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MIT Faculty Newsletter

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March 23 Protest at MIT

Improving the Urgent Care Experience Through Student-Informed Care

Cecilia Stuopis

LIKE ALL DEPARTMENTS, LABS, and centers, MIT Medical is always looking for ways to evolve and improve. Whether it's focusing closer on the customer experience, being more fiscally responsible, or turning our attention toward planning for the future, we are constantly striving to be our best.

In that spirit, in 2016, MIT Medical commissioned a patient journey map that used data-driven methodology to give us a holistic view of how our patients experience care at MIT Medical. This involved analyzing more than 1,000 comments from post-visit surveys, interviewing staff, and shadowing patients. In the end, our journey map (see page 22) identifies every touchpoint within an episode of care and highlights touchpoints where we're exceeding patient expectations as well as opportunities for improvement.

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The Erosion of Social Norms Guiding the Government-University Relationship

Bish Sanyal

ARE WE WITNESSING A MAJOR shift in the relationship between the federal government and universities? To speed up the industrialization of the nation in the nineteenth century, the U.S. government provided free land and revenue to start land grant colleges. In the twentieth century government-sponsored research rose sharply, especially after Sputnik. Yet now the federal government proposes taxes on university endowment earnings and graduate students' tuition stipends and wants to dictate which international students universities can admit! Is this a fundamental change in the norms which guided the government-university relationship in the past, or only a temporary setback created by a particularly anti-intellectual administration that dislikes academia, distrusts scientific research, and sees universities as dominated by a liberal elite?

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Editorial

MIT Should Not Be Supporting the Saud Monarchy

THIS PATRIOTS' DAY MARKS 243 years since farmers, tradesmen, merchants, and sailors fought a bloody war to throw off the yoke of King George and the British monarchy. They established a republic in the place of the monarchy, and sought to make the government accountable to the people.

In the years since, the people of most of the Earth's nations have followed suit and rid their nations of monarchical governments. Among the absolute monarchies still in power, the most egregious is that of the Saud family of Saudi Arabia. We are appalled that the MIT administration agreed to meet and presumably negotiated programs with the Saudi Crown Prince, Mohamed Bin Salman (MBS). This was done without any consultation with faculty or student organizations.

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MIT Should Not Support Saud Monarchy
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Saudi Arabia, in fact, remains an oppressive absolute monarchy, and the source of great human suffering, most notably from their war on the people of Yemen. Bin Salman was on a U.S. tour, and earlier met with President Trump, who had approved the sale of $billions worth of U.S. missiles and warplanes to the Saudi government. The weapons are among those used in the Saudi-led war on Yemen that has left thousands of civilians dead since 2015. The United States is also assisting the Saudi monarchy in the coalition's targeting selection for aerial bombings and actively providing midair refueling for Saudi and United Arab Emirates jets that conduct indiscriminate airstrikes – the leading cause of civilian casualties. Meanwhile, the Saudi coalition is starving millions of Yemenis as a grotesque tactic of war. According to the UN, the blockade of Yemeni ports by the Saudi military has resulted in "the largest famine the world has seen in decades" causing a massive cholera epidemic and leaving 400,000 children malnourished.

Bin Salman's extensive public relations campaign directed at Americans has painted him as a "reformer" who is supporting, for example, the rights of women to drive, while ignoring the continuing general oppression of women in Saudi Arabia, imprisoning hundreds without trial, and actively opposing democratic movements in other Arab states. Cambridge City Councilor and MIT alumnus Quinton Zondervan, speaking at the demonstration against Bin Salman's visit, stated clearly "We do not need to show respect to an oppressor and a bully and a warmonger." U.S. Congressmen Rho Khanna, Marc Pocan, and Walter Jones (*New York Times*, October 10, 2017) have criticized our government for "participating in a military coalition led by Saudi Arabia and the United Arab Emirates in a brutal military campaign in Yemen."

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On April 2 the Cambridge City Council went on record in opposition to the oppressive policies of MBS and Saudi Arabia, stated its disappointment at the manner in which the visit was hidden by Harvard and MIT, and requested that copies of the resolution be delivered to the Presidents of both MIT and Harvard as well as MBS.

The Tech reported on the meeting in their April 5 issue, and published a cogent and critical editorial.

Due to the complete lack of candor of the MIT administration, we don't know the precise nature of the business between the Crown Prince and MIT. According to Grif Peterson and Yarden Katz, of Harvard's Berkman Klein Center for Internet & Society, writing in the *Guardian* (Friday, March 30, 2018) ". . . Bin Salman's foundation, MiSK (***https://misk.org.sa/en***), was accepted as a 'member company' to MIT's Media Lab in 2017, which requires a minimum annual contribution of $250,000 (with a three-year commitment) to the lab. In return, MiSK receives access to the lab's personnel, technology, and intellectual property." Regardless of the content, MIT should not be entering into an agreement with representatives of the Saudi regime. This recalls the Shah of Iran's effort to secure nuclear engineering graduate slots for the Shah's chosen candidates. This was eventually rejected due to opposition from the faculty.

At a minimum, President Reif should have reported to the faculty on the visit of Bin Salman. He now needs to ensure that MIT has not entered into any further agreements with the Saudi government or Royal Family that ignore their record of oppression, discrimination, and human rights violations.

Editorial Subcommittee

From The Faculty Chair

MIT Undergraduate Education at a Crossroads

Susan S. Silbey
Rick Danheiser
W. Craig Carter

WHATEVER PATH ONE TRAVELS, Robert Frost taught us, we may come to think over time that the choice was consequential, "made all the difference." But, along any selected path, one thing always leads to another and different routes each have attractions. As Frost was in the yellow wood a century ago, MIT education is now unquestionably at a similar crossroads. Changes in technology, in the global economy, in our democracy, in our students, and in vehicles for delivering education challenge us to examine the path we have hewn. We can continue along the same route, or we can change directions, very slightly or significantly. The choices, however, are ours – stay the course or make adjustments. Although the curriculum is iteratively shaped through the decisions we continually make in departments and in faculty committees, the accumulated changes beg us to give more than routine attention at this moment to the shape and content of the MIT undergraduate degrees. If we are to provide responsible guidance for our students now, and stewardship for the Institute into the future, we ought to consider the curricular paths we offer and do so through actively engaged, intense deliberation.

Your faculty officers are not alone in recognizing the changes in the world and in our students that have brought us to a crossroads. Consider the recent spate of new majors, experiments, and proposals including, for example, Vice Chancellor Ian Waitz's Design Class on the First Year Experience, the NEET (New Engineering Education Transformation) experiment, the First Year Projects Initiative, the proliferation of "flexible majors," the review of whether ABET certification is necessary for engineering degrees, calls for new GIRs in computational thinking, statistics, as well as ethics and public policy.

To initiate a broad and deep, participatory and energetic, conversation about the MIT undergraduate program, we are hosting an all-day workshop on June 14. The workshop will explore the path we have been following and the crossroads we face. Although we are orchestrating the workshop, we do not have any preconceptions about what its outcomes will be: what is desirable in the way of changes and what is worth preserving. We are open to anything. We are proposing a conversation, more specifically, a process, not a conclusion.

We are encouraged in this effort by the thoughtful exchanges at recent faculty meetings as curricular proposals have been brought for open debate. We expect the workshop to consider the basic components of the undergraduate academic program, including its structure or configuration (i.e., the number of subjects and hours for a degree); the distribution of content (i.e., subject matters, choices, options and flexibility); and, variations in pedagogy (i.e., vehicles for delivery, forms of student-faculty and student-to-student interactions). Although we wish to prescribe little beyond a process for deliberation, we hope the conversation will generate a variety of curricular paths that will initiate detailed discussion and exploration beyond the workshop itself.

Our goal is to examine the current undergraduate program critically from the perspective of what is best for our students in the twenty-first century. Their needs, no less than their desires, are markedly different from those of students 50 and 60 years ago. Our current students encounter a world more unsettled than it has been for decades, a time of economic, political, and environmental uncertainty. Student anxieties about the future are understandably more intense than the usual angst youth experience as they move from adolescence to adulthood. Students voice apprehension about the future of the environment, about the prospects of nuclear war, and certainly most immediately about the prospects for meaningful and lucrative employment. They are worried, but they are also passionate. They seek better advising and mentoring to explore options and seek flexibility to respond to both positive and negative course experiences. They embrace MIT's ambition to make a better world and sometimes recognize the limits of what they do not understand. They seek our guidance.

Students' unease may not be expressed in quite the same ways as the faculty's, although there are important convergences, some involving issues concerning the HASS component of the GIRs. Faculty voice concerns about enrollments driven by markets for jobs rather than educational experimentation and curiosity, radically skewing the distribution of students across subjects. While some faculty worry about an excess of theoretical knowledge and insufficient hands-on project learning where innovation thrives, others are also distressed by the insufficient attention to the consequences of technological inventions. Students lack knowledge of history and social organization, and so they keep bumping into these unseen forces with which they are too often ill-equipped to recognize or manage. This is a world of considerably more knowledge than we had a century, even a half-century ago; employers expect scientific and technological skills in just about all workplaces, jobs MIT students are especially well equipped to fill. Yet, at the same time, the need for a workforce knowledgeable about public policy and experienced in ethical decision-making and responsible citizenship has never been greater. As the collective consequences of single, perhaps individual decisions propagate in a digitally connected world, our students, some faculty say, seem to display a noticeably reduced lack of commitment to the public collective, preoccupied with individual autonomy. The better world they imagine is often one where each person should be an agent of entirely unconstrained desire.

Turning to the science/math/engineering component of the GIRs, recent discussions of a computational thinking requirement have triggered a general discussion of the SME GIRs. While there is no consensus about how to move forward, few faculty members disagree that computational thinking is now an essential tool in an educated person's toolbox (although there are more than a few disagreements on the definition of computational thinking). But if we, and colleagues elsewhere, agree that this is important, how many faculty would agree that the addition of that tool is wiser than other possibilities? Across the faculty we have heard compelling arguments that probability and statistics, ethics, history, and public policy are equally valid as General Institute Requirements.

Repeatedly, past reviews have identified three aims for the GIR component of the MIT undergraduate curriculum. First, the SME GIRs provide our students with *foundational building blocks* – a common body of knowledge that departments can then assume in teaching advanced subjects. Second, the GIRs confer *basic literacy in essential fields* by providing substantive knowledge in areas with which every MIT graduate should be familiar. Finally, the GIRs introduce students to *methods for creative analytical thinking* by equipping students with portable tools and strategies for problem solving applicable to a variety of different kinds of knowledge and thought.

