

Factors Affecting the Adoption of Faculty-Developed Academic Software:

A Study of Five iCampus Projects

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The TLT Group
Teaching, Learning, and Technology
A Non-Profit Corporation

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Factors Affecting the Adoption of Faculty-Developed Academic Software: A Study of Five iCampus Projects

Executive Summary¹ of Findings and Recommendations

Stephen C. Ehrmann, Steven W. Gilbert, and Flora McMartin, The TLT Group

“Initiated in 1999, iCampus is a research collaboration between Microsoft Research and MIT whose goal is to create and demonstrate technologies with the potential for revolutionary change throughout the university curriculum.”² The program was made possible by a \$25 million research grant from Microsoft to MIT, and involves extensive collaboration between MIT and Microsoft staff.

The TLT Group has been asked, “In light of the experience of iCampus, especially those projects selected by MIT and Microsoft for close study, what can be learned about priorities for educational technology initiatives in the future and about how the spread of such innovations can be more effectively supported?”

In the past many large-scale faculty-developed content-specific projects had had great success as pilot tests, but had failed to be widely used. So The TLT Group and iCampus decided to focus this study on five quite different projects that had already achieved some degree of institutionalization and wider use. Over 150 interviews were conducted with faculty members, staff and students at MIT and other institutions, and project documents were studied. The five projects are:

- iLabs – students can use web browsers to design experiments and collect data from distant laboratory equipment;
- iMOAT – the web is used to manage the process of large-scale assessment of student writing;
- TEAL – two terms of introductory physics have been redesigned around inquiry, discussion, experimentation, and visualization;
- XMAS – students can ‘quote’ video legally in their online discussions, presentations, and projects about films in courses such as Shakespeare
- xTutor is to be a tool kit for creating online courses; its strength is checking computer programming homework and providing feedback.

We have concluded that:

- A. These five projects have improved important elements of an MIT education by making learning more authentic, active, collaborative, and feedback-rich. For example, they have been institutionalized in a two-term physics sequence required of most MIT students, three of the four core courses required by MIT’s largest undergraduate major, and in the writing assessment used for incoming MIT students. For all five projects, ideas and materials have also been adopted by additional faculty at MIT and by faculty at other institutions. These adoptions, along with evaluative evidence, demonstrate the value of these projects.

¹ The full report is posted on <http://icampus.mit.edu> and will also be posted on <http://www.tltgroup.org>

² From the iCampus web site, <http://icampus.mit.edu>, November 10, 2006

- B. Nonetheless, wider adoption has been extremely difficult to promote, despite the fact that the materials are free and that over \$2.5 million has been allocated for outreach. Because there is little incentive or support at most institutions to seek out and adopt innovations from other institutions, the burden falls almost entirely on the innovator and iCampus to seek out, persuade, and assist the innovator's peers to use the innovations. This was made even more difficult by gaps in communications channels as well as a lack of supports and incentives at both ends of the adoption channel.
- C. Adoptions did occur, however. They were aided, first, by certain project features (e.g., the ability to try out software freely over the Web; development procedures that engaged potential adopters from the start).
- D. Second, adoption was easier when innovators could take advantage of existing 'coalitions for instructional improvement' to attract the attention of potential adopters without seeming to tell them how to teach, and then assist them with adoption.
- E. Third, adoption was easier when the adopting institution was unusually motivated to adopt iCampus innovations and then to disseminate them further. Distance seemed to help institutions work with MIT; many of these motivated institutions were in other countries.

Innovations rarely prosper for long at any one institution unless they also spread among many institutions; if wide use is achieved, the various users can support each other and long term survival of the innovation is far more likely. So widespread adoption for expensive R&D projects is a virtual necessity for getting full value for the original investment..

Our full report contains actionable recommendations for universities, government funding programs and foundations, and corporations. This executive summary includes only the headings of those recommendations. Our first recommendation draws on Finding A and on wider experiences in the field:

1. Improve education widely so that it becomes more authentic, active, collaborative, and feedback-rich. iCampus software and ideas provide useful elements for such a campaign.

