

MIT Faculty Newsletter

<http://web.mit.edu/fnl>

in this issue we begin a focus on some of the recent and upcoming Institute financial decisions that will affect all faculty as well as the rest of the MIT community. The article below, "Changes in MIT's 401(k) Plan," and our Editorial "Retirement Planning" initiate what we hope will be a continuing discussion. We welcome contributions on any and all related matters.



Hoppy Holidays

Teach Talk

What Else (Besides the Syllabus) Should Students Learn in Introductory Physics?

David E. Pritchard, Analia Barrantes,
Brian R. Belland

RECENTLY OUR EDUCATION RESEARCH group has turned its attention from studying micro-learning (see relate.mit.edu) to issues that lie at the heart of any educational reform – even though they are often overshadowed by discussions of what the syllabus topics should include. The questions we're addressing include:

- What should students learn?
- What do they actually learn? and
- What do they retain at graduation?

This contribution is based on a survey we administered to ~ 600 teachers and students concerning the first question – what students should learn in introductory physics. Since our survey was designed to emphasize student habits, pedagogical objectives, and overall

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Changes in MIT's 401(k) Plan

Peter A. Diamond and Andrew W. Lo

Among the many benefits that MIT faculty and staff receive, the Supplemental 401(k) Plan is one in which a large majority of the MIT community participate.

ON A REGULAR BASIS, the MIT Supplemental 401(k) Plan Oversight Committee reviews MIT's 401(k) plan. The committee has just completed a thorough review of the plan investments – (an activity that is unrelated to the work of the Benefits Task Force). The review has led to a number of changes, which will provide participants with more passive investment choices (i.e., investments that are tracked by measuring against a broad market index such as the S&P 500), including "target date" funds, generally improved fees, and more user-friendly written and Web-based materials. In addition, these changes will reduce the

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Editorial Retirement Planning

THE MIT HUMAN RESOURCES

Website allows each employee to study in detail his or her personal retirement benefit profile. The site is well done, an easy-to-use guide to planning retirement options within the framework of MIT's *current* retirement system. The MIT Task Force asks us to consider substantial changes to this system: Theme 5 in the Idea Bank (ideabank.mit.edu) entitled "Modern Workforce Policies and Practices," describes possible changes in retirement options, rules, and programs, all of which are aimed at reducing MIT's costs. Among them are:

- Revision of the 401k plan
- Freeze surviving spouse special death benefits
- Eliminate some pension disability benefits

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Subscriptions

\$15/year on campus
\$25/year off campus

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Retirement Planning
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- Change the actuarial method for accrual of defined benefits after 65
- Cap the career-based pension formula in the defined benefits plan
- Change the interest rate used on the cash balance pension plan
- Shift to a 5% cash balance defined benefit pension plan for new hires and current employees with short years of service
- Shift to three-year vesting for new hires
- Eliminate supplemental pension accruals for high-salaried employees
- Adopt an allocation strategy that matches pension assets to liabilities to recover all pension costs on federal grants and contracts.

If we adopt some subset of these recommendations will the machine remain properly geared? It is relatively easy to trace the effects on employees of just one of the changes proposed by the Task Force if all other features of our retirement plans are held fixed and if medium to longer term feedback behavior induced by a change in the structure of the plan are ignored. However, two or more simultaneous changes can interact in ways that are not immediately identifiable and can lead to unforeseen and unintended consequences – unless someone builds a model of our retirement system that properly accounts for the simultaneous effects of two or more changes in the plan's structure over a relatively long time horizon and uses it to trace consequences.

There are many, very different stakeholders at play. Each MIT employee wants to know:

- “How does a particular combination of changes in the MIT Retirement Plan affect my current, future, and retirement income stream?”
- “How do my contributions to retirement change? How does MIT's contribution to my retirement portfolio change?”

- “How will my benefits at retirement change?”
- “Life is uncertain. Is there any guarantee that restructuring our retirement plans is ‘permanent’? Or can we expect future changes?”

Even if we allow only one change in each domain – treatment of the 401k plan or adopting a 5% cash balance defined benefit plan for new hires, for example – our list yields $2^{10} = 1024$ possible combinations (including the current plan). The number of possibilities is, in reality, at least one to two orders of magnitude larger.

A retirement “program change” can be viewed as a choice of “where to be” in each of the thematic elements of change cited earlier. There are a very large number of choices. Even if we allow only one change in each domain – treatment of the 401k plan or adopting a 5% cash balance defined benefit plan for new hires, for example – our list yields $2^{10} = 1024$ possible combinations (including the current plan). The number of possibilities is, in reality, at least one to two orders of magnitude larger.

Not only are a large number of options at play here. Our retirement plan is part of a large organizational dynamic system which, in turn, is imbedded in a competitive marketplace for intellectual talent. This has not gone unnoticed in commentary our colleagues have posted about the Task Force recommendations. Here is a sample:

“Reducing retirement and medical benefits is, of course, a reduction in tax-free or tax-deferred compensation. If we believe agency theory, then the best faculty and staff, those that MIT wants to retain, will get market-based compensation. Over time taxable salaries will increase to compensate for the reduction. MIT will book some savings, but the net

cost, which is not easily observed, will not be on the books and will be illusory. The slight savings will come as a cost to our culture. It is the people that we will most want to retain who will leave or over whom we will spend time in recruiting

wars. We may not be able to attract the people we care about most.”

“With retirement benefits reduced, faculty and staff will be less likely to retire...and fewer opportunities for faculty renewal. The bottom line is that, in equilibrium, the proposed savings could likely be, in reality, net additional costs to MIT, but costs that are hidden.”

“Think carefully about the tradeoff between a salary reduction and a reduction in retirement benefits. Reducing salaries by one dollar also reduces Federal and State income taxes by a dollar so that an employee who pays aggregate taxes of 35% is ‘giving up’ only 65 cents. A dollar reduction in *after tax* benefits costs an employee one dollar. The multiplier effect on investment of tax-free dollars versus taxable dollars over many years magnifies the difference. Of course, we all must have immediate disposable income, but, for most of us, a salary freeze for a substantial period of time sounds decisively preferable to substantial cuts in after tax benefits.”

“I think people, institutions, societies, indeed, countries, are judged by the way they treat the most vulnerable people in their midst. Who are the most vulnerable people in an institution like MIT (apart

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Retirement Planning

continued from preceding page

from the students, whom we all serve)? I think the answer is that in general they are the very young and very old. I hope the administration will consider very, very

“For employees with five or more years of service Stanford contributes 5% of salary to what is essentially a 401k and matches up to another 5% of salary. In other words, for employees over 40 who contribute 5% of salary, Stanford contributes a total of 10% of salary. This is two times what MIT currently contributes towards retirement.”

seriously, the impact on morale across the Institute that reducing benefits, particularly for those approaching retirement, will have.”