Are these aims still valid as goals for the General Institute Requirements? How well do the current offerings in physics, biology, chemistry, math, and the laboratory and REST subjects fulfill these objectives? Are there other subjects that ought to be included as SME requirements? As substitutes for existing GIRs, or as alternatives? Are HASS GIRs working as planned? Can the first-year curriculum be revitalized by the inclusion of more hands-on and project experiences? Should we incorporate more flexibility in the GIRs, empowering students to explore more diverse subjects early on? These are all questions that we hope to address in the June workshop.

Our students are graduating into a world with a society – and its science and technology – that would be unrecognizable to those who conceived the current configuration of the MIT degree. If we agree that our existing curriculum ought to provide the foundation to be a responsible citizen in this brave new world, then we should evaluate its design and effectiveness to assure that we achieve its goals. Real education certainly isn't easy, and perhaps it shouldn't be. Focused mental exercise is the gift we hope to give our students. Facts (or those bits and bytes of information represented to be facts) are now a cheap commodity. Determining fact from fiction is a skill we hope to teach. Alumni who discover and analyze facts are what we hope to educate. The inevitable tension between securing the immediate-benefit of specialization and the long-term rewards of general-background education are a continuing challenge for higher education. More concretely, while a specific degree may help a student find a particular job, it may not help them progress in that job. From this viewpoint, MIT's *fundamental education* – experienced as the ability to learn new things – will likely provide the most tangible and rewarding future benefits.

If MIT is the world's premier technological institution, this status comes with great responsibility. Perhaps we should consider our self-reflective inquiry not as just one more university taking a hard look at itself, and not just an organization's response to consumer demands, but as an opportunity to set a new standard for scientific and technological literacy. If we cannot avoid the significance of this tumultuous historical moment when history seems to have turned a corner, we certainly need to look at our role in its emergence. How did we get here, nationally and locally, and at MIT? Is it too self-important to think that something about our education has fed, not only among our own graduates but the public at large, an addiction to tweeting and anonymous surveillance, fake news and widespread bullying, all in the name of autonomy and connection?

With the June 14 workshop, we hope to move beyond our familiar and otherwise well-functioning committee processes. We want to engage the faculty's collective wisdom and experience to think together about the future of our students and what well-educated alumni need from us now. The workshop is not aimed at making decisions. It will be about imagining possible futures. Certainly MIT is not going to abandon what we have done well. We do need, however, to consider carefully what we have achieved. Detail will be needed to flesh out schematic possibilities, and thus subsequent or parallel in-depth reviews of the GIRs should be undertaken along with a variety of options for the curriculum writ large. All proposals face practical constraints: about requirements, about options, flexible alternatives, and time the limit of eight semesters.

Eventually, we must discuss the curriculum, including the GIRs, and how they relate to what we – the faculty – believe would be best for our future alumni. After discussion, to begin in June and certainly continue next year, it may be that no change occurs at all. It would be a tragedy, however, if there were no discussion at all.

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The Erosion of Social Norms
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In a recent article in *The New York Times* (November 30, 2017) Professors E.J. Levine of the University of North Carolina at Greensboro and M.J. Stevens of Stanford University describe the current reality: an economy where median household income has stagnated while university tuition keeps rising. They argue that the old social contract was damaged beyond repair before the present administration was elected: "When student loan debt eclipsed the total amount that Americans owed on their credit cards in 2010, a rebellion against fancy academics was well underway. Institutions once deemed essential partners in nation-building came to seem overstuffed and defensive – they enjoyed generous tax breaks, yet crankily rebuffed calls for cost containment. This is the historical context in which Congress is summoning universities back to the bargaining table."

Why has this shift been met with so little collective opposition from the academic community? Senior academic administrators of the universities that have to pay the new tax on endowment income must have jointly lobbied against it; and graduate students, nationwide, did successfully lobby against taxation of their tuition benefits. But these two specific responses, one successful and the other not, against two specific government policies, do not indicate widespread resistance to government's intrusion on universities' autonomy to manage their own resources. This is particularly surprising because the government has not managed its own resources well. In fact, the recent reduction in corporate taxes is likely to further increase fiscal deficits.

This thought had occurred to me first in 2007 when Senator Charles Grassley of Iowa spearheaded a federal initiative to force universities to spend more of their income from endowments. I was Chair of the MIT Faculty then and remember a discussion in Academic Council about how to respond. Lobbying by university presidents might have stopped Senator Grassley then, but what really hurt that governmental initiative was the sharp drop in the stock market, which reduced endowment earnings to negative numbers. Now that the stock market is bullish, the government is back taxing universities for saving and investing well.

Why does the government want to change the norms of its relationship with American universities when they have been so successful as entrepreneurial entities? . . . I want to share my concern with the readers of the *Faculty Newsletter*: that precisely because of their entrepreneurial roles, universities have become more market actors than non-profit institutions. In an economy characterized by rising inequality of individuals' income and earnings, universities cannot advocate for equality when the income gap between wealthy universities and their relatively poorer counterparts has also steadily widened over the last 20 years or so.

Levine and Stevens do not explore why universities in general have raised tuition, particularly since the mid-1980s. Public universities faced severe budget cuts from state governments, and raising tuition was one way to handle the sharp decline in resources. Private universities may have had other reasons for raising tuition, such as the decline in government support for research, the growing cost of managing research facilities, and the increased cost of the university administration as its activities and investments increased in complexity with rapid globalization. By the end of the 1980s, with the collapse of the Soviet Union and the emergence of the Internet as a major technological change, most universities were under pressure to become more entrepreneurial. They devised new strategies for revenue generation, including large-scale investments in real estate, not only to construct up-to-date dormitories, but also to build innovation hubs for entrepreneurial activities that promised new streams of revenue. In many cases American universities, both public and private, looked abroad for additional revenues by creating joint research centers and universities, even in nations that differ sharply from the U.S. in their political systems. The rapid progress and spread of information and communication technologies presented yet another set of possibilities for revenue generation.

Both public and private universities also made significant efforts to raise endowment funds. In the 1980s, university capital campaigns sought to raise hundreds of millions of dollars; by 2000 the campaign goals had increased to billions. In this fundraising climate, universities accepted donations from everyone. While courting funds from wealthy donors and wealthy governments, irrespective of their stance on any social issues, universities assured their trustees, faculty, and students that no donor could chip away the universities' autonomy to follow their self-established missions. This argument was put forward even when universities accepted funding from private firms to conduct particular types of research that would benefit those firms. In fact, universities courted close ties with private firms – and they could do so because of new real estate holdings. In sum: universities celebrated the new era of entrepreneurship with a wide range of programs, and the new information and communication technologies enabled them to reach far beyond their traditional catchment area as the entire world wanted to learn from U.S. universities how to become entrepreneurial.

Why does the government want to change the norms of its relationship with American universities when they have been so successful as entrepreneurial entities? There could be many possible explanations, which are probably better understood by senior academic administrators than by me. Nevertheless, I want to share my concern with the readers of the *Faculty Newsletter*: that precisely because of their entrepreneurial roles, universities have become more market actors than non-profit institutions. In an economy characterized by rising inequality of individuals' income and earnings, universities cannot advocate for equality when the income gap between wealthy universities and their relatively poorer counterparts has also steadily widened over the last 20 years or so. No wonder then that no unified group of institutions of higher learning opposed the government's recent initiative to tax the endowment income of the wealthiest private universities, even though this new government tax policy signifies a direct attack on the universities' autonomy.

The stratification of universities as institutions competing for new revenue and global rankings does not seem much different from the way people view corporate entities. The annual announcement of university presidents' high salaries in leading newspapers adds to this perception of the university as a corporate entity, not a place primarily for education and learning. The recent ranking of universities based on a ratio of income earned by recent graduates to total tuition paid for college education is emblematic of the way average citizens view education as yet another commodity in the market place.

Why weren't faculty as organized as the graduate students in opposing the new tax laws? Political opposition to government policies is not new to American campuses. From protests against the Vietnam War in the 1960s to the more recent marches against immigration policies barring international students from certain Muslim countries, faculty have vocally opposed government policies they consider unfair or ill-intentioned. Perhaps faculty do not perceive the tax on endowment as a direct attack on their interests. Or perhaps they have come to view the university as a business enterprise in which they are not stockholders. Faculty may be glad to see their universities making a good return on endowment investments, but rarely do they realize any direct benefits from such returns in terms of higher salaries. In contrast, when endowment income declines, as it did in 2007-2008, faculty have been asked to accept a freeze on annual salary increases. What's intriguing is that faculty rarely oppose salary freezes, perhaps because they are grateful for relatively stable employment. As a recent study cited in the *Chronicle of Higher Education* (January 24, 2018) has shown, faculty also make a tradeoff between salary increases and flexibility in their work schedule.

Whatever may be the reason for their lack of response, faculty need to be aware of the larger significance of changes in the government-university relationship. As the old norms are chipped away, faculty may face a situation where the value of tenure is questioned, retirement rules are reformulated, faculty productivity is monitored by groups outside the university, and academic freedom is equated with free speech, as Joan W. Scott recently warned in the *Chronicle of Higher Education* (January 7, 2018). The assault on the autonomy of the academic community may begin with small steps geared towards reducing the privileges of only its wealthiest members, but it may not end there unless the entire community – and that includes faculty, students, and administrators – is vigilant.

As for students, it is worrying that even though they so forcefully opposed taxes on their stipends a significant number of graduate students are now interested in forming unions and, thus, seemingly being treated as employees in educational enterprises (*The Tech*, February 1, 2018, p.1). This is another sign that knowledge production is being viewed increasingly as a profit-making and reputation-building activity whose benefits should be passed on to "the workers." Should the association between faculty and students be reduced to a contractual relationship guided by labor laws? Or, are educational institutions places of learning where relationships between mentors and mentees are guided by higher motives not reducible to market forces?

That U.S. universities have benefitted in many ways from working closely with market institutions cannot be denied, but the mission of universities is greater than the sum of its entrepreneurial activities, whether selling online education or serving as incubators of market savvy innovations. The issue is: What makes a university an autonomous community of knowledge seekers, and also an independent voice of moral reasoning – particularly when it is rare to find such reasoning in public discourse?