Selected specific sector recommendations for implementation include:

1.1.5 Colleges and universities: Academic computing, the teaching & learning center, distance learning, the library and any other units responsible for professional development and course improvement should coordinate and organize their collective efforts around these goals.

1.2.2 Government/Foundations: Support development of appropriate methods for assessing these teaching/learning activities and outcomes in the disciplines.

1.4.2 MIT specific: MIT should systematically review all educational innovations supported with major grants from sources such as iCampus in order to determine which deserve internal support for wider deployment or further development.

(See pp. 107-110 for complete discussion of Recommendation 1)

As described in our findings, however, it has been difficult for higher education to make such improvements and to respond to societal needs and technological change, because it is so difficult for ideas and materials to spread and evolve through use across many institutions. Therefore, to encourage and assist faculty not only to create innovations but also to search widely for innovations to adopt, we make these additional recommendations.

2. Create demand for adoption of new ideas by rewarding faculty members for continually and cumulatively improving teaching in their programs. Selected specific sector recommendations to implement this general statement include:

2.1.1 *Colleges and universities:* Assist and reward all faculty members who discover, adapt and share practices and findings from other institutions as part of the process of improving their academic programs.

2.1.4 *Colleges and universities:* Specialists, such as reference librarians, staff in information technology, and staff in teaching and learning centers, should work together to help faculty seek out relevant ideas and materials in their disciplines

2.2.1 *Government/Foundations:* Explore ways of providing faculty development opportunities in which *all* interested instructors nationally can participate.

2.3.1 *Corporations:* When funding faculty to apply new technology to educational problems, insist their proposals build on relevant improvements from other institutions, especially developments in their own disciplines.

2.4.1 *MIT-specific:* Requests for discretionary funding for faculty to improve their teaching should be assessed against best practices worldwide.

(see pgs. 112-114 for complete recommendations)

3. Nurture coalitions for instructional improvement, within and across institutions, in order to create better channels for sharing and improving innovations.

Selected specific sector recommendations to implement this general statement include:

3.1.1 *Colleges and universities:* Develop and improve ways in which faculty members and students routinely discuss improvements in courses in their disciplines, within and across institutions.

3.2.1 *Government/Foundations:* Fund well-staffed, long-term, content-specific coalitions with the responsibility for reaching out to all faculty members nationally who teach that course or small group of courses.

3.3.2 *Corporations* should investigate the feasibility of a service to help faculty members who teach comparable courses to share information on how they teach and assess, share materials, and even collaborate in teaching.

3.4.1 *MIT-specific:* Study how various departments teach multi-section courses, and the impact of various teaching practices on the testing and sharing of ideas for teaching the course.

(see pgs. 114-116 for complete recommendations)

4. Create more higher education-corporate alliances in order to support the development and dissemination of new educational technology materials and practices. Selected specific sector recommendations to implement this general statement include:

4.1.1 *Colleges and universities:* Host corporate staff on campus to help make the alliance work.

4.2.1 *Government/Foundations:* Fund more R&D projects with higher education and corporate partners

4.3.2 *Corporations:* Fund more collaborative R&D projects that involve faculty at multiple institutions working with corporate staff.

4.3.3 *Corporations:* Take responsibility for promoting adoption of ideas and materials emerging from the collaboration by allocating corporate staff and budget to the task.

(see pgs. 116-120 for complete recommendations)

5. Supply faculty innovators with central services in educational design, software development, assessment methods, formative evaluation, and/or in sharing ideas with others who teach comparable courses. Selected specific sector recommendations to implement this general statement include:

5.1.5 *Colleges and universities:* Provide dissemination/adoption support for innovative ideas and materials.

5.2.1 *Government/Foundations:* Insist that faculty developing innovative uses of technology get all the kinds of help they need: educational design, programming, assessment, program evaluation, and dissemination; budget funds for these services where necessary.