“It would be helpful to explain why the Task Force selected this particular example: ‘...a 51-year-old employee with 19 years of service would, if he or she retired at age 65, receive a projected total income (including the basic MIT retirement, 401k withdrawals, Social Security and retiree medical benefits) of 108 percent of his or her annual income just prior to retirement.’”

This last “example” may be a case of selection bias: an atypical member of a large population is chosen to illustrate a general feature of the population. The example may or may not be an accurate characterization of most MIT employees. We do not know until a more complete analysis is done. Display of histograms of the ratios of projected total income at retirement to projected income just prior to retirement for

(a) non-academic employees for (b) academic employees and for (c) all MIT employees would tell us much more. In turn, account for the effect of length of employment on retirement benefits by partitioning each of (a), (b) and (c) according to length of employment at MIT.

“Our neighbor Harvard seems to offer better retirement benefits: ‘The University provides a number of generous, competitive pension plans. For most staff, once any employee is with the University six months the University contributes to their pension plan retroactive to their hire date. Each month the University contributes 5% of salary below the social security wage base to those under age 40, and 10% of salary below the social security wage base for those age 40 or over. For earnings above the social security wage base, the percentage is higher: 10% and 15% respectively.’

“For employees with five or more years of service Stanford contributes 5% of salary to what is essentially a 401k and matches up to another 5% of salary. In other words, for employees over 40 who contribute 5% of salary, Stanford contributes a total of 10% of salary. This is two times what MIT currently contributes towards retirement.”

Talent has many options. Stanford and Harvard are our principal competitors – and both appear to have more generous retirement plans than we do. There are, as one would expect, dissenting voices:

“MIT’s benefit packages are totally out of control. In most respects, they are even worse than the public sector benefits that are dragging California into bankruptcy. Hire Towers Perrin, or some other benefits consultant and instruct them to do a comparison between other ‘peer’ schools and also between MIT and comparably sized private sector employers. Use this independent study to reduce these ridiculous, crippling benefit packages.”

We recommend that the Task Force engage undergraduates and graduates and give them the task of building a retirement plan model capable of projecting the consequences for *any* MIT employee – administrator, service employee, assistant, associate, full professor – of a vector of changes in retirement options and plans that span those presented in the Task Force report.

Along with changes in our retirement plans, the Task Force considers major changes in MIT Medical benefits, in employment practices, and in use of space. MIT has been a supportive, stable, and generally equitable working environment for faculty and overall an excellent place to work. We need our current administration to continue to fully engage both faculty and staff in planning and implementing substantive changes, if we are to maintain a collegial, creative, and productive environment. ■

Editorial Subcommittee

From The Faculty Chair Holiday Readings and Reflections

Thomas A. Kochan

I HOPE EVERYONE TAKES TIME to enjoy the upcoming holidays with family and friends. As you do so, I'd encourage you to take a few documents home with you and use them to reflect on where we are going as a community. The reports capture much of the hard and thoughtful work our peers have put into helping shape the future of MIT.

I would put the report of the Initiative on Faculty Race and Diversity at the top of your list. This committee has conducted a two-year comprehensive review and assessment of MIT's efforts to attract and retain minority faculty. Committee Chair Paula Hammond summarized the report at the November faculty meeting and it will be available in mid-January on the Institute's new "Inventing Our Future" Website: diversity.mit.edu. The report will demonstrate that MIT has made some progress in this area but still has much work to do to meet our objective of attracting and retaining a more diverse faculty. This cannot and will not be a report that is issued and then put on the shelf. All of us from the chair of the faculty, to deans, department heads, to individual faculty members need to use this report as a working guide for how to redouble our efforts to obtain the benefits in education and research that flow from diverse faculty. I welcome your ideas on how we can put this report to work.

The final report of the Institute-wide Planning Task Force should also be available for holiday reading. This is a remarkable document both for its substantive ideas and for the process that generated it. This is *our* report – generated by over 80 faculty and another 120 or so staff,

student, and administrative contributors. Now we need to sort through the ideas in the report, test their costs and benefits more completely, modify and sharpen them as necessary, and then implement

The Sloan School has launched a very promising "talent bank" experiment to expand opportunities for current staff and reduce reliance on temporary and contract help. Others are working on modernizing our travel and procurement systems. Still others will process ideas for new revenue generation. This is MIT at work.

those that can both help address our budget problems and make MIT stronger for the long run.

Some of this is already underway. A very hardworking faculty and staff advisory group is looking at the alternatives posed for reducing benefit costs. Watch for more information coming from this group soon. The Sloan School has launched a very promising "talent bank" experiment to expand opportunities for current staff and reduce reliance on temporary and contract help. Others are working on modernizing our travel and procurement systems. Still others will process ideas for new revenue generation. This is MIT at work. Let's keep it up. Read the report and find some ideas that interest (or concern) you and get engaged in taking them to their best logical conclusion.

To satisfy your global interests, look carefully at two recent reports on MIT's international linkages. There is no doubt that our global reach will continue to grow in the years ahead. The real question

is how can we shape and control this process. The report of the International Advisory Committee, *Mens et Manus et Mundus* (web.mit.edu/provost/reports/IAC_Report_20090903.pdf), outlines a

set of suggested criteria for assessing opportunities and proposals as they either come to us from outside of MIT or from an internal faculty or administrative group. Another report, prepared by the MIT Global Council (web.mit.edu/provost/reports/Global.Council.Report.pdf), summarizes the growing number of international educational opportunities available to our students. Together these reports give us a roadmap for assessing proposals that come to MIT and for being more proactive in developing opportunities that advance our mission.

Reading these reports will demonstrate the range of faculty members working on key strategic issues, and perhaps encourage you to get involved in the year ahead. But the holidays are a time to reflect not just on our professional but also on our personal lives. So let me end with my best wishes to you and your families for the holidays and the new year. ■

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Changes in MIT's 401(k) Plan
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complexities of investing for retirement without restricting those who desire greater flexibility.

Along with these changes, we thought it would be helpful for our faculty colleagues to have an explanation of the process and reasoning that led to these developments, supplementing the information being provided by MIT to all participants. What will not change is MIT's record-keeper for the 401(k) Plan, Fidelity Management Trust Company. Fidelity will continue to provide administrative and recordkeeping services, including the enrollment of employees in the Plan, changes to investment and contribution elections, and the processing of beneficiary designations, loans, exchanges, and withdrawals.

The Supplemental 401(k) Plan Oversight Committee

The Supplemental 401(k) Plan Oversight Committee was established by the MIT Executive Committee to help MIT meet its fiduciary responsibilities under the Employee Retirement Income Security Act (ERISA). The committee is responsible for the selection and monitoring of investment options and consists of members appointed by the MIT President from among the senior officers, faculty, and staff of the Institute. [The current composition of the committee may be found at web.mit.edu/committees/president/Rosters/supp401k.pdf.] This oversight role is limited to the performance of the investments offered through the 401(k) Plan and does not include oversight of administrative operation or plan design.