That U.S. universities have benefitted in many ways from working closely with market institutions cannot be denied, but the mission of universities is greater than the sum of its entrepreneurial activities, whether selling online education or serving as incubators of market savvy innovations. The issue is: What makes a university an autonomous community of knowledge seekers, and also an independent voice of moral reasoning – particularly when it is rare to find such reasoning in public discourse? I realize that universities are not religious institutions that seek to preach morality. But, unlike the stock market, universities are not amoral institutions either. They provide a forum for free deliberation of moral issues. In fact, universities should be in the forefront of

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The Erosion of Social Norms
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drawing public attention to issues of high social significance. Likewise, the government should not have to dictate to universities about issues such as sexual assault or tell them how to expand access to education for people of all colors, sexual orientations, and religious beliefs. To the contrary, universities should help government to see how inequalities in access hurt national productivity. To what extent universities' expanding market entanglements are affecting its moral role is not a new question but an important one. Similarly, the extent to which the university system is beginning to take on the negative characteristics of markets needs to be assessed.

MIT is uniquely positioned to play a leadership role in halting the slow erosion of norms that guided the government-university relationship in the past. It has a strong reputation as a place of learning and creativity without the frills usually associated with wealthy private universities. When one reads about the turmoil at Michigan State, or the outrageously high salaries of presidents of some private universities, it is amazing how MIT has avoided being singled out for any serious breach of the social norms expected of universities. MIT seems like a place still devoted mainly to serious scholarly research. Being an institute of "technology" provides MIT a strong legitimacy, not only in the U.S. but around the world, as its central mission still seems to be scientific inquiry and inventions, not just profit making.

Remember when President Charles Vest announced to the world that with OpenCourseWare (OCW) virtually all of MIT's course content would be available online at no cost, and the overwhelmingly positive reactions to that announcement because there was no profit motive behind MIT's noble gesture? Remember when MIT announced that women faculty in the sciences had been treated unfairly? I cannot think of a similar reaction now even as MIT engages in the ambitious capital campaign "to make the world a better place." Most universities would argue that they too are involved in making the world a better place, but none has as yet captured the public imagination with an issue of huge moral significance. Through the recent acknowledgement of its past connection to slavery, MIT – like a few other universities – is coming to terms with this painful history. The government did not ask MIT to address this issue; autonomous social inquiry led MIT to a moral decision, and this will be respected worldwide as yet another sign of a great institution where concerns of human dignity override all other concerns. The decision to create a task force to study the impact of automation is also a good example of how universities can study markets from the perspective of a social concern and not just as a potential stakeholder in reaping the benefits of markets.

MIT is uniquely positioned to play a leadership role in halting the slow erosion of norms that guided the government-university relationship in the past. It has a strong reputation as a place of learning and creativity without the frills usually associated with wealthy private universities. . . . Being an institute of "technology" provides MIT a strong legitimacy, not only in the U.S. but around the world, as its central mission still seems to be scientific inquiry and inventions, not just profit making.

If university faculty understand the significance of government action at both federal and state levels – such as in Arizona where legislatures are paying to push conservative studies (*New York Times*, February 26, 2018, p. A11) – perhaps there will come a time when they will lead a march on Washington, DC, like the million-man march or the more recent women's march, to demand autonomy of knowledge production, which is key to academic excellence. I sincerely hope that such a march will not be necessary, but the growing signs of increasing government control over university affairs worry me – a lot.

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Naming the MIT Intelligence Quest

Kenneth R. Manning

WHEN I FIRST READ President Reif's letter announcing the new MIT Intelligence Quest (MIT/IQ) initiative, I was impressed with its vision and potential, but distressed by the possible perception embedded in its logo. I promised myself to write a letter to the President and Provost regarding my concern about the logo, and about the need for caution in approaching the topic of intelligence. Unfortunately, I dropped the ball, perhaps because I was apprehensive about raising this concern with the project so far along. Now I regret that I did not write the letter.

During the discussion announcing the initiative at the February Institute faculty meeting, my disquiet increased when Professors Susan Silbey and Anne McCants took the podium to comment. So I decided to weigh in then and there, even though the project had gone public some weeks earlier. As a graduate student over 45 years ago, I had organized protests on the use of IQ (Intelligence Quotient) tests to argue inferiority of blacks by Richard Herrnstein, Arthur Jensen, and others. Since coming to MIT in 1974, I have always taught the perils and negative ramifications of shoddy scholarship surrounding IQ and its eugenic uses, especially its espousal of racial inferiority. I joined my friends and colleagues Stephen Jay Gould, then at Harvard, and Stephan Chorover, here at MIT, to challenge this so-called scholarship. Gould's classic work, *The Mismeasure of Man*, should be required reading for colleagues as context for all research on intelligence.

For us at MIT, it is worth remembering too that Nobel Laureate William Shockley earned his doctorate here. After winning the Nobel, he went on to pursue spurious, ill-informed scholarship on IQ, outside his field of expertise (semiconductors). Even though our new initiative is future-oriented, our community must approach it with full knowledge and appreciation of past (and some present) abuses of scholarship surrounding human intelligence.

The unfortunate choice of the logo IQ was perhaps not simply a language slip. It suggests that the initiative would benefit from a greater diversity of faculty input, to help sensitize the community to quandaries that they have either internalized or of which they are entirely unaware. Some at MIT, especially in my two departments – STS (Science, Technology, and Society) and CMS/W (Comparative Media Studies/Writing) – are well suited for an active role in adding nuance and context to this important initiative. Having said that, I wish to caution that social, political, and ethical issues should be woven into the fabric of the project and not "outsourced" to any one group or person, say, the School of Humanities, Arts, and Social Sciences or its dean, as seemed to be the thrust of the faculty meeting. These issues are the responsibility of colleagues in the School of Engineering, equally if not more so. Indeed, they are the responsibility of everyone.

We should take this as an opportunity to reflect on the history underlying the complicated subject of human and artificial intelligence, particularly the ways in which it has been used for both positive and negative purposes. We will then be in a better position to show how our approach at MIT is different, and how we can achieve the goals that we set. We will also be able to explain how the checkered notion of Intelligence Quotient differs fundamentally from our initiative known as Intelligence Quest.

The proverb "If wishes were horses, then beggars would ride," comes to mind in response to the hope expressed in February's meeting for faculty to get involved voluntarily. We should not take that chance. This initiative is so innovative, with such remarkable potential, that proactive grassroots efforts are required to ground it in responsible social values.

The Provost, the Chair of the Faculty, and a representative from the Office of the Dean of Engineering responded swiftly to concerns raised at the February faculty meeting, and to the call to action, through further discussion among themselves and with other faculty members. Many now share these concerns and want to change the logo so as to disassociate it from historical abuses tied to the acronym IQ. The challenge, as I understand it, is how to make the change with least disruption. Alternatives are being floated for consideration. Though the logo naming is likely to be solved with persistent follow-through, we must continue to frame and articulate a responsible vision for this pioneering initiative, given the regressive social, cultural, and political agendas that have emerged – and continue to emerge – around such research. In our probe for intelligence, we must exercise vigilance to preserve scientific integrity throughout.

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Nuclear Weapons Education Project

Luisa Kenausis
Aron Bernstein
Robert Redwine
Michael Hynes

NUCLEAR WEAPONS POSE AN existential threat to all of humanity by their very nature, and the recent tensions between the United States and North Korea have brought that threat back into the public eye. It is essential for young people, particularly those who grew up after the end of the Cold War, to be educated on what nuclear weapons are and on their potential effects on the world. The Nuclear Weapons Education Project at MIT aims to support this goal by helping professors and lecturers in various disciplines prepare a lecture or two, or selected course materials, involving nuclear weapons topics for their introductory-level courses, thus reaching large numbers of students. We believe that even a limited introduction to the issues surrounding nuclear weapons could help engage student interest in a topic that is unfortunately increasingly relevant to the young people of today.

The long-term objective of the Nuclear Weapons Education Project is to teach our students, who will become future policymakers, scientists, journalists, lawyers, and voting citizens, about the nature and importance of nuclear weapons. Nuclear weapons play a massive and complex role in national and global security. It is essential that colleges and universities take steps to prepare the next generations of policymakers and citizens for the tremendous task of protecting the United States – and the world – from ever enduring the unthinkable devastation of a nuclear war. One or two lectures on nuclear weapons is not enough to dive into the nuance and detail that these issues demand from a policy perspective, but we believe it is enough to plant the seeds of interest and urgency in the minds of students who are interested in facing challenging global problems. Further, we believe this would provide an opportunity to equip students with the foundational knowledge and informational resources to continue learning about these issues on their own.

With increasing effort over the last few years, the members of the Nuclear Weapons Education Project have been working to advance this initiative at MIT in several ways. We are working with the instructors of introductory physics classes to include materials relevant to nuclear weapons issues in problem sets and other assignments. Also, during IAP 2016, Prof. Bernstein co-taught a course on nuclear weapons with Prof. Jim Walsh of MIT's Security Studies Program (Department of Political Science). The course offered a concise overview of the history of nuclear weapons, some technical discussion of their physics and physical effects, and an introduction to the political issues and consequences of nuclear weapons to a class of about 12 students. Luisa Kenausis, then a junior, was a student in the class. This past IAP, the Nuclear Weapons Education Project offered a series of three lectures on nuclear weapons topics, taught by Ms. Kenausis, Prof. Bernstein, and Dr. Michael Hynes, of the Department of Nuclear Science and Engineering.

The long-term objective of the Nuclear Weapons Education Project is to teach our students, who will become future policymakers, scientists, journalists, lawyers, and voting citizens, about the nature and importance of nuclear weapons. . . . It is essential that colleges and universities take steps to prepare the next generations of policymakers and citizens for the tremendous task of protecting the United States – and the world – from ever enduring the unthinkable devastation of a nuclear war.

Lastly, we have made significant progress developing the Nuclear Weapons Education Project's Website (***nuclearweaponsedproj.mit.edu***) into an informative resource for educators filled with brief, reliable summaries of information on a variety of nuclear weapons topics. Work remains to be done on that initiative, and we plan to complete most of the remaining tasks with the help of student researchers.

Going forward, four undergraduate students will be working through the UROP program on broad-ranging, summary-level research on nuclear weapons for use on the Nuclear Weapons Education Project Website. The students will be coordinating with one another as well as with their faculty advisors – Prof. Bernstein, Prof. Redwine, and Dr. Hynes – on the topics they choose to research and summarize. Since the content being produced for the Website is intended to be a high-level summary of the most important information that is publicly available online, we believe that this UROP will offer student participants an opportunity to educate themselves on nuclear-related topics that are of interest to them while requiring minimal background knowledge or research experience.

In keeping with the spirit of the Nuclear Weapons Education Project, we have sought to make the process of researching and self-educating on these topics accessible to our UROP students, who are mostly freshmen. We hope that the relative newness of these students to the field of nuclear weapons will prove to be a benefit in their work. Since the intended reader of the Website is an educator, likely without a background in nuclear weapons, students who do not specialize in nuclear issues may be particularly well-equipped to identify the concepts that will be most foreign and challenging or most interesting to a non-nuclear audience.