5.3.2 *MIT specific:* Provide more support for units that can provide innovative faculty with assistance in educational design, programming, assessment, program evaluation, and dissemination. *(see pgs. 120-124 for complete recommendations)*

Chapter 1: Prologue and Methodology

The iCampus Joint Steering Committee began supporting outreach and, ultimately, this study because of their concern with enhancing the impact of the projects which they had supported.

Speaking simplistically, this question of ultimate impact can be broken down into two parts:

1. Is there reason to believe that selected iCampus projects are worth adopting? In other words, if more faculty and students were to do what at least some users of these projects have already done, would education improve in some substantial ways?
2. If so, what factors influence whether these ideas and software do indeed take root and spread?

The TLT Group research team³ and the Joint Steering Committee first had to decide to balance the study's effort between those two questions. To make that decision, we relied on two insights from the literature on those subjects and from our experience:

- 1) technology can be used to support teaching/learning activities that in turn improve outcomes; but
- 2) spreading such innovations across thousands of institutions and hundreds of thousands of instructors has been very difficult in the past.

1. Appropriate Use of Technology Can Improve Educational Outcomes

Decades of research have documented a variety of ways in which computers and the Internet can enable teachers and students to change what they do in ways, changes in teaching/learning activities that in turn improve educational outcomes.

It's no longer doubted that computers can enable the teaching of needed content, for example, from computer science to the study of classical Greece (e.g., the Perseus collection of primary source materials on the Web⁴).

It's no longer in question that computers are useful in expanding access to an education for more, and more kinds, of students: through distance learning, blended learning, and materials that are more accessible to students with various learning disabilities.

It's no longer in question that computers can be used in ways that make learning more effective. But that topic was investigated for some time before that conclusion was reached. And the way that the question was resolved has a major influence on the shape of this study.

³ For a description of The TLT Group, its Flashlight Program, and the research team, see Attachment IV.

⁴ Perseus is an interesting case study because of its longevity as well as because of its value. When Greg Crane first approached the Annenberg/CPB Project about funding for Perseus in 1985, he argued that classicists would be unlikely to use the package unless it was obvious that Perseus would last for twenty years. That became the guiding principle of Perseus development: creating a resource for learning and research that would obviously outlast the hardware and software on which it was originally designed. This is quite a challenge because, historically, upgrading software to run on a new platform can cost as much or more as the original development. Perseus was carefully designed to avoid that problem, and the transition from Macintosh to Windows and the Web about nine years after development began cost only a few percent of the original development cost. Perseus is still around and still growing, over twenty years after its inception. It can be seen on the web at <http://www.perseus.tufts.edu>.

Back in the 1970s and 1980s, James Kulik and his colleagues published a series of papers documenting substantial improvements in educational effectiveness (test score gains) in courses that used self-paced instruction compared with courses that used mass presentation of instruction. (Kulik et. al., 1979; Kulik and Kulik, 1987; Kulik, 1994)

Richard Clark then pointed out that self-paced instruction could also be implemented on paper, with similar instructional gains and argued that technology was merely a delivery vehicle with no impact on outcomes. Clark pointed to parallel research that had already documented the fact that if information was presented one way from expert to learner, the outcomes were on the average the same, no matter what technology was used to carry the transmission: a lecture hall, a book, a videotape, or any other technology of presentation. Clark concluded that what mattered was the learning activity, not the technology used to support it. (Clark, 1983)

To reach this conclusion, however, Clark downplayed an important fact. When it comes to supporting a particular learning activity like self-paced instruction, or carrying out a scientific experiment, or analyzing a video, not all technologies are equivalent. When it comes to effectiveness of learning, one cannot simply ask “does this project improve learning outcomes?” Instead there are two questions:

1. Does the activity that the project is designed to support (e.g., getting rapid feedback on homework) improve learning outcomes?
2. Is the project an especially good way to support that activity?