The committee is chaired by MIT's Executive Vice President and Treasurer. In 2007, MIT was very fortunate to have recruited Theresa M. Stone for this important role. An MIT Sloan alumna, Terry came to us with deep financial experience, having served as Chief Financial Officer of a Fortune 500 company, Vice Chair of the Board of the Federal Reserve Bank of Richmond, and Chair of the

Board of the MIT Investment Management Company (MITIMCo), which is responsible for managing the Institute's endowment, defined-benefit pension plan, and welfare benefit plan. Terry's extensive financial expertise and leadership were invaluable as the 401(k) Oversight Committee conducted a major

retirement issues, Peter also participated in several subcommittee meetings.

Actions of the MIT 401(k) Subcommittee

The subcommittee's initial tasks were to interview and then recommend a professional investment consulting firm to assist

This process was extensive, and was made all the more challenging by the financial crisis that started in 2007, and reached a crescendo during the fourth quarter of 2008 with the collapse of Lehman Brothers. During this time, the subcommittee met frequently to keep abreast of the impact that the developing financial crisis might have on the 401(k) plan. . . .

review of the investment options available to plan participants.

One of Terry's first actions as Chair of the 401(k) Oversight Committee was to confer with the President and Provost about the composition of the committee, with the twin objectives of bolstering its investment expertise and maintaining broad representation of the entire MIT community. Based on Terry's recommendations, two seasoned investment professionals were appointed to the committee: Marty Kelly and John Nagorniak. Marty is currently a managing director at MITIMCo responsible for marketable securities, and John was the Chief Investment Officer of State Street Bank and Trust Company before founding Franklin Portfolio Associates, and is currently a director of MITIMCo. Also, Institute Professors Peter Diamond (Economics) and Barbara Liskov (EECS), and Larry Candell (Lincoln Lab) were added to the committee, and Professor Andrew Lo (Sloan) was re-appointed. In the fall of 2007, the committee appointed a subcommittee consisting of Marty, John, and Andrew to engage in a more detailed analysis of the 401(k) plan's investment options, and to report back to the full committee with specific recommendations and alternatives to consider. Given his expertise in the economics of Social Security and

the committee in discharging its duties, and to review the existing 401(k) plan's choice of investment options and their presentation. From October 2007 through March 2008, the subcommittee interviewed several investment consultants, and based on its feedback, the committee chose unanimously to engage the services of Mercer Investment Consulting, Inc. Mercer brought considerable experience to the committee, having advised many corporate and educational retirement plans similar to MIT's. The Mercer consultants assigned to MIT have been extremely helpful in every aspect of the committee's deliberations, focusing particularly on regular reviews of the 401(k) plan's investment performance, the selection of new investment options, and the operational aspects of moving assets from one manager to another.

From March 2008 through the end of the year, the subcommittee reviewed the investment design of the 401(k) plan and the specific investment choices available to plan participants. The subcommittee considered a variety of new managers, new investment products, the fee structures of existing funds, and the possible termination of underperforming managers. This process was extensive, and was made all the more challenging by the financial crisis that started in 2007, and

reached a crescendo during the fourth quarter of 2008 with the collapse of Lehman Brothers. During this time, the subcommittee met frequently to keep abreast of the impact that the developing financial crisis might have on the 401(k) plan, but the primary focus was on the broader agenda of improving the plan's investment options and their presentation. Given a recent change in the law, the committee also had to decide how the 401(k) plan should invest the funds of participants who join the plan but do not select an investment option.

During the first half of 2009, the subcommittee formulated a proposal that included several new investment options including "target date" or "life-cycle" funds, the termination of consistently underperforming funds, the transfer of some of the plan's assets to new managers, and a presentation of the investment options that placed more emphasis on passive index funds with lower fees. At the same time, the subcommittee was sensitive to ensuring that the 401(k) plan's existing investment options would still be available as part of the new investment program (except in cases of consistent underperformance) so as to provide as much continuity as possible for those participants who were satisfied with their choices. These considerations were not trivial because prior to the creation of the current plan structure, MIT offered two investment options (an all-equity fund and a bond/stock fund), and to preserve continuity in moving from the legacy to the current structure, the Bond Oriented Balanced Fund and the Diversified Stock Fund were created, organized as commingled pools (i.e., combines the money of many investors who own a share of the pool) managed by MIT. These funds invest in a combination of underlying asset classes that were selected to approximate the underlying investment strategy of the legacy vehicles. Since many plan participants stayed with these options, they currently hold nearly 65% of the total funds invested in the plan. However, the choices of new participants have a very different pattern, with over 66% of new-

participant assets being allocated to the "Investment Window," which is a broad offering of mutual funds. Apart from the termination of a small number of underperforming funds, the new investment options will allow all participants to continue with their current choices if they

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wish, with some of the choices having new managers.

The proposed changes to the MIT 401(k) plan were approved by the Oversight Committee in the spring. In November, all plan participants were informed of the changes by e-mail and direct mail. The changes will go into effect at the start of 2010.

Before describing the changes in more detail, we would like to acknowledge the enormous contributions made by the other members of the Oversight Committee (Alison Alden, Larry Candell, Marty Kelly, Barbara Liskov, and John Nagorniak) and the MIT staff who support this committee (Gary Cahill, David Chused, Sophia Maniaci, and Jean Samuelson). None of these changes would have been possible without the dedicated efforts of these individuals over the past two years.

Our discussion of the 401(k) plan's new investment structure begins with a summary of the changes in managers of existing funds since this is of direct interest to those invested in these funds. We then turn to the addition of new funds – including Vanguard Lifecycle Funds – to the investment array, and also describe a change in how the plan's investment options are presented to participants. We conclude with a brief discussion of the new default choice for participants who

do not choose an investment option when they join the plan.

I. Changes in Managers

Bond Oriented Balanced Fund. This fund is a "commingled pool" currently combining seven separate funds managed by

Pyramis, a division of Fidelity Investments. Two of the smaller Pyramis funds will be retained, which together represent 7% of the assets in this fund. The rest of the existing assets will be managed by PIMCO and Vanguard (approximately 40% of total assets to PIMCO and 53% to Vanguard). In terms of asset classes, the overall portfolio is not being changed, just the managers. With this change, we anticipate a reduction of expenses from .22 to an estimated .1655. With lower fees and a good track record of management, we think this is a better choice going forward. People invested in this fund do not need to do anything, but, of course, do retain the option of moving their investments to other funds.

Diversified Stock Fund. This commingled pool currently consists of six separate funds managed by Pyramis and Fidelity Investments. One of the smaller Pyramis funds will be retained and the rest of the assets will be managed by Vanguard. Again, part of the reason for a change is the anticipation of lower fees, with expenses estimated to decrease from .25 to .0759. People invested in this fund do not need to do anything, but, of course, do retain the option of moving their investments to other funds.

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Changes in MIT's 401(k) Plan

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Some of the separate funds that make up these two commingled pools also are available as separate stand-alone investments. These separate investments will also experience these changes in management.