The Nuclear Weapons Education Project is also continuing to pursue opportunities to promote education on nuclear weapons issues outside of MIT. Prof. Bernstein has also been coordinating with physicists at over a dozen universities who are working to advance this goal in the courses they teach or develop new courses or seminars at their university. We have made particular progress with Prof. Jim Napolitano and Prof. Bernd Surrow, the chair and vice chair, respectively, of the Department of Physics at Temple University.

Meanwhile, Ms. Kenausis departed from MIT at the end of January to begin a Herbert Scoville Jr. Peace Fellowship at the Center for Arms Control and Non-Proliferation in Washington, D.C., where she continues to work on the Nuclear Weapons Education Project in a part-time capacity. In Washington, D.C., Ms. Kenausis hopes to enlist the support of other individuals interested in promoting nuclear weapons education via research and organizational efforts. More concretely, Ms. Kenausis is also planning to give talks on nuclear weapons issues at public high schools in the D.C. area over the coming months with Dr. Sara Kutchesfahani, her colleague at the Center.

The current members of the Nuclear Weapons Education Project steadfastly believe that the education of future generations of policymakers and citizens will be a vital step towards the development of safe and effective nuclear weapons policy. Further, we believe that a substantive introduction or exposure to nuclear weapons issues can be enough to trigger a student's interest in these issues, even if that introduction is brief. This belief is not founded solely on optimism: Ms. Kenausis's academic and career path were powerfully shaped by her first exposure to nuclear weapons topics in the classroom, and that experience underlies her commitment to this project.

For his part, Prof. Bernstein has been particularly engaged with nuclear weapons issues since the Cuban Missile Crisis. He sat through that event with a Russian colleague, Oleg Chubinsky, who had recently come to work in the cyclotron that Prof. Bernstein was running. Prof. Bernstein's involvement with nuclear arms control was further increased by his interactions with some of the Manhattan Project's alumni, including MIT's Victor Weisskopf and Phillip Morrison, and Henry Linschitz of the Brandeis Chemistry Department.

For those of us who are old enough to have lived through the Cold War and who recall all too well air raid drills and discussions of possible paths to survival in case of nuclear war, it is sobering that we must initiate related discussions at this time. But the world has probably not been paying enough attention to this ongoing threat in the past few decades, and recent events have only emphasized this reality.

With the recent and unexpected news of a possible summit between President Donald Trump and North Korean leader Kim Jong-un in the near future, the work of the Nuclear Weapons Education Project only stands to become more relevant. Accordingly, we are actively seeking the help and support of others to move this project forward and expand our reach. There are two primary ways in which members of the MIT community can support the Nuclear Weapons Education Project:

1. *Contact the authors of this article* to get involved with the Education Project, by joining our mailing list network of educators or perhaps in ways that suit your specific interests.

2. *Spread the word about our initiative* by sharing this article, and the Nuclear Weapons Education Project Website, with friends and colleagues at other universities. We welcome contact from educators and students at other schools interested in joining our network and/or seeking advice about promoting nuclear weapons education on campus.

In closing, the Nuclear Weapons Education Project does not advocate for any particular political goal or promote a certain solution to the challenges posed by nuclear weapons. We do not wish to indoctrinate students with our personal beliefs or ideas about nuclear weapons or visions for nuclear policy. Instead, we aim to promote the use of carefully-researched, factual, concise information about nuclear weapons to give students the intellectual tools to critically engage with the challenging issues of nuclear weapons. As today's students become the policymakers and citizens of tomorrow, even a small investment in our students' knowledge of nuclear weapons issues will help set the stage for safe, informed nuclear weapons policy in the future. We welcome feedback at *nwep_leaders @mit.edu*.

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Teach Talk

MIT Students and Deep Learning: Perspectives and Suggestions

Dave Pritchard

Abstract

In the September/October 2017 *MIT Faculty Newsletter*, Freeman et. al. ("How Deeply Are Our Students Learning?") exhibit a number of apparently straightforward (to professors) problems that befuddle the vast majority of students who are doing well in the course that teaches the skills necessary to do that problem. This is taken as evidence that our teaching imparts the ability "to run the model" without imparting "deep learning." My research group (***RELATE.mit.edu***) has found some additional troubling student difficulties including failing to check "solutions" for obvious flaws, starting problems without either a conceptual analysis or a coherent plan, and worsening attitudes towards learning science after taking 8.01 (Physics I). The main thrust of this article is that the education research literature provides many important insights into these – and that improving our educational outcomes forces us to bring this research (and research-developed instruments) to bear on these problems. In particular, literature on expert-novice differences, modeling-based pedagogy, and students' epistemological approaches. Additionally, we urge departments to adopt standard MIT engineering design to reforming subjects in which learning outcomes and methods of assessing them are agreed upon first, and relevant contemporary knowledge is applied to reach the desired outcomes.

Introduction

The September/October 2017 FNL article contains a strong indictment of the results of our instructional process by a group of MIT teachers who are widely respected for their thoughtful devotion to educating MIT students: Dennis Freeman, Sanjoy Mahajan, Warren Hoburg, David Darmofal, Woodie Flowers, Gerald Sussman, and Sanjay Sarma (hereafter Freeman et. al.). They supply clear evidence that our students (and those at other top universities) have gaping holes in their "deep understanding." They cannot "use Newton's laws . . . to model the world," and are unskilled at "making the model and interpreting the results." What they are good at is "manipulation without understanding" and "running the model."

Additional Troubling Deficiencies

Freeman et. al. is a description of multiple observed student deficiencies, but does not offer perspectives (e.g., from the education literature) that might illuminate the diagnosed difficulties, nor does it suggest how we might change our pedagogy so that students obtain deeper learning of skills and habits of mind that would enable them to overcome the aforementioned difficulties. I take these omissions as an invitation to respond to their article. Before sharing some perspectives on these student difficulties, let me first add some additional difficulties discovered by my group's (***RELATE.MIT.edu***) research on teaching introductory Newtonian mechanics: 8.01, 8.011, 8.01L, and a three-week Mechanics ReView taught over IAP to 8.01 students receiving a D that offers an opportunity to move on to 8.02 rather than repeat all of 8.01.

Student Attitudes About Learning Science

It is important to realize that students learning 8.01, 18.01, 6.002, etc. are young adults who have already developed both knowledge about many GIR subjects and personal beliefs about what constitutes learning them. Several Physics Education Research (PER) groups have addressed the problem of determining students' personal epistemologies by constructing surveys that "measure student beliefs about physics and about learning physics" – quoting from the abstract of the latest such survey, the Colorado Learning Attitudes about Learning Science Survey [CLASS, (Adams et. al., 2006)]. The CLASS probes beliefs about personal enjoyment of the subject, perceptions of relevance of the subject to the world, and especially the conceptual thinking and self-confidence of students with respect to solving problems. Students are deemed more expert-like if they *agree* with statements similar to these:

- Physics comes from a few principles.
- When studying physics, I relate the important information to what I already know rather than just memorizing it the way it is presented.
- I am not satisfied until I understand why something works the way it does.
- I enjoy solving physics problems.

And *disagree* with these:

- After I study a topic in physics and feel that I understand it, I have difficulty solving problems on the same topic.
- If I don't remember a particular equation needed to solve a problem on an exam, there's nothing much I can do (legally!) to come up with it.

• A significant problem in learning physics is being able to memorize all the information I need to know.

The last time (2004) the CLASS was administered in 8.01 TEAL it revealed a ~ 7% *decrease* in learning expertise from pre- to post-survey that extended across all eight categories that CLASS probes. Faint comfort might arise because typical introductory physics courses in the U.S. lower the expertness of learning attitudes ~ 10% across these categories. Of particular concern is our additional finding for the D and F students in this class: their problem-solving self-confidence after taking this course was down ~ 30% (in all other categories their responses were indistinguishable from the ABC students).

I find this personally distressing: Newtonian Mechanics was the first science where mathematics was used to model the world based on a few fundamental assumptions – the prototypical model of most science and engineering that we teach at MIT; it is also the foundational science for several MIT majors. To teach our students that it is a pile of formulae unrelated to their world, their interest, and their future is a *pedagogical travesty.*

Algebra First vs. Planning a Solution

MIT professors want students to solve problems like an expert in that domain; often this means by starting with a solution plan based largely on conceptual reasoning. Yet 8.01 students typically start by writing an equation in which the given variables are already plugged into a fundamental equation (e.g., momentum conservation) – often remembered from a previous similar problem. To encourage this, part a) of several problems on the 8.01 final demanded written problem plans. My research group found that just over half of our students couldn't make a coherent plan (i.e., unambiguous, even if incorrect) – *irrespective of whether their grade was A- or C* (Barrantes & Pritchard, 2012). In individual discussions with ~ 20 of our students, all but one said they started those problems by seeking relevant formulae and solved algebraically, then went back and wrote the verbal plan (which was part a). They neither made a plan based on physical concepts, nor did they adduce physical reasons to buttress the applicability of the equations they started from. These findings demonstrate that neither high school nor MIT taught their students to make coherent plans for solving problems, nor even provided a learning environment where the "good" students learn such planning for themselves.

This serious divergence from faculty expectations stems from student vs. faculty differences in what they think the objective of answering the problem is: roughly "get the answer" vs. "understand how you got the solution" and what epistemological approaches should be used to reach this objective. Students' tools were studied by closely observing small groups of students solving problems (Tuminaro & Redish, 2007), then cataloging the "epistemic games" they brought to bear on the problem. Their University of Maryland students used primarily six, including:

• Mapping Meaning to Mathematics: map the problem story (circumstances and givens) to mathematics.

• Mapping Mathematics to Meaning: Identify target variables, find equation relating target to given information (similar to "plug and chug").

• Physical Mechanism Game: construct story about equations – often in terms of "phenomenological primitives" (DiSessa, 1988) such as a bigger object requires more force, more force → more velocity, gravity wins out in the end, etc.

The expert approach of "understand problem and plan solution starting from physical principles" was not observed. For example, when Mapping Meaning to Mathematics, "students often rely on their own conceptual understanding to generate this [mathematical representation] – not on fundamental physics principles" (Tuminaro & Redish, 2007).