For example, as many studies have shown, active and collaborative learning activities are excellent ways to improve learning outcomes; so are learning activities that engage students’ energy and attention and impel them to spend more time studying (Chickering and Gamson, 1987; Pascarella and Terenzini, 1991).

2. Widespread Dissemination of Such Activities is Very Difficult

In the hours before he passed away, Sir Donald Wolfit, the British actor and theater manager, was asked what it was like to die. He quipped, “Dying is easy... comedy is hard!”

Transforming a course for a few years with a piece an innovation developed by its instructor is (relatively) easy. Making a lasting improvement in the outcomes of a degree program, at a university or nationally, is hard. That’s true whether or not modern technologies are in play. Woodrow Wilson, then president of Princeton University, once remarked that it is easier to move a graveyard than revise the curriculum. Yet changing the ways that students learn, and faculty members teach, is essential for two different reasons:

1. These changes can influence whether larger numbers of students succeed in college, as well as how much those students learn.
2. It’s nearly impossible to make definitive, generalizable findings about the value of technology in changing those outcomes unless new technology-enabled teaching/learning practices are in widespread and relatively stable use.

Why has large-scale adoption of changes in university practices and outcomes been so difficult for innovators to promote, even when the innovation has been shown to be valuable?

Many different factors combine to make widespread adoption so challenging:

1. **The ‘market’ for higher education responds weakly, if at all, to changes in educational effectiveness.** The market for higher education does not function the way that, say, the market for computers does. In higher education the ‘customers’ (the students) supply only some of the funds (the bulk of it comes from governments, donors

and others). Nor do the customers receive all the benefits of the service that has been purchased for them; society is also a beneficiary. In any case, students and the people who buy education for them don't have very good information about the nature of the product they're buying and won't know until much later, if ever, whether their purchase has produced the advertised results: it is very difficult to measure educational outcomes or to associate those outcomes with particular elements of how a university is run. On the other hand, the marketplace is more responsive to issues with implications for course content; when the demand for computer scientists began to grow, institutions responded quickly to adapt or add programs that might attract the students who were responding to that shift in the job market. When students and parents made it clear that they expected dormitory rooms to be wired, universities often spent vast sums to meet that expectation. But reforms that promise changes in educational outcomes ('You'll be a 10% better writer if you come here!') rarely provoke that kind of market response.

2. **Academic freedom is just one of several good reasons why busy faculty often ignore ideas and pressures from others to change their practices.** The faculty members we know tend to be extremely creative, committed, and busy people, pulled in many different directions by the demands of their professions: research, teaching, consulting, and service. What they read and hear is geared to those factors that can make a difference in their lives: progress in their research fields and the prospects for grants, for example. Their crowded lives make them something like jugglers, with as many objects in the air as they can manage. Along comes an innovator offering a great new object to juggle. Can they manage one more thing? Can they safely drop one object and start juggling another, without dropping anything else they're juggling? Safer to ignore the innovator!
3. **External forces and internal dynamics both tend to create a short institutional attention span for educational reform.** Again, there are many reasons for ways in which a succession of issues so quickly grab university attention and then fade, to be replaced by other issues. In the absence of other factors, committed faculty can get energy and power from doing something novel. As Robert Knapp, one of our faculty colleagues at an innovative educational institution, once observed, 'we educators live on the Hawthorne Effect.'⁵
4. **It can easily take 8-12 years or more to create a visible, rewarded change in the outcomes of a degree program or a university education.** Even the comparatively simple change of adding education for a new career path (e.g., a computer science track oriented to data security concerns) can take years between the time it's first conceived and the time that the university can begin boasting about the successes of its graduates in this field. Producing, say, a tangible improvement in the ability of graduates to understand and apply scientific principles, or to be creative designers, can easily take much longer. It's hard to get enough faculty engaged (unless their program is under threat), hard to get the time and resources to change courses, time-consuming to figure out ways to measure changes in outcomes of the program, and time-consuming to develop an effective message about that outcome that reaches potential students, benefactors, and others. It's not impossible. Alverno College has achieved a worldwide reputation for its prowess in assessment. The University of Iowa is widely known for the value of its program for writers. Everyone can probably come up with a few examples