Fidelity Bond Pool. The existing underlying investments in this pool will now be managed by PIMCO (60% of the allocation) and Vanguard (40% of the allocation). The name will change to Core Bond Pool and expenses are estimated to decrease from .20 to .1898.

Fidelity US Equity Index Commingled Pool – Class 2. This fund will no longer be part of the larger commingled pools. By moving this fund out of the Bond Oriented Balanced Fund and the Diversified Stock Fund, the decrease in total assets under management will impact both the expenses, which will increase from .05 to .10, and the share class, which will change from Class 2 (institutional shares) to Class 1 (investor shares). You can access the Vanguard Institutional Index Fund in the Investment Window at an expense ratio of .05.

II. New Investment Options

Vanguard Target Retirement Trusts, Vanguard Index Funds. Some participants in the 401(k) plan want to actively manage their portfolios. Others are looking for investment options that can sensibly be held with limited attention to making changes. The new options and the new layout of options are designed to particularly help those who do not want to be actively managing their investments. When an individual invests in an “actively managed fund,” where the managers are choosing the investments and possibly changing them over time, the individual investor has to pay attention to how good a job the manager is doing. In contrast, a well-run index fund simply attempts to match the outcomes

in some standard index of investments, such as the S&P 500 index. Given stochastic variation in the returns to any investment strategy, it is easier to tell whether an index is being adequately matched than whether, over time, an active manager is doing a good job. While not all passive fund managers do exactly the same in matching, there is not as large a concern about monitoring the performance of the manager. Thus “passive funds” are more convenient for those not planning on more monitoring of their investments. To aid those who want to follow the passive investment strategy, we have added a number of Vanguard Index Funds to the array of options. These Vanguard passively managed index funds generally carry lower expenses and fees than actively managed funds. While MIT's 401(k) plan has always had some index funds among its investment options, the presentation of investment options available under the Plan has been redesigned to create greater visibility and easier access to these funds.

Recently, there has been growing interest in lifecycle funds. These are funds made up of a number of underlying asset classes that change the mix of different classes over time. The idea is to slowly move to a less risky portfolio which may be desired by some investors as they age. Among the 401(k) plan's new investment options is a family of Life Cycle Options that will provide participants with a diversified investment option with relatively low expenses (.14) – the Vanguard Target Retirement Trusts. “Life Cycle” or “Target Date” options are designed to automatically adjust the balance between stocks and bonds as participants approach the target date. These options may appeal to Plan participants who do not want to actively manage their investments and the stock/bond mix of their investments on their own. Again, as detailed below, we have placed them in an easy-to-find location in the presentation of investment options.

III. Presentation of Investment

Options

The previous terminology that refers to Tiers I, II, III, IV is replaced by (1) Life Cycle Options, (2) Asset Classes, (3) Investment Window, and (4) Brokerage Link. The Asset Classes set of options includes the Bond Oriented Balanced Fund and the Diversified Stock Fund and a number of index funds covering different asset classes, both bonds and stocks. The presentation of the options in written material and on the web has been changed to make choosing easier. Some investment options have moved into Asset Classes or the Investment Window, but are otherwise unchanged.

IV. Change in Default Investment

Option

Currently, when a participant does not select an investment for contributions, the contributions are placed in the Fidelity Retirement Money Market Portfolio. The 2006 Pension Protection Act (PPA) no longer permits use of a money market fund as a default investment, although it will still be available as an active choice. The new law permits the use of life cycle or target date funds as a default or automatic option for faculty who do not select an investment option. The new default will be the age-appropriate Vanguard Target Retirement Trust and will apply to new contributions. Thus the accumulations as of January 1, 2010 of participants who have been defaulted into the money market fund will remain in the money market fund, with new contributions placed in the lifecycle fund.

The committee will continue to provide oversight of MIT's 401(k) Plan and periodically re-visit the investment lineup. We believe these current changes enhance the MIT plan and offer more choice for the MIT community. ■

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What Should Students Learn in Physics?
Pritchard et al., from page 1

student skills, it will be relevant to faculty in all General Institute Requirement (GIR) courses.

Historically, introductory physics was a lecture-recitation course, and discussions of course reform were limited to changing syllabus topics or whether to have laboratories with the course. The development of tests of conceptual understanding, such as the *Mechanics Base Line Test* and the *Force Concept Inventory*, however, revealed limitations of conventional instruction. As a consequence, new instructional techniques (peer instruction, interactive lectures, discovery labs) and Web-based activities (*phet.colorado.edu*, *WebAssign.net*, *MasteringPhysics.com*) have been developed to enhance learning, and which of these to adopt has become a new focus of course reform. In a recent major reform – 8.01 and 8.02 TEAL – the Physics Department adopted *MasteringPhysics.com* and switched to studio physics (students are seated at tables and do much work in groups) and peer instruction (using clickers) with the objectives of teaching students conceptual knowledge as well as creating more student-teacher dialog.

This paper represents an attempt to shift the course reform discussion in introductory physics – and hopefully other subjects – to instructional goals rather than teaching techniques and syllabus topics. This is imperative, because numerous learning goals have recently come under contemporary discussion in physics education research including cognitive abilities, scientific abilities, and *habits of mind* (e.g., demonstrating problem-solving skills by initially developing a qualitative description of the problem).

To elicit non-topical learning goals for introductory physics we used a Delphi study approach, starting by asking about 20 successful instructors – mostly from the Physics Education Research (PER) or American Association of Physics Teachers (AAPT) communities – to suggest such goals in their own words. From their responses we distilled 12 alternatives.

Then we polled successive groups of instructors, using the question:

“Due to a change in the academic calendar, you have 20% more time to teach the calculus-based introductory course to non-physics majors, and the syllabus has not been expanded. What learning will you seek to add or emphasize with this extra time?”

The respondents were asked to vote for two of the 12 alternatives, which were grouped into four categories:

1. Course Content

- Wider content: e.g. gyroscopes, optics, quantum mechanics, modern physics....
- Discovery or Traditional Labs.

2. Instructional Themes

- Scientific method, hypothesis and experimental test.
- Physics is constructed from a few ideas that can be expressed mathematically.
- Epistemology: how do I know, derivations?

3. Problem Solving

- Vocabulary of Domain.
- Concepts: “Be Newtonian thinkers.”
- Problem Solving: understand, plan the solution starting with concepts (plan set-up).
- Problem Solving: make sense of an answer (includes estimation) using units, special or limiting cases, symmetry, etc.

4. Relation to the Outside World

- Write/Present scientific argument either in oral or written formats,
- Science in news and society, to read science news critically, e.g., be able to examine a *New York Times* article for sense and consistency.
- Physics applied to everyday life/things, to understand how objects around you work.

It should be noted that this approach leaves two major questions out of the discussion: Should we adopt a more modern approach (e.g., basing discussion of matter and interactions on an atomic viewpoint), and should we assess students more broadly than by their ability to solve problems (e.g., a term paper or project)?

