction to promote quality management. As an occasional participant in this effort, I can report that it goes very slowly. The principal barriers are these: a) Unwillingness on the part of the top management to learn something new, to accept that a paradigm shift is required in these turbulent times; b) A disbelief on the part of faculty that they have anything to learn from the experiences in industry; and c) An inability to see how quality methods could possibly improve what they do.

The seeds of discontent, apparent in the *Newsletter*, suggest that the time is ripe for change. This retiree will watch with great interest.

Myron Tribus
Professor Emeritus