⁵ The "Hawthorne Effect" was observed in a study of productivity that found that any change in conditions could produce a temporary increase in worker productivity. For more on the Hawthorne Effect, the Pygmalion and other effects of novelty and expectancy, see for example Draper (2002).

where a programs' market recognizes its educational value, and perhaps changes in that value that have developed over a period of years. But, as we've already seen, that's a long time for a university or one of its departments to keep working on the same issue.

In short, innovators who come bearing gifts that can potentially improve the outcomes of educational programs encounter faculty members who have every reason to ignore them. And if an attempt is made to implement the innovation, there are continual distractions, disruptions, and competing demands for resources. Yet it takes many years actually to implement such reforms. Because university programs can rarely focus long enough to succeed at reforms and reap any rewards that might have come with such prolonged attention, they have no institutional memory that a prolonged campaign to change the curriculum and improve educational outcomes might actually pay off in improved support from their markets.

For these reasons, this investigation has focused mainly on what could be learned from the iCampus experience about how to foster widespread adoption of its ideas and materials. As a field, we already know something about how to use technology to make successful educational experiments. But we are desperately in need of insights into how to foster effectively the spread and lasting use of those same ideas and materials.

Methodology

iCampus is relatively small and its projects are extremely varied, with equally varied goals. Many were more proof-of-concept tests than efforts to promote wider-spread changes in practice directly, for example.

We decided early in our discussions with MIT to rely mainly on extensive interviews and reviews of project documents. Machine-collected data was spotty and rarely of direct relevance to our work; for example, people who used iCampus software online or downloaded it were not required to create a user account so there was no way of knowing who had looked at what. Although we held out hope for some time that a survey or two might be devised that could somehow complement the findings of the interviews, in the end we decided that further interviews were a better use of scarce resources. The list of interviews and some of the documents we studied are listed in the Attachments to this report.

In commissioning The TLT Group to do this study, the iCampus team selected five projects for us to study, each of which a number of adopters and other faculty or institutions had considered for adoption but had not yet gone forward. The preceding sentence implies that it is easy to look at another faculty member or institution and say unambiguously whether the innovation had been adopted. That is not at all true. All of these innovations had more than one way in which they could be adopted (e.g., adopting ideas but not software; using services directly from MIT but not installing the software on local servers; different ways of using the software or the service). In fact, it was rare to look at a single potential adopter and to be able to say, unambiguously, that the innovation had been adopted in a way likely to last for years.

With this variety and ambiguity of evidence in mind, we decided to focus on a close study of instances of attempted adoption, inside MIT and outside. Our goal was for the projects individually and then for the projects as a group to see what was important in influencing the chances of adoption. Were any of these factors surprising to the principal investigators in this study? [Together we have over five decades of experience in working with innovative uses of educational technology in colleges and universities around the world, including almost two decades as a funder of innovative projects whose aim was widespread adoption.⁶]

⁶ See "About the Authors," in Attachment 4.

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Chapter 2: A Brief History of the iCampus Program and Descriptions of the Projects Highlighted in this Report

Foundations

MIT has made many contributions to computing, from early mechanical computers in the early 20th century, to ‘core memory’, to time sharing computing in the 1960s, and, more recently, X Windows and DSpace. MIT also has a long history of using computing in education. For example by the early 1960s engineering students were already programming digital computers as tools for design and analysis.

Project Athena (1983-1991) – “Can Computers Really Help Undergraduates Learn Faster and More Effectively?”