We received 708 responses from instructors representing different groups: *educators* at AAPT meetings, *atomic researchers* at a Gordon Research Conference, and *education researchers* at a physics education research meeting. These three groups agreed on some topics, but also disagreed substantially on others. We also asked several groups of students what they wanted to learn, given the same alternatives, receiving a total of 562 responses. Students in different institutions were in reasonable accord, but their preferences generally anti-correlated with those of their instructors. The percentage of positive responses on each of the alternatives is presented in Figures 1 and 2. The dashed portion of the bars corresponds to the 95% confidence intervals for proportions calculated using a normal distribution. The scientific method and vocabulary of subject domain were unpopular (average under 2%) with the three groups of instructors and with students as well; therefore, they are not included in the figures.

Similarities and differences between instructor groups

The most striking fact about instructor preferences in Figure 1 is that there is no “must do” selection. Sense-making of an answer was the instructors’ top choice (17% of the votes representing ~34% of the teachers, since they could vote twice). All instructor groups showed about average preference for both laboratories (10%) and understanding science in news and society (10%), and a disdain for wider content (4%).

The most notable difference among instructors was on problem solving – the combination of vocabulary, concepts, and plan set-up. Educators selected problem solving (excluding sense-making) at 39%, more than atomic researchers (16%) and even more than education researchers (7%). For education researchers, epistemology (17%) generally applies to the construction of individual students’ knowledge (e.g., whether the student thinks problem solutions are obtained by

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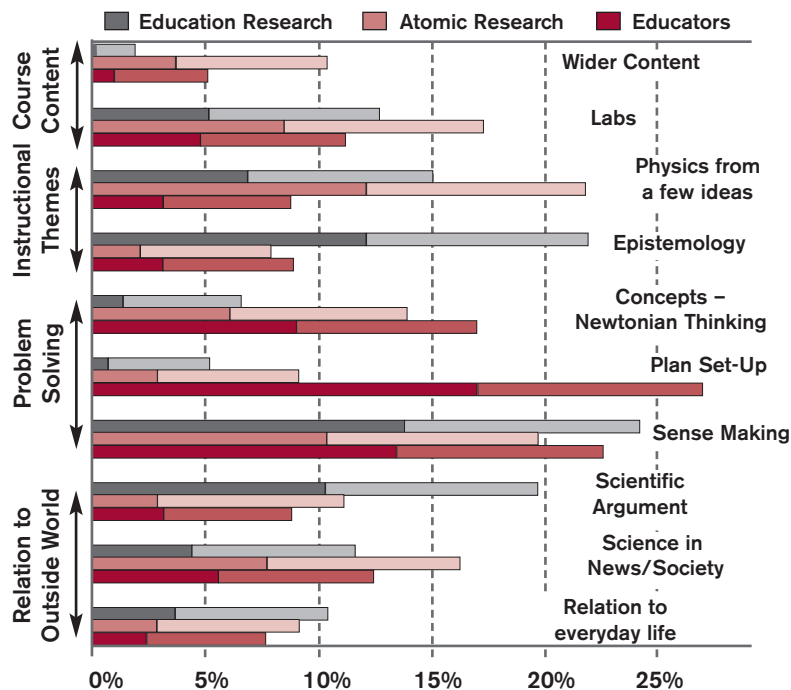


Figure 1. Percentage of each instructor group choosing each topic as an important addition to the syllabus. The lighter portion of the bars corresponds to the 95% confidence limit (i.e., have total length of 4 sigma). If two lighter portions just overlap, the chance the two group averages are really the same is $p \sim 0.01$.

applying memorized formulae rather than thinking about the concepts), and a good fraction of epistemological effort is aimed at better problem solving. Counting most of the “epistemology” responses as problem solving, responses puts Education Researchers near the average of all instructors in this category. Education researchers thought “scientific argument” (15%) was more important than the other two instructor groups (average of 5.5%). Atomic researchers rated “physics from a few ideas” (17%) as their top selection, while educators were less enthusiastic (6%).

Similarities and differences between instructors and students

The substantial difference between the preferences of students and instructors (average of educators, atomic researchers, and education researchers) is shown in Figure 2. Wider content was students’ top preference but instructors’ lowest (19% vs. 4%). The relation of physics to everyday life/things was students’ second pref-

erence but the instructors’ second lowest (15% vs. 6%). On the other hand, students had no interest (3%) in sense-making, which was the instructors’ top selection (17%). Students had little interest in scientific argument (2%) whereas instructors thought it merited significant attention (9%). Students and instructors agreed on priorities of five of the 10 options – physics from a few ideas, epistemology, concepts, plan set-up of problems, and understanding of science in news and society. However, the differences on the other selections were so marked that the correlation between students’ and teachers’ preference is -0.4 . In other words, the students’ interests are more than orthogonal to their teachers’ – they are 115 degrees apart!

Implications for Course Reform at MIT

What do these findings imply about course reform for introductory physics? The most significant finding is that students’ preferences anti-correlate with ours. We instructors seem to be saying, “We are

What Should Students Learn in Physics?
Pritchard et al., from preceding page

going to make you into expert physicists,” and the freshmen seem to be replying, “Before we commit to that much hard work, tell us how physics connects to the world around us and to society’s problems, and teach us new things we haven’t studied before.” Freshmen don’t see the relevance of introductory physics to their lives, as evidenced by a survey we took in 8.02 where, by nearly 2:1, they characterized their prime motivation in 8.01 and 8.02 as “goal-oriented” [to pass the requirement] rather than “mastery learning” [of the subject]. In contrast, they indicated, also by $\sim 2:1$, that they’d choose to learn the subject matter of their major but receive no degree rather than get a degree that was accompanied by little learning. Arguably, students don’t realize that introductory physics underlies a large majority of their likely majors. Many students view introductory physics primarily as a required hurdle and focus exclusively on how to do problems like those on exams, rather than focusing on any other aspect of the subject, such as epistemology, history, and relevance to their major or to their everyday observations or reading.

To get students’ engaged attention we should demonstrate the relevance and utility of physics to their lives and careers. We can do this without sacrificing a great deal of course time, simply by selecting illustrative examples involving “physics applied to everyday life/things” and “science in the news and society.” Our moving mass problems could involve topics such as air resistance and how airplanes fly – rather than artificial examples like a railroad car slowing because it is filling with rain – and our treatment of mechanical energy could mention the energy crisis. We could use examples that illustrate the application of basic physics in other disciplines at MIT as well, and in current research.

Demonstrating the relevance of introductory physics would address two of the students’ four top preferences, but not their top preference – new topics.

Unfortunately, research literature and concept tests show that we already sacrifice basic conceptual understanding by covering too many topics. Thus a better approach might be to add sufficient real world and societal relevance to existing topics (certainly not part of what our students learned in high school) so our students find revitalized interest.

At MIT, teaching students to become critical thinkers is one of our professed general educational goals. A foundational skill for critical thinking is to “make sense of an answer (includes estimation) using units, special or limiting cases, symmetry, etc.” – the top instructor choice in our survey. In honesty, we (and most professors nationwide) do not regularly make sense of our example solutions; we employ a partial credit grading system that often awards significant credit for physically ridiculous answers, and only sometimes do we take a point off if the answer is dimensionally incorrect.