We have made several efforts to teach students to write problem plans, including introducing "Tweet Sheets" that provide a framework for problem plans; space for ~ three lines of text and a small graphic and instruction on what constitutes a plan. Students can fill these in after doing group problems in class, then can bring them to the weekly quizzes. After the first few weeks, only about 15% of the students brought them to the quiz. When queried about this, most students said "I didn't know what to write." (About 10% of the students said "After I review the problem and write the tweet sheet, it is so easy to remember that I don't need the sheet.") My research group is still experimenting to find ways to help students learn to plan solutions. Tentatively we've concluded that they should have deliberate practice (Ericsson, 2009) of two important skills: first, determining which physical principles apply and why, and second, learning to decompose problems into sub-problems within which a unique subset of principles apply.

Perspectives For Understanding These Difficulties

The findings of Freeman et. al. together with our additions are all indications that our students lack "deep expert-like understanding"– in spite of their ability to score well on our final examinations. These findings include:

1. Overreliance on the mathematical manipulations of the models they are trying to apply,
2. Inability to create these models or to discover them,
3. Inability to plan a solution, or even to state one retrospectively after answering correctly,
4. Inability to make sense of, verify, and interpret the solution once it has been worked out, and
5. Loss of self-confidence in problem-solving and decrease of perception that Newtonian mechanics is either relevant to their lives or intrinsically interesting.

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Expert-Novice Studies

The novice-expert literature provides the best framework for understanding these difficulties, essentially providing a research-discovered list of "novice characteristics" that contain many items on the list above. The watershed paper in this field is *Categorization and Representation of Physics Problems by Experts and Novices* (Chi, Feltovich, & Glaser, 1981). This paper shows that novices categorize problems using surface features (pulley, block on inclined plane, collision, . . .) rather than according to fundamental domain principles as do experts. Thus students, even when asked to classify problems on the basis of similarity of solution, classify a block sliding down a plane without friction as similar to a block on a plane with friction, rather than as similar to a mass on a pendulum (since both exemplify energy conservation – i.e., gain kinetic energy mgh after descending a height h).

Students classifying problems based on surface features need a huge mental library of solved problems to find one that's sufficiently similar superficially to a given exam problem that the same solution principles also apply, as evidenced by our students' increasing (on the post-test) agreement with the novice-like question on the CLASS "If I want to apply a method used for solving one physics problem to another problem, the problems must involve very similar situations."

Many of the 6000+ references to Chi's paper expand the list of specific expert-novice differences: experts consider the problem conceptually and from different representations to plan their approach before starting to write equations, classify problems according to deep principles of the domain, have much more interconnected domain knowledge, and are able to retrieve and apply domain-specific models appropriately to unfamiliar problems (this is called strategic knowledge). When solving a problem, experts check that their solution process makes sense as they proceed, and importantly "make sense of" their answer using limiting cases, dimensional analysis, comparison with common sense, similarity to past problems, etc. Novices assume that manipulating the mathematical procedure for obtaining the answer will give a result that is correct without checking the result.

I would emphatically add "making sense of the answer" to the list of our students' deficiencies. When I ask MIT freshmen how they'll check their answer to a mechanics problem, they'll most frequently say "I'd check the algebra." I know that most physics faculty will acknowledge this deficiency: in our (Pritchard et. al., 2009) study *What Else (besides the syllabus) Should Students Learn in Introductory Physics?* sense-making was the top choice of the professors, and the second-lowest preference of the students. That's understandable: students don't get into good colleges by pausing on question 4 on a high stakes exam to consider ways to check the answer.

Many of my departmental colleagues express a strong desire to help undergraduate students "think like a physicist." When pressed to be more specific about what this means, they typically say "check that what they do 'makes sense'," "organize their knowledge coherently," "approach problems using concepts rather than algebra." I suggest that "think like an expert" is a good description of the outcome that most MIT faculty really want for their students.

The list of expert qualities accords well with what we demand of students on our PhD candidacy exam. I find that classifying just one or two student responses to novel questions as novice vs. expert-like enables me to reliably predict whether the committee will pass or fail a student. The NAS study *How Students Learn* (Chi, Bassok, Lewis, Reimann, & Glaser, 1989)(Bransford, Brown, & Cocking, 2000) summarizes novice-expert differences and is a good place to start learning this valuable perspective.

Modeling

David Hestenes (Hestenes, 1987) has convincingly argued that models form the everyday mental tools that most STEM professionals use. The word *model* appears 12 times in Freeman et. al. and I find it valuable in my professional and teaching life. Models and modeling are central to MIT and explicit in many upper division subjects, especially engineering: we use mathematics to make models of the structure and behavior of some well-specified system.

Yet in most GIRs, we fail to impart knowledge about models explicitly:

1. None of the Science GIR subjects mention "model" – with the exception of 8.02.
2. We recommend textbooks that don't give a modeling perspective, e.g., the best-selling Young and Freedman (11th edition used in 8.01 & 8.02) mentions "model" briefly in the introduction and not again in the subsequent 1714 pages.
3. We often provide "formula sheets" that list formulae without indicating what role each formula plays in which model (e.g., law of force, constraint, law by which state variables change, . . .), thereby encouraging the belief that "subject X is a pile of formulae" rather than imparting the view that the formulae are only one part of a particular model of reality in that subject.

The result is students who, at the end of introductory subjects, can manipulate the equations, i.e., "run the model" in Freeman et. al. – often without being able to name the model they are applying or knowing its limitations. For example, in 8.01 the equations F=ma and $F = \mu_{friction} * m * g$ are used in the same solution without knowledge of the very limited applicability of the second formula (fails for static friction, assumes that normal force is mg). Expert scientists and engineers are careful to check the applicability of the model as part of their solution process – the types of systems and circumstances under which the model containing these formulae applies, the model's limitations, and whether its predictions make sense (NAS13).

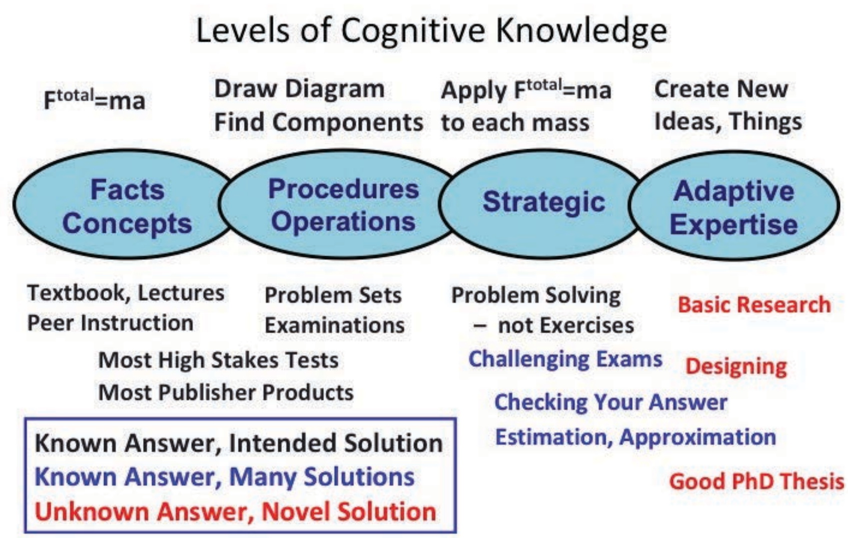
Hestenes and collaborators have developed a pedagogy called "modeling instruction" for physics that is explicitly designed to teach the ideas and procedures of modeling reality. In modeling instruction, students are guided to discover the basic models in laboratory, and to apply them to problems – a process called "modeling." This pedagogy leads to very large improvements of students' scores on both concept inventories and more problem-oriented tests; high school students start lower but finish higher than students taking traditional introductory courses at selective colleges (Hestenes, Wells, & Swackhamer, 1992). A recent review paper of ~ 50 different introductory physics courses (Madsen, McKagan, & Sayre, 2015) documents another benefit of modeling instruction: it uniformly *improves* the expertness of students' learning attitudes as measured by the Colorado Learning Attitudes about Science Survey (CLASS) – typically by ~ 11%.

Hestenes' group started the American Modeling Teachers Association (***modelinginstruction.org***) that runs two-week workshops on modeling instruction which upwards of 10% of all U.S. high school physics teachers have attended, and this pedagogy is widely known among physics high school teachers. (This summer there will be a total of ~ 62 workshops for biology, chemistry, physical science, and physics teachers.) This is known by only a small percentage of college or university faculty – unfortunate because modeling pedagogy would give many MIT professors a valuable perspective on reforming their subjects.

As an example, in developing MIT's three-week Mechanics ReView, my group has designed a modeling-based approach to categorizing domain knowledge and problem solving, and found that in addition to improving grades on the final exam by ~ 1.5 grades it improved their expert-thinking by ~ 11% as measured by CLASS. Importantly, these students also showed an improvement in their subsequent 8.02 performance relative to their peers who either did not take the ReView or who took another full semester of traditionally taught 8.01 (A. Pawl, Barrantes, & Pritchard, 2009; Rayyan, Pawl, Barrantes, Teodorescu, & Pritchard, 2010).

Cognitive

The MIT course catalog is based on a list of topics that are taught in each subject. A complementary perspective is to specify the cognitive skills that the student is supposed to learn. Indeed, a cognitive perspective is highly germane to understanding the student difficulties mentioned above. The figure below shows a cognitive hierarchy, and gives the teacher's relationship with tasks corresponding to questions at each cognitive level (below).



The figure divides cognitive knowledge into four categories, shown as overlapping ovals with examples from Newtonian mechanics at the top. These start on the left with a foundation of facts, definitions, and simple concepts like how to define and measure acceleration. Built on this factual foundation (expressed by its oval overlapping) is knowledge of procedures and operations – these are the models. Confronted with an unfamiliar problem, an expert applies strategic knowledge to sort through the known procedures (models) to determine which might be relevant or helpful, then solves the problems using the relevant model(s). At the very right is Adaptive Expertise, the knowledge/ability to create something new. These categories are closely paralleled by cognitive taxonomies like those of Bloom and Marzano (Marzano & Kendall, 2007; Teodorescu, Bennhold, Feldman, & Medsker, 2013).

This perspective illuminates typical tasks assigned by teachers; these are presented (below the ovals) in different colors depending on whether the problem/task has a known answer, and whether the teacher who poses it intends the student to answer it in a particular way. Let's categorize our current instructional approach (e.g., in 8.01) through this lens: list the topics in the syllabus, teach this material (mostly concepts and procedures). Such instruction doesn't improve students' strategic knowledge because they don't need to learn how to determine whether momentum is a key to this problem when momentum is this week's topic.