In 1983, Dean of Engineering Gerald Wilson led the effort that launched Project Athena, successfully obtaining the financial and technical collaboration of IBM and the Digital Equipment Corporation for what came to be called Project Athena. The first Athena press release began, “Can computers really help undergraduates learn faster and more effectively? Educators at the Massachusetts Institute of Technology think so, and to find out how, MIT has launched a major experimental program to integrate the next generation of computers and interactive graphics into undergraduate education throughout all five of its schools.”⁷

Athena’s announced goal was “to explore diverse uses of computing and to build the base of knowledge needed for a long term strategic decision about how computers fit into the MIT curriculum.” It is estimated the Athena cost around \$100 million; a significant part of this was supplied by Digital Equipment Corporation and IBM in external funds, equipment, services, staff and other resources. (Champine, 1991)

This translated into two agendas, a relatively focused technical agenda and a more exploratory, divergent educational agenda.

The technical agenda, as described in 1983, was to “create a new educational computing environment at MIT built around high performance graphics workstations, high speed networking, and servers of various types.” At the time Athena was planned, MIT’s educational computing budget was only about 3% of the total IT budget. In that era, most research was done on main frame and mini-computers. (Personal computers such as Apple IIs and IBM PCs were not generally regarded as adequate for MIT’s educational needs). Athena’s vision was based around the idea of networked workstations with graphical user interfaces (the kind common today, but quite unusual in 1983) and running a computer operating system called UNIX⁸. To develop and deploy such a system posed significant challenges: technical, financial, political. Athena fulfilled its goals. The new software for a network of secure workstations worked, computer clusters were built, the network became operational, and by 1997 (six years after the end of the project), almost all students had Athena accounts. Almost half those students used

⁷ Quoted in Champine, 1991: p. 259

⁸ Today’s personal computers most often run Microsoft Windows, the Apple Macintosh operating system, or Linux (an open source cousin of Unix)

Athena on a daily basis. Although the Athena file sharing system did not become a widely used product outside MIT, the architecture was influential and the Kerberos protocol for authentication, developed by Athena, is still widely used. To borrow a term from politics and war, the Athena ‘campaign’ was victorious.

Educationally, Athena pursued a more exploratory ‘let a thousand flowers bloom’ strategy. Despite the question asked by the original Athena press release (“Can computers really help undergraduates learn faster and more effectively?”), Athena was not designed as an educational research project. Nor would such a research project have been compatible with the technical agenda. On the technical side, Athena was trying to create a new kind of educational facility. But educational outcomes are not ‘caused’ by facilities alone. Students learn because of the ways in which they study, and because of how they are taught. Those activities are not dictated by facilities: not by classroom design, not by Athena networks. To even come close to answering the question in its press release, Athena would have had to identify and support some kind of pattern of teaching and learning, made possible by Athena, embraced by large numbers of faculty and students, and potentially able to speed learning. THEN a project could have been designed to promote and evaluate that widespread change in teaching and learning. Such an implementation/research campaign was so far from possible, and so removed from the technical Athena agenda, that there is no record that it was even considered.

Instead Athena solicited proposals from faculty. Over the years, Athena funded about 125 projects, mostly faculty-led curricular uses of computing, such as tools for writing, intelligent tutors, and simulations. It’s estimated that only 1/3 of these projects were ever sufficiently completed to be used in a classroom, however. The money was spread widely so it is not surprising that faculty grantees complained about being under-funded. Some also complained about a lack of common tools that they could use for project development. Most completed Athena-funded projects seem to have had their impact within individual courses. Discussions about a post-Athena Program to develop a more coherent set of curricular improvements produced a number of reports, but little action.⁹ Nor, so far as we are aware, did anyone attempt to investigate whether any educationally significant changes had occurred across an MIT degree program in how or what faculty taught, or in how their students studied, changes somehow made possible by Athena’s tools, changes significant enough to influence what the graduates of that program could do later in their lives. So the question posed by that initial Athena press release remained unanswered.