Both students and instructors want students to become more expert problem solvers, although students don’t see the value of making sense of their answers. (According to research, novice problem solvers put their faith in procedures rather than concepts.) Currently introductory physics is primarily oriented to problem solving, especially in TEAL, and clearly achieves success – students exiting 8.01 show a learning effect in excess of two standard deviations on the problems requiring an analytic answer (versus just over one on conceptual questions). However, typical physics problems represent a narrow slice of possible assessment tasks. They give only necessary and sufficient information, use standard notation for the various physical quantities, give the approximations, and (at MIT) rarely involve numbers. A consideration of possible consequences, such as not assessing “thinking like a physicist,” encouraging novice problem solving techniques, or failing to give a quantitative view of the world is important in a discussion of course reform, but lies outside the scope of this article.

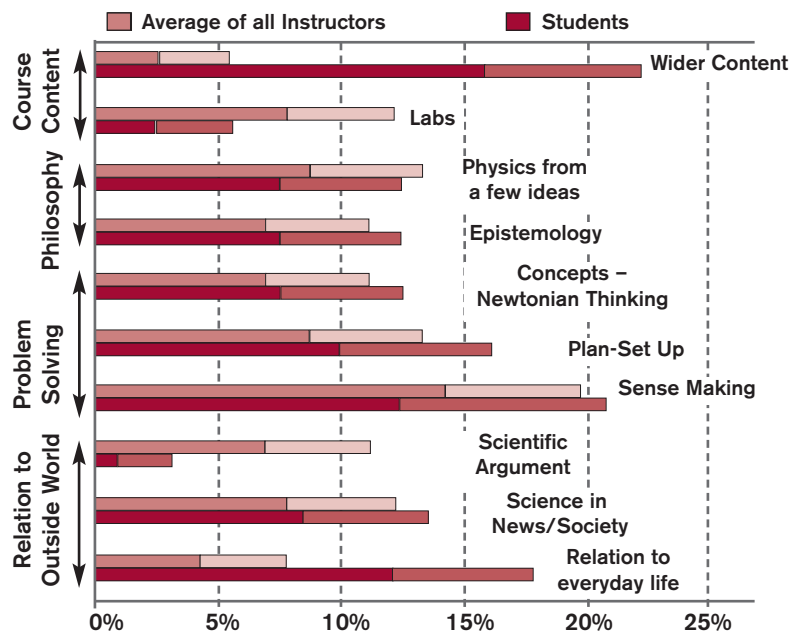


Figure 2. Percentage of instructors (average of educators, atomic researchers, and education researchers) and students choosing each topic as important. The lighter portion of the bars corresponds to the 95% confidence limit (i.e., have total length of 4 sigma). If two lighter portions just overlap, the chance the two group averages are really the same is $p \sim 0.01$.

Our results, like any exploratory study, raise new questions. In addition to the professors and the students, the educational goals of the Institute at large, the Physics Department, and the instructors of courses requiring 8.01 and 8.02 have priorities that must be considered in any comprehensive discussion of what to teach. Also there might be other groups of instructors with different preferences; or student priorities may change over time. (Results from College of DePaul indicate that students lose interest in studying more topics and become much more interested in problem solving by the end of the semester. MIT seniors highly value 8.01 and 8.02 for teaching them problem solving.)

These refinements aside, our results show a robust mismatch between our teaching and what students are interested in learning; moreover they show that we physics teachers ignore our own top preference – making sense of the answer. We really should consider addressing such disparities when we reform our GIRs.

Future articles in this series will address what students actually learn in 8.01 and how much of it they still retain at graduation.

Acknowledgments

We are grateful to E. Cornell, C. Monroe, M. Sabella, and J. Thompson for giving us time to survey the attendees at their conferences, and to T. Carter and D. Demaree for administering the survey to their classes. We are grateful for support from NSF grant PHY-0757931.

Note: This work is part of a study for national publication that will hopefully affect physics discussions nationally. The views are those of the authors and not of the Physics Department.

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Memorial Resolution for David B. Schauer



The following resolution was passed unanimously at the Institute Faculty Meeting on October 15, 2009.

IT IS WITH GREAT SORROW that we regretfully acknowledge the sudden death of our friend and colleague, Dr. David Schauer, on June 7, 2009 – one day after his 48th birthday. David Schauer was known not only for his keen scientific mind, but also as a friend whose empathy and compassion touched countless individuals. David's warm personality and gentle nature evoked a sense of genuine trust and caring. His students loved him for his openness, unpretentious manner, and ability to sit down with them to discuss research projects, or talk about personal issues or life in general. This appreciation is shared by the many colleagues he interacted with not only here at MIT but also those more widely at the national and international level.

David was born in New York but spent his youth in North Carolina, where he

graduated with honors in biology from the University of North Carolina in 1983. He was then accepted into the School of Veterinary Medicine at North Carolina State University. He chose this career path after being counseled by a research veterinarian and mentor, Dr. James Pick, who convinced David that a veterinary education would allow David to establish solid foundations in science and comparative biology. Indicative of David's passion for science, he undertook laboratory research during his veterinary education with Dr. Paul Orndorff, professor of veterinary microbiology, and published his first two first-authored papers while in Dr. Orndorff's laboratory. He graduated with a doctorate in veterinary medicine in 1987, and then after a year's experience in private practice joined the laboratory of Dr. Stanley Falkow at Stanford University to gain a doctorate in microbiology and immunology. Dr. Falkow considers the publications resulting from David's research on *Citrobacter rodentium* as seminal contributions on the role of microbes in inflammatory bowel disease and colon cancer.

Following completion of this work, David was recruited to MIT in 1993 as an assistant professor in the Division of Comparative Medicine and the Division of Toxicology, transitioning in 1998 into what is now the Department of Biological Engineering. In 1999 he was promoted to associate professor, and four years ago he became a full professor. Along the way, David became increasingly involved with undergraduate and graduate education at MIT, both in the Biological Engineering Department and institute-wide. He served on the MIT Undergraduate Curriculum Committee as chairman, and

helped establish a new interdepartmental program in microbiology in 2007, as co-director, with Alan Grossman of the Biology Department. David will be long remembered as a gifted and dedicated teacher both to undergraduate and graduate students at MIT, and additionally at the Chulabhorn Graduate Institute in Bangkok, Thailand, where he taught during a number of summers.

David's research was supported on a continuous basis by the National Institutes of Health throughout his career at MIT. His studies on microbial pathogenesis of gastrointestinal pathogenic bacteria, particularly *Citrobacter rodentium*, a murine model of enteropathogenic *Escherichia coli*, and enterohepatic helicobacter are widely known and respected. David's research provided important insights into the molecular mechanisms evoked by enteric pathogens and how the infections caused by these bacteria perturb the gastrointestinal barrier, elicit inflammation, and produce clinically relevant disease. His scientific research is chronicled in scores of journal publications, review articles, and book chapters. Professor Peter Dedon, a colleague in Biological Engineering here, describes David as a "brilliant scientist and an absolutely wonderful experimentalist."