The facts & procedures-based instructional approach allows little opportunity for helping the students obtain strategic knowledge spanning the whole range of topics in that subject – the ability to organize their knowledge of different facts and procedures so that it can be fluently accessed when confronting an unfamiliar problem. Indeed, in my bookshelf of introductory physics textbooks, *not one attempts explicitly to instill strategic knowledge*, for example with a chapter

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whose title is something like "How to analyze a new problem to determine which of the previous 12 chapters can help you solve it." It is not surprising that unfamiliar final exam problems involving several of the studied procedures are considered to be very difficult by our students. Many of the problems in Freeman et. al. don't have a clear similarity to any of the weekly homework problems in the subject; hence they expose the students' lack of strategic knowledge.

Other Helpful Perspectives

Several other useful (to me) perspectives are Kahneman's Type 1 and Type 2 thinking (quick and reactive vs. thoughtful and logical) and its relevance to short concept questions vs. traditional long-form problems, the importance of quick association among relevant domain vocabulary as a measure of knowledge interconnectedness (Gerace, 2001), and defining "understand a concept" as "fluency with, and interrelating of, the representations commonly used with that concept." (e.g., Motion with constant acceleration might be represented with a table of position vs. time, a formula for velocity vs. time, a strobe picture, or a graph of velocity vs. position.)

Addressing These Deficiencies

Having broadened the list of troubling student deficiencies and offered some perspectives, I now turn to how individual departments can reform our subjects to help students overcome these difficulties.

Outcomes and Goals

Freeman et. al. and I are distressed that, having done well in our subjects, our students are *not reaching the learning outcomes* involving skills, habits, and attitudes that many faculty strongly believe are important. I put the blame on our system (shared by other colleges) that defines a subject as a syllabus of *topics and subtopics* that will be taught by an expert in that subject. This teacher-centered description lacks any specification of what is expected of students in terms of skills, habits, or abilities. Thus addressing these deficiencies starts with:

#1 Departments must specify subjects in terms of outcomes expected of students – both learning outcomes with respect to specific topics, and general skills.

The main thrust of this article is that the education research and cognitive science provide many important insights and remedies that address the serious student deficiencies identified by Freeman et. al. and in this article – and that improving the outcomes of our subjects forces us to bring this research (and research-developed assessment instruments) to bear on our efforts to improve our courses.

Thus, where the current course description lists a topic, e.g., "momentum," there would be a learning objective "identify when momentum is/is not conserved." This has the advantage that a professor can write a problem that most other department members would agree assesses a particular learning objective. Importantly, learning objectives can address more general learning outcomes than topics – for example "learn to check their solutions using dimensions and limiting cases." Specifying learning objectives would enable us to emphasize general skills and habits that are generally considered important in the twenty-first century such as the 4 C's – collaboration, communication, critical thinking and problem solving, and creativity (p21.org, (NGSS Lead States, 2013)).

I also recommend that we move our instructional goals toward Strategic and Creative cognitive levels because smart phones and Internet search engines provide instant access to facts and integrated collections of procedures (like Wolfram alpha, the computational package r, Mathematica, etc.). For example, we can remove "challenging" algebra-intensive problems the first time students are exposed to a topic, and add review problems later that explicitly require students to say which previously studied topics apply in a given physical situation and why – or give problems with multiple choice answers where the distractors can be eliminated by dimensional analysis or special cases. Given that freshmen will forget over half of what they learn but don't use regularly by graduation (Ebbinghaus, Ruger, & Bussenius, 1913; Andrew Pawl, Barrantes, Pritchard, & Mitchell, 2010), but will improve on skills that they reuse, answer checking, dimensional analysis, and determining what's conserved should receive more emphasis than they do now – especially when reforming subjects like GIRs where most students will major in another course.

Assessment

Given that the department has set the learning objectives and goals, it is important to realize that assessment sets the standard for student learning (and has strong influence on the instruction). So,

#2 Departments must adopt assessment instruments and develop calibrated question pools that accurately assess their learning goals.

This process should strongly consider incorporating some of the research-developed instruments. Examples might include instruments that evaluate students' ability to reason from fundamental physical principles (Andrew Pawl et. al., 2012), assessments of general scientific reasoning (Lawson, 1978), and widely used instruments whose typical results are known for different institutions, e.g., the CLASS, Test of Understanding of Graphs (TUG), and discipline-based instruments like the venerable Force Concept Inventory that has transformed teachers' views on the importance of conceptual reasoning. We should also consider making some instruments of our own – a good place to start would be to collect questions like those in Freeman et. al. This process will result in stable year-to-year assessments of student knowledge and learning. As a side benefit, these assessments can complement student evaluations of learning in assessing teacher performance.

DBER – Discipline-Based Education Research

The main thrust of this article is that the education research and cognitive science literature provides many important insights and remedies that address the serious student deficiencies identified by Freeman et. al. and in this article – and that improving the outcomes of our subjects forces us to bring this research (and research-developed assessment instruments) to bear on our efforts to improve our courses. This is a tremendous challenge due to the immensity of the possibly relevant literature. To put this in perspective, a typical faculty member is well acquainted with literature in a specialty like Atomic Physics Research for which a Google search will have ~ 0.1M hits, in comparison Physics Research will yield ~ 2.7M, and Education Research ~ 12.4M, a count that probably excludes much education-relevant research from fields like cognitive science, behavioral psychology, etc. Hence it is unrealistic to expect even our most dedicated professors to know the literature relevant to education – even the dedicated teacher-authors in Freeman et. al. believe that "researchers in STEM education [have not] . . . identified these problems and shown their solution." I believe that the only realistic route to filtering through the voluminous education research to get beyond the "educational technology fix of the day" and find what will truly help us improve our subjects is that:

#3 We must incorporate Discipline-Based Education Researchers into processes #1 and #2 above, as suggested in the recent National Research Study, (Singer, Nielsen, & Schweingruber, 2012).

Summary

The above three recommendations – set goals, agree on how to assess them, and incorporate relevant educational research – are consistently recommended by education reformers, and have been successfully implemented at two selective universities by Nobel prizewinner Carl Wieman (Wieman, 2017). Grant Wiggins has advocated them, calling the process "backward design" to contrast it with the topics first/assessment last approach that is typical in universities (Mctighe & Wiggins, 2012).

It should be easy for MIT faculty to adopt backward design because it is really the "forward design" that we practice in our professional lives: select goals, determine how we'll measure them, build on relevant literature, experiment/fail/recycle until the goals are met then publish or patent. Hopefully, we can adopt this familiar practice to *systematically and scientifically* improve MIT undergraduate education.

I acknowledge many helpful and relevant comments by Lori Breslow, Sanjoy Mahajan, Leigh Royden, and Gerald Sussman.

I welcome comments on this (*dpritch@mit.edu*) and encourage further *Faculty Newsletter* articles on improving MIT education.

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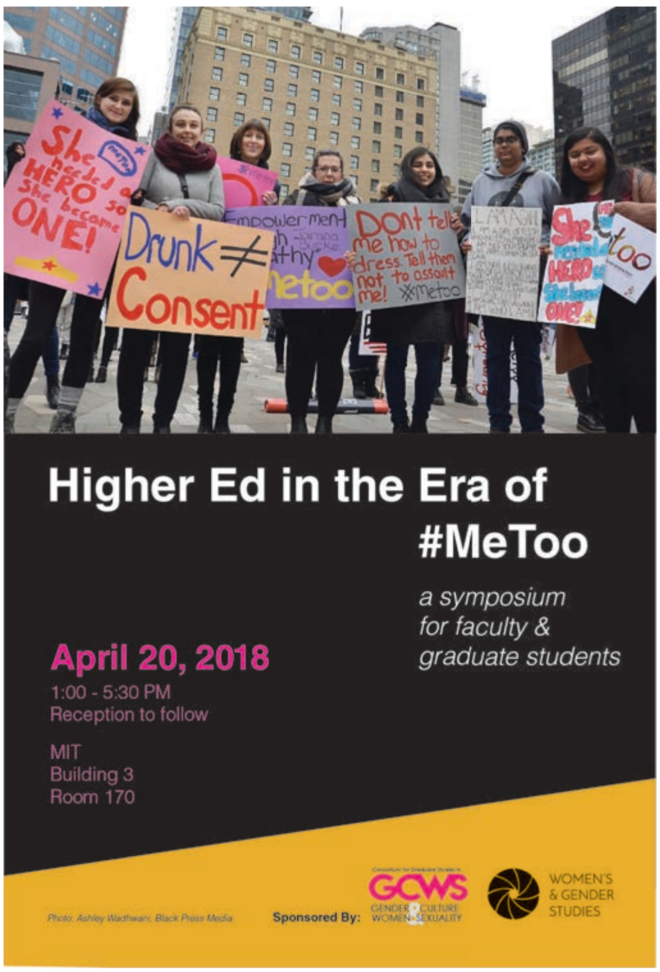
Higher Ed in the Era of #MeToo: A Symposium for Faculty and Graduate Students

Stacey Lantz



THE GRADUATE CONSORTIUM FOR Graduate Studies in Gender, Culture, Women, and Sexuality (GCWS) at MIT is hosting a free half-day conference on how the recent #MeToo movement has impacted higher education, specifically at the graduate and doctoral levels.

The #MeToo movement, started by Tarana Burke in 2006, has highlighted the prevalence of sexual violence within all aspects of our society – from Hollywood to college campuses. More survivors are sharing their experiences and demanding change from their peers and institutions. It is critical for us to have more creative ways to support, prevent, innovate, and collaborate on this issue. Many marginalized communities, both inside and outside of academia, have led the fight to end sexual violence and we must elevate these voices and communities.

During the conference we will feature work by academics, researchers, activists, legal experts, and many in other fields as we look at this issue through an interdisciplinary lens. Panels will focus on how sexual harassment and assault impact graduate and doctoral students differently than they do undergraduates, and how we can specifically address that difference through a critical analysis of Title IX and the gaps that are created by current legislation, and a focus on the impact of media on the #MeToo movement. Workshops will establish the space for deeper conversations on creating safer environments, focusing on the specific needs of people with marginalized identities, and specific action steps that people, regardless of their role, can take.

The conference will be followed by a cocktail reception to share what was learned and continue the discussion!

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MIT Day of Action

Roger Levy
Sally Haslanger
Ceasar McDowell
for the MIT Day of Action Organizing Team

WE ARE DELIGHTED TO ANNOUNCE MIT's second annual Day of Action, to be held on the ground floor of the Stata Center on Tuesday, April 17, from 10 am to 8 pm. The Day of Action is a large-scale grass-roots civic engagement and action event devoted to the political, economic, and social challenges facing us today.

Please join us as we act together to fulfill MIT's mission "to bring knowledge to bear on the world's great challenges," seeking open-minded dialogue with peers and colleagues of diverse backgrounds and views. All of us, regardless of political affiliation, can contribute to identifying and seeking out the roots of the greatest challenges facing our society, and to planning for actions addressing these challenges in the present day and in times to come. The Day of Action is open to all, representing the full diversity of our society. We are made stronger by open, respectful dialogue and the exchange of ideas from the widest variety of intellectual, religious, class, cultural, and political perspectives. We invite you to join us, to share your concerns and questions, your hopes and ideas, and your knowledge and skills.

Last year's Day of Action drew an estimated 1,000+ participants from MIT and the broader local communities; we hope to see a strong turnout again this year. Sessions provide opportunities to *learn from experts, build skills, and connect with community*. This year's sessions, continually updated at ***https://dayofaction.mit.edu/events***, include:

Learn from Experts

Perils for Democracy; with Daron Acemo lu and Daniel Ziblatt

Confidence at the Ballot Box: Russian Bots, Midterm Elections and Cybersecurity; by Suzanne Mello-Stark

Language, Bias, and Power; by Justin Khoo and Roger Levy

Black Panther: Call for Liberation or Repressive Desublimation?; with Michel DeGraff, Grégory Pierrot, and M. Amah Edoh

Conflict on the Korean Peninsula Today: History, Technology, Politics; by Arissa Oh and Vipin Narang
Coming Out Faithful: A Multi-Faith Conversation with LGBTQ Religious Leaders; by The Lutheran Episcopal Ministry at MIT
How Not To Be Evil: Tech Workers Against Racism, Sexism, and Surveillance; by Moira Weigel and Ben Tarnoff
Remote Activism in Electoral Politics Workshop with **Sister District Project** & **Indivisible Somerville;** by Graham Jones and Patrick Joyce
Experiences from prison: Incarceration, education, and rehabilitation; by Joli Sparkman-Bayron, Reentry Coordinator at Bethany House
The Baltimore Leadership School for Young Women: a screening of the documentary STEP, with Q&A by Visiting Professor Kimberly Juanita Brown
Who Are We Talking To? The Humanities, the Public, and the Streets; by Darien Pollock and Myisha Cherry
Transforming Education Across the Globe: How MIT Open Learning is Improving Access and Quality of Education; by Brandon Muramatsu, Anna Schrimpf, Sarah Hansen, Robert Fadel, Eryn Heying, and Vijay Kumar (moderator)
Demystifying the MIT Corporation; by Paul Kominers
Asmarina: A film screening and discussion about Race, Immigration, Citizenship and the Habesha Community in Milan; by Medhin Paolos (director) and Lorgia Garcia Peña
Korea: The Forgotten War, a documentary screening and discussion
If You Care About Truth, Fight for Justice: Universities and the Communities They Interact With; by Naomi Scheman, Ceasar McDowell, and Libby Hsu
The History (and Present State) of Student Activism at MIT; by Steven Penn and Tanya Llanas

Build your Skills

Organizing for Radical Inclusion: Stories From Hackathons; by Elaine Harris, Fahad Punjwani, Steven Max Patterson, and Hildreth England
Open access: How you can help make the world's scholarly works available to all; by Katharine Dunn, Herng Yi Cheng, Ellen Finnie, Roger Levy, Nick Lindsay, and Jeff Rosenberg
Science Advocacy 101: From interest to action; by Ortal Ullman of the Union of Concerned Scientists
Corrupting the Public: Philosophy for the People; by Brianna Toole and Alex Hargroder
Reimagine Education Through Design Thinking; by Ela Ben-Ur, Jared Cosulich, and Julian Serrao
Everyday action: Solidarity investment; by Ryan Harrison
Connect with Community by meeting and discussing with local representatives of the Union of Concerned Scientists, the Center for Science and Democracy, Mass Peace Action, and the Green Century Fund.

The Day of Action is free and open to the general public; RSVP is appreciated but not required. There are also opportunities to volunteer to help with day-of-event logistics. Please visit ***https://dayofaction.mit.edu*** to learn more – we hope to see you there!

Roger Levy is an Associate Professor in the Department of Brain and Cognitive Sciences *(rplevy@mit.edu)*;
Sally Haslanger is a Professor in the Department of Linguistics and Philosophy *(shaslang@mit.edu)*;
Ceasar McDowell is Professor of the Practice of Community Development in the Department of Urban Studies and Planning *(ceasar@mit.edu)*.

letters

Suicide and Sexual Harassment at MIT

To The Faculty Newsletter:

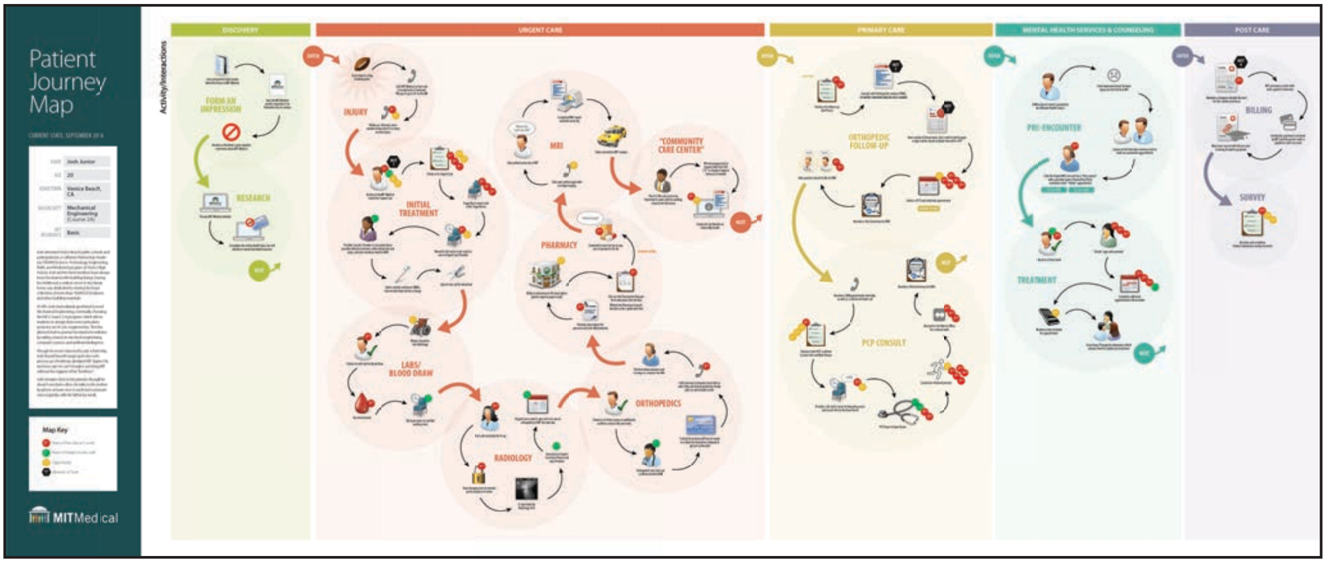
MIT STUDENTS HAVE A significantly higher suicide rate than students at other universities. According to "Reappropriate," an Asian American feminist Website (***reappropriate.co/2015/05/asian-american-student-suicide-rate-at-mit-is-quadruple-the-national-average***), the rate of suicide among Asian students at MIT is quadruple that of the national average. In 2015, two MIT students committed suicide in one week, and already this year an MIT mathematics graduate student took her own life. These facts would make one think that suicide should be the major concern that the MIT administration has about the well-being of their students.

Thus it is both strange and disturbing that sexual harassment, and not suicide, is the issue that President Reif and Provost Schmidt think is paramount. The only explanation is that they believe that unwelcome sexual experiences are worse than death and that their belief justifies their threat to remove any faculty member or staff who does not take the sexual harassment course that they have chosen to inflict on us.

As those who have taken the course are well aware, its content violates every principle for which an MIT education stands. MIT courses are designed to stimulate original thinking; this course is designed to discourage it. When a student or colleague approaches you about a problem that is related to sex, the course mandates that you parrot the words that it has taught you to say. To make a human response based on one's own experience is forbidden. It is sad that MIT has chosen to adopt this form of thought control, but it is consistent with other decisions made by President Reif about the direction in which he wants MIT to go.

Dan Stroock
Professor, Department of Mathematics

Improving the Urgent Care Experience
Stuopis, from page 1



MIT Medical Patient Journey Map

The map tracks the experiences of a fictional patient, "Josh Junior," who sustains an injury while playing flag football. Our use of a student persona for this mapping exercise was deliberate. After all, students are at the core of the Institute's mission and are, by extension, the very reason for MIT Medical's existence. Josh's journey begins with his impressions of MIT Medical before becoming a patient and follows him through his initial visit to Urgent Care and subsequent need for specialty and primary care.

From the start, we knew that a student-focused map would put a particular spotlight on our Urgent Care service. For most MIT students, Urgent Care is their first exposure to MIT Medical; for many, it is the only interaction they have with MIT Medical during their time in Cambridge. Our 18,000 Urgent Care visits each year account for approximately 15 percent of clinical encounters across all of MIT Medical. Not surprisingly, students account for 58 percent of Urgent Care visits.

Gathering More Data

Following our internal operational analysis, we were fortunate to work with a talented team of four students enrolled in Sloan's Health Systems Innovation Healthcare Lab (H-Lab) course. As part of the requirements for this course, students undertake a four-month-long action learning project in host healthcare institutions. These projects typically involve looking at complex problems in Internet technologies, operations management, strategic marketing, and other areas. Similarly to the journey mapping process, our H-Lab team collected and analyzed data, interviewed stakeholders, and synthesized a set of concerns:

1. *Reputation:* We have a reputation problem with students. Our wait times are not transparent, and they can be long, sometimes up to four hours. Students also have concerns about privacy during check-in and triage.

2. *Systems and operations:* Our systems and operating processes are unaligned, inefficient, and sometimes fall short of meeting patient expectations. This includes everything from staffing and the check-in process, to our hours of operation and the ways clinical staff communicate with each other.

3. *Identity:* Urgent Care has an identity crisis. Is it an emergency room? (Answer: No) Is it primary care? (Answer: No) Is it convenient care? (Answer: Well, the location is convenient, but the long wait times aren't.) To further confuse the issue, unlike many local urgent care facilities, ours doesn't offer ancillary services like lab or radiology after hours or on weekends.

The result of all of these issues is a disjointed patient experience that disproportionally affects students.