Along with his scientific contributions, David's personal interactions as a mentor and collaborator in his research program have had significant impact. Dr. Vince Young, now on the faculty at the University of Michigan, joined David's laboratory for a postdoctoral fellowship in infectious disease. Vince credits the training he received under David's supervision as his primary motivation to focus his research on the microbial ecology of the gastroin-

testinal tract. As Vince describes, David remained a steadfast friend and was readily available for advice, “which was always useful and always cheerfully given.” Dr. John Leong, a professor at the University of Massachusetts Medical School, was a collaborator and friend. He describes David’s genuine interest in the work of others in the field and his innovative approach to environmental health problems on a global scale. Dr. Scooter Holcombe, currently a staff veterinarian and immunologist at Massachusetts General Hospital, was David’s classmate in veterinary school and a close friend for 25 years, who also echoes these sentiments. Scooter fondly remembers David’s sense of humor and intense focus, whether in the laboratory or relaxing with sports activities.

Dr. Schauer’s membership on the Gastrointestinal Mucosal Pathobiology Study Section exemplifies the esteem in which David was held by his colleagues. Dr. Richard Peek, a professor at Vanderbilt University and a co-member of this study section, recalls that David “exuded enthusiasm, integrity, and vigor for his work as well as the work of others.” David also served on the editorial board of several

journals and as a scientific reviewer for many others. His colleagues at MIT and his collaborators throughout the world also valued his keen scientific insights and, importantly, his friendship.

David’s family and his Jewish faith were the center of his personal life. Along with Carol, his wife of 25 years, he was the proud father of two sons, Nathan and Sam, both young adults; Nathan is a sophomore in college, and Sam is a recent high school graduate. The family resided in Newton, Massachusetts, and was actively involved in their temple. David introduced his sons to the Young Judea Summer Camps and the 9-month Young Judea Program in Israel, where he and Carol had first started dating. In addition to participating in a variety of sports including intramurals with our graduate students, David relished the outdoors and always eagerly anticipated camping trips with his family and bike treks with his wife in Europe and Asia.

David is survived by his mother, Francine (Ross) Schauer of Scottsdale, Arizona, and 2 brothers: James of Madison, Wisconsin, and Andrew of Denver, Colorado.

We will miss and remember David in many ways, each of us with special thoughts of his warm, gentle spirit, his openness to others’ views and ideas, and most importantly how he embraced life, both personally and scientifically, and deeply appreciated its boundless opportunities.

“BE IT RESOLVED: THAT THE FACULTY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY, AT ITS MEETING OF OCTOBER 21ST 2009, RECORD ITS PROFOUND SENSE OF LOSS ON THE DEATH OF OUR BELOVED COLLEAGUE AND FRIEND, DAVID B. SCHAUER, AND EXPRESS ITS DEEPEST SYMPATHY TO THE SCHAUER FAMILY.”

Douglas A. Lauffenburger

James G. Fox

Peter C. Dedon

Steven R. Tannenbaum

Colleagues in the Department of Biological Engineering and Division of Comparative Medicine

(edited from “In Memoriam” article by J.G. Fox in *Gastroenterology*) ■

letters

Allocating Faculty Time

To The Faculty Newsletter:

THIS NOTE IS IN RESPONSE TO your September/October editorial “altering the culture” query about administrative involvement in allocation of faculty time to teaching vs. research.

From a business/financial perspective MIT has two main educational businesses – undergraduate education funded almost exclusively by students and donors, and research-centered graduate education funded largely by fellowships and student RA earnings billed to sponsors. Independent of their absolute “profitability”, the former relies significantly more on charity than does the latter and therefore

our finances would clearly not be improved by increasing the former at the expense of the latter, as some have suggested.

The alternative option of increasing the graduate program makes sense financially only if that business is “profitable” in an absolute sense (unlikely), and shrinking both businesses makes sense financially only if we assume the charitable component will shrink less over the long term. The optimum strategy is therefore likely to be continuing improvements in long-term operational efficiency that promote teaching and research productivity within a cost-effective plant. MIT has been blessed relative to its peers by its healthy evolving strategic balance, so it is reasonable to

expect that optimum solutions should not dramatically shift that hard-won multi-dimensional balance as costs are reduced, barring significant shifts in our sponsor/donor environment. Beyond insightful efficiency improvements and pruning, the main remedy for financial stress is creative increases in income and thoughtful reductions in compensation that preserve institutional /esprit de corps/ and academic excellence. In summary, moderation and balance will be key.

Dave Staelin

Professor

Department of Electrical Engineering and Computer Science

The MIT150 Symposia: A Call for Proposals

MIT WILL CELEBRATE ITS 150TH anniversary during the spring semester of 2011. In addition to a variety of other programs that will celebrate the past and envision the future, the Institute will sponsor a series of five symposia. The goal is to create a series that will explore issues and topics of interest to MIT's commu-

nity for these symposia. A subcommittee of faculty, senior administrative staff, alumni, and students will select proposals for funding. This initial request is for two-page "pre-proposals," from which a number will be selected and invited for longer proposals.

scholarly works, permanently recording the events in a combination of books and online materials.

Requirements

Each proposal should identify as a leader at least one faculty member or senior administrative staff member, include potential speakers from both within and outside of MIT, and represent more than a single department or center.

Recommended

Strong proposals will identify matching funds and/or additional fundraising, highlight MIT's intellectual focus and impact, engage a range of MIT stakeholders (alumni, faculty, staff, students), and gather participants from around the globe.

Dates and deadlines

- *December 20, 2009* – Pre-proposals due
- *Early January 2010* – Pre-proposals selected for further development
- *February 15, 2010* – Complete proposals due

Contact

Pre-proposals should be directed to the attention of Professor David Mindell, chair of the MIT150 Steering Committee, and sent as a PDF to mit150@mit.edu by December 20, 2009. Questions? Please contact Ted Johnson, director of planning and operations for MIT150, at tej@mit.edu. ■

This series will focus on how MIT as an institution fosters innovation, and together with an academic convocation to be convened by the president, forms the scholarly and intellectual centerpiece of the MIT150 program. The ideal symposium keynotes will feature individuals with MIT ties who are leaders around the world.

nity of scholars, students, and staff and to communicate those issues to the world.