Putting Patients First

As part of this process, we have also turned to our internal experts for their advice. For example, within the field of mental health, there is a well-known best-practice model known as *trauma-informed care*. This means building a practice that is a safe space for trauma survivors – where they feel safe, understood, and listened to. Trauma-informed care can take many forms, from redesigning intake forms to replacing bench-like seating in waiting areas with individual seats that don't force trauma survivors to sit in close proximity to strangers. But at its heart, trauma-informed care means placing the care of one's most vulnerable patients at the core of an organization's mission and vision.

As mental health practices began to adopt this care model, they discovered something interesting – that the changes they made to become more sensitive to trauma survivors were also welcomed by patients who were not trauma survivors. That when you design a system to provide the best possible care to the most vulnerable patients, it improves care for everyone.

Everyday examples of this phenomenon can be found in the environment around us. Closed captioning, originally intended to benefit deaf and hard of hearing individuals, now allows everyone to access television programing in noisy bars, gyms, and airports. Similarly, access ramps and sidewalk curb cuts are utilized not only by wheelchair users, but by countless others – parents pushing strollers, delivery people with handcarts, travelers with rolling luggage, and many more.

With this model in mind, Associate Medical Director and Chief of Mental Health and Counseling Karen Singleton and Chief of Student Health Shawn Ferullo have suggested that the organizing principle for MIT Medical should be what they are calling *student-informed care.*

While MIT students are exceptionally intelligent and capable individuals, as patients, they remain our most vulnerable group. Many are novices at seeking healthcare independently, and few have established clinical relationships at MIT Medical. By restructuring our practice to provide the best possible care for students – our least savvy healthcare consumers and our most vulnerable patient population – we believe we can elevate the care we provide to all our patients.

Urgent Care Reimagined

As our Urgent Care Service evolves to provide more student-informed care, let's imagine how different Josh Junior's next experience will be:

Early one Saturday morning, around 2 am, Josh starts to feel ill. He goes online to ***medical.mit.edu*** *to see what to do. The website has information about common ailments and suggests that Josh's symptoms are severe enough that he should call for advice. When Josh calls, he reaches a friendly nurse, who listens, is sympathetic, and instructs him to try to get some rest. She tells him that if he feels worse or the same in the morning, he should come in after 8 am, when Urgent Care opens.*

Josh wakes up and still feels unwell. But though Josh is sick, his ailment is hardly urgent. He reaches for his phone and visits the MIT Medical website, where he sees that the current wait time in Urgent Care is 45 minutes. He doesn't want to wait that long, and since it's a Sunday with no classes, he uses the website to make an appointment for a few hours later, sets his alarm, and goes back to sleep.

Later, Josh makes his way to MIT Medical. By now, Urgent Care has most likely been renamed to better reflect the type of service we provide – MIT Medical Convenient Care, Same-day Care, or Walk-in Clinic. When Josh arrives, the signage is clear, and a friendly person at the front desk guides him to a check-in kiosk. After scanning his ID and answering some questions on a touch screen, he's checked in – no more clipboards, paper forms, and pens, or having to discuss what is bothering him in a somewhat public setting. The system alerts us that he has arrived and tells us why he is here.

Josh takes a seat in the comfortable waiting area, where he finds snacks, a coffee machine, and charging station for his phone. Since he made an appointment earlier, a medical assistant greets him promptly. He is discreetly called to an exam room, where the medical assistant takes his vital signs and communicates that information to the doctor or nurse practitioner who will treat him. When the clinician comes into the room, he or she can begin treating Josh immediately. There will be no repetitive "What brings you in here today?" questions, because Josh has already provided that information and talked with the medical assistant.

Josh and his clinician look at his medical record together on the large flat-screen TV on one exam-room wall. The clinician gives Josh a prescription and instructs him to go to the lab to get some blood work done. Before he leaves, Josh is handed an iPad to fill out a quick survey about his experience.

Then he heads to the lab, which, along with the pharmacy, is conveniently open during the same hours as Urgent Care – even on weekends. He doesn't have to leave campus to get his blood test or fill his prescription, so he can begin taking his medication right away. In under an hour, he's back at his dorm, and when he feels better, he tells his friends about the great experience he had at MIT Medical.

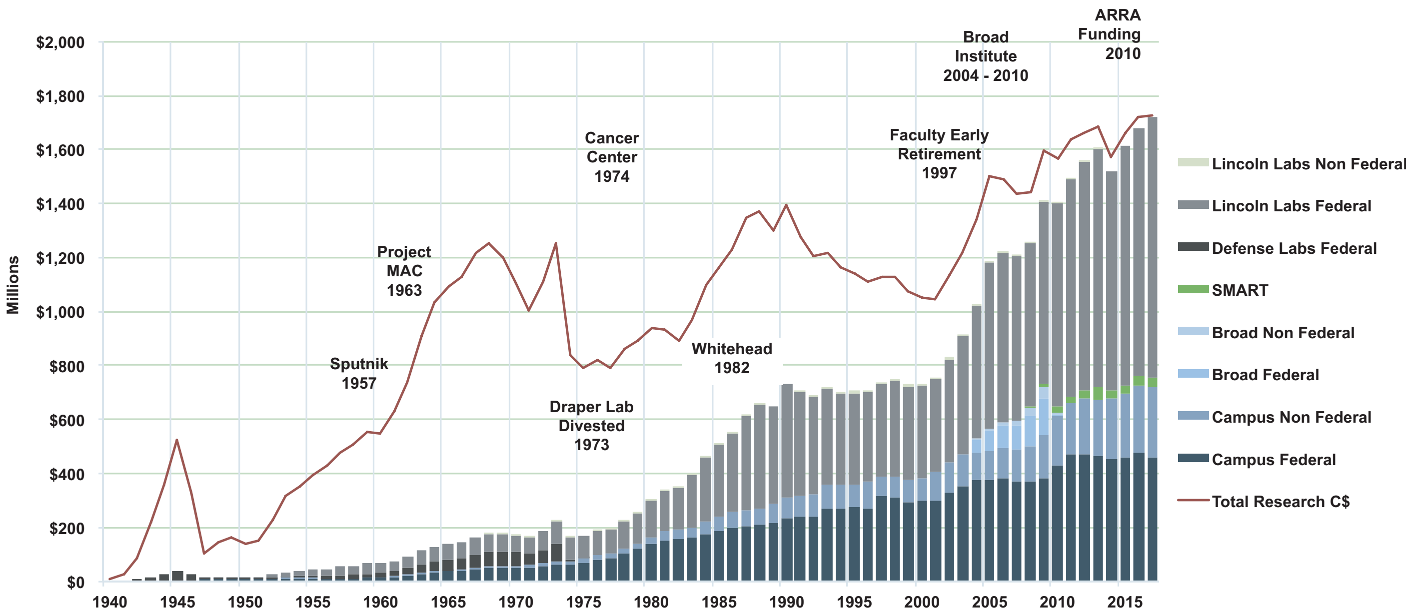
Over the coming year, our team at MIT Medical will be working to make this vision a reality. Our new electronic medical record, patient portal, and practice-management system implementation in June 2018 will be a big step toward realizing these aspirations. After reviewing our data and conducting several pilots looking at our hours, we also anticipate changing the operating hours for Urgent Care to 8 am to 8 pm 7 days per week, likely with the next academic year. This change enables us to open lab, radiology, and pharmacy for expanded hours, thus improving our ability to care for our students and other patients during the times we are open. Additional work is also underway to evaluate the benefits of a new name and brand, and to improve staffing patterns, patient flow, and facilities.

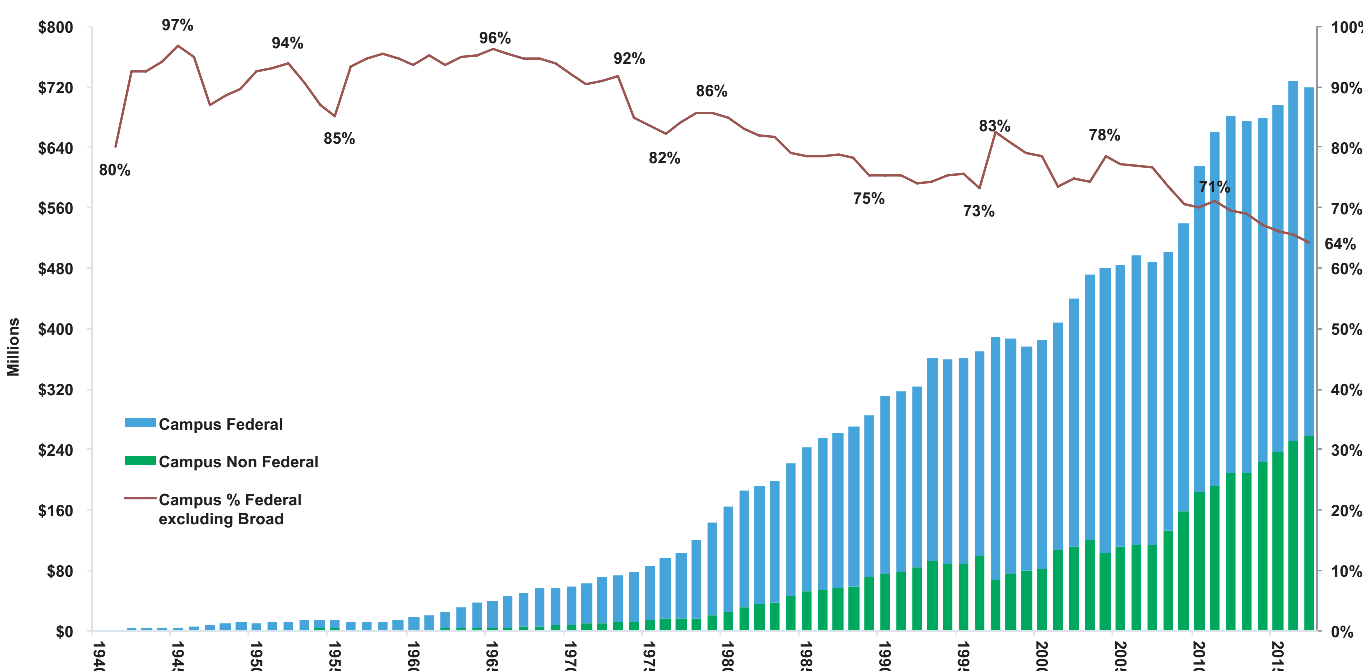
Through data collection, listening, and our transformation to a student-informed care model, MIT Medical's Urgent Care Service will deliver the best possible care to the MIT community. By focusing on student needs, we will elevate the experience of every patient who walks through our doors.

Cecilia Stuopis is Medical Director and Head, MIT Medical *(cstuopis@mit.edu).*

M.I.T. Numbers

MIT Research Expenditures 1940–2017





Source: Office of the Provost/Institutional Research