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The MIT150 Steering Committee is seeking proposals from the MIT commu-

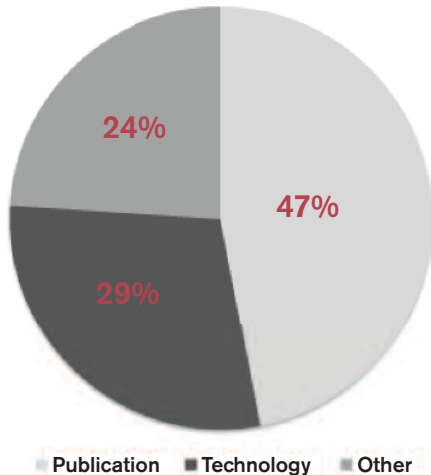
The committee offers the following examples for symposium topics, although it emphasizes these are to generate ideas more than specify proposals:

- Organizing to solve global problems
- MIT as an engine for the economy
- Establishing new disciplines and fields
- Great laboratories at MIT
- Technology and the arts
- MIT as an innovator in education
- MIT and global partnerships
- MIT and the future of exploration

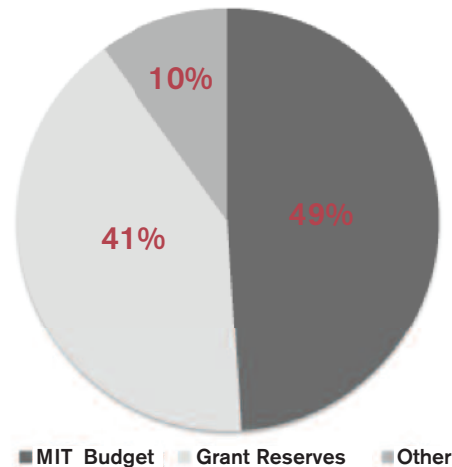
Each symposium will last 1 to 1.5 days, although the committee is open to other formats. Each symposium will contribute papers and transcripts into a collection of

M.I.T. Numbers OpenCourseWare (OCW) Expenses and Funding

FY09 Expenses (Total \$3.5M)



FY09 Funding (Total \$3.5M)



- 12% reduction from FY09 budget
- “Other” includes outreach, evaluation, management, administration, and fundraising

- Grants have provided 72% of OCW funding to date
- Grant reserves will run out in FY12
- “Other” includes small donations, interest income, and Amazon.com revenue

Request for Proposals for Teaching and Education Enhancement

Alumni Class Funds

supported by the Classes of 1951, 1955, 1972, and 1999

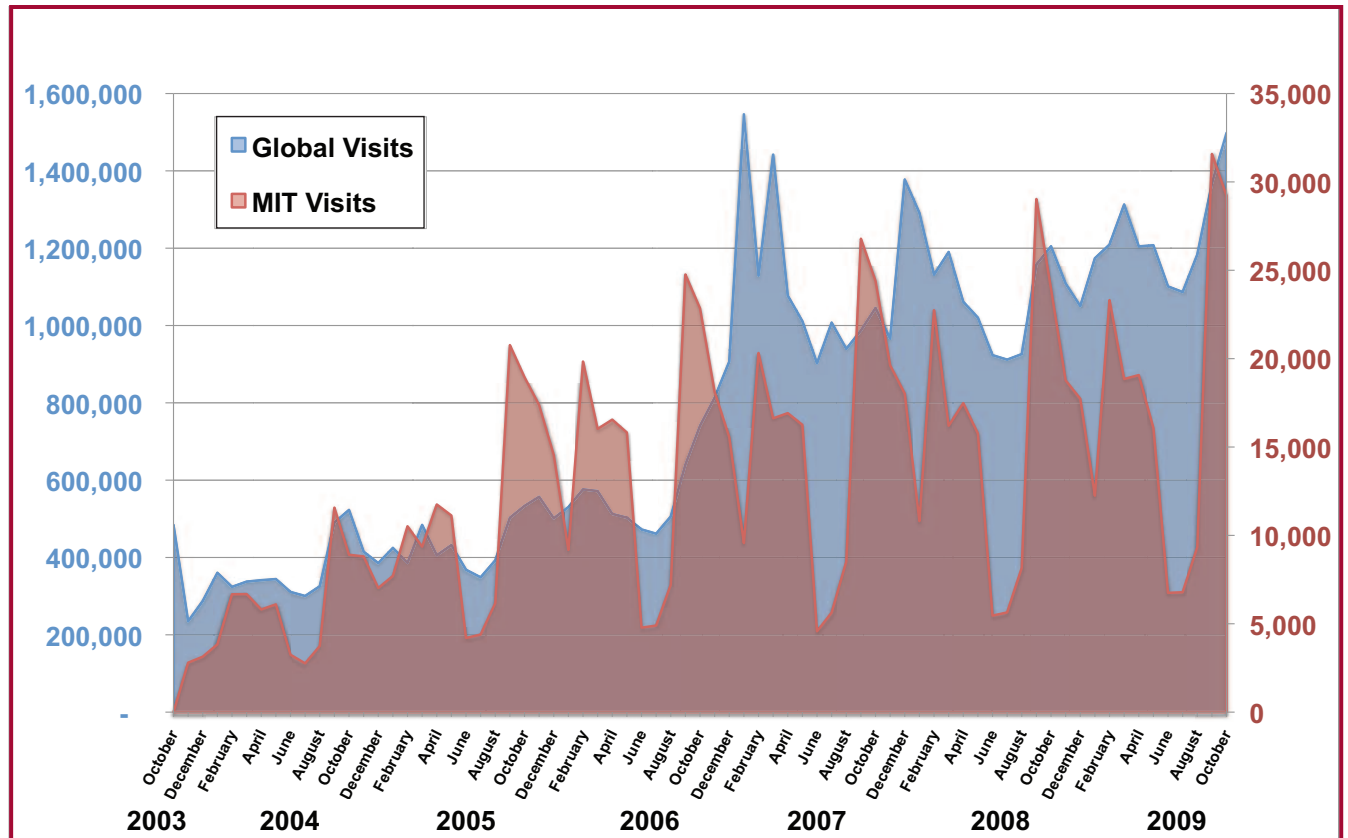
The Office of Faculty Support seeks proposals for innovative projects for the 2010-2011 academic year that improve the quality of teaching, enrich students’ learning experiences, and uphold the tradition of innovation at the Institute. Grants typically range from \$10,000 to \$50,000 and cover a wide variety of creative curricular and pedagogical projects.

Guidelines and more information including past awards can be found at web.mit.edu/alumnifunds or by calling the Office of Faculty Support at 3-6776.

Proposals are due on Monday, February 1, 2010.

M.I.T. Numbers

OpenCourseWare (OCW) Monthly Global and MIT Visits



OCW Benefits

External

- 56.8 M total visits from 35.7 M unique visitors directly to the MIT OpenCourseWare site; 30 M additional visits to OCW content in translation
- 60% of OCW visitors are from outside North America
- 66% of visitors are mostly or completely successful at meeting educational goals; 27% are somewhat successful

Internal (MIT)

- 92% of undergraduates, 84% of graduates, 73% of faculty, and 47% of alumni use OCW
- 96% of students report a positive impact from OCW on student experience
- 90% of faculty say OCW furthers MIT's public service mission; 92% feel it reflects positively on MIT; 82% consider it an important element of MIT's international engagement