The iCampus Grant

By the late 1990s, excitement about the Internet and the World Wide Web was boiling the technical and economic pot. Some observers called into question the continued existence of campus-based universities. Incoming Chairman of the MIT Corporation (MIT’s board of trustees) Alexander d’Arbeloff persuaded the Institute that, instead of giving money for a building, he should be allowed to make a multi-million dollar gift to fund educational innovations. The d’Arbeloff Fund would make some grants that complemented those of iCampus.

During this same period, MIT was campaigning for major corporate-funded projects; the template was for a \$25 million, 5 year grant for R&D. With this in mind, MIT President Charles Vest arranged a brief meeting with Bill Gates of Microsoft.

In a limo together on the way to an airport, Gates agreed that Microsoft would make such a grant to MIT, the topic to be determined later. Gates asked Rick Rashid, Head of Microsoft Research,

⁹ Cheung, Chow, Li, Koontz and Self (2001).

to take the lead in the subsequent discussions about what the project would be, while Vest asked Dean of Engineering Thomas Magnanti to play a similar role for MIT. Magnanti soon was joined by Prof. Harold (Hal) Abelson.

Hal Abelson is a computer scientist with a history of interest in educational applications, going back to his work with Prof. Seymour Papert on Logo, a computer programming language that was used in schools to support innovative approaches to learning mathematics and other subjects. In the 1990s, Abelson was a leader in Institute discussions about uses of computing to improve education.

After surviving the best efforts of attorneys to point out the risks of such a collaboration, the MIT-Microsoft agreement was hammered out. The agreement said that a “research relationship will be established directed primarily toward achieving the following goals: (i) create technologies and content to improve student learning; (ii) create and deploy technologies to assist faculty in teaching and in deploying courses and learning modules; and (iii) create enterprise level tools to improve university administration.” (This third goal was later dropped by mutual agreement.) Abelson became the de facto leader of iCampus and would play a continuing and highly personal role in soliciting and working with projects.

Goals and Strategies: iCampus is an R&D program with ambitious and broad goals. The original press release asserted that the Microsoft-MIT Alliance would “involve research and development in three broad areas in which information technology has a major impact on university education:

1. “New pedagogical approaches and structures. Possibilities include remote access to laboratory instruments, new software tools for delivering education content, and new tools to aid student learning such as tutoring and mentoring at a distance, and web-based virtual museums.
2. “Integrating information technology concepts and methods throughout university education. Examples include large-scale collaborative engineering design, the study of complex systems, and the creation of information-based curricula across traditional disciplinary boundaries.
3. Addressing the changing environment of university education, such as providing education at a distance and life-long learning to a larger community, and the impact of digital information technologies on academic publishing.”

The press release also asserted that, to “support the goal of broad impact in technology-enhanced education, both MIT and Microsoft plan to engage additional academic and industry partners and produce materials that adhere to open standards, with results and source code that can be widely published and disseminated.” MIT President Charles Vest said that, “Education-focused research supported by Microsoft will lead to new learning environments for our students and will make us an even better university. Still more important, the MIT-Microsoft alliance will help create knowledge and information-based services that can improve higher education worldwide” (MIT News Office, 1999)¹⁰

With these goals and with a bankroll of \$25 million, iCampus saw itself in some ways as a funder like a foundation or a government program, with goals for international influence through its research and development. Yet in other ways, iCampus saw itself as an internal program for MIT, supporting MIT faculty and students (and some Microsoft staff) with a review process that

¹⁰ This ambition has continued as an important iCampus theme. As the program nears its end, its web site says that the Alliance’s “goal is to create and demonstrate technologies with the potential for revolutionary change throughout the university curriculum.”

included only MIT and Microsoft staff. Proposals were not subjected to external peer review. Nor were the proposals expected to meet the same standards of building on previous disciplinary achievements as the proposals submitted by those same faculty for their disciplinary research. In this way, iCampus was administered like the discretionary funding provided by many institutions for their faculty in order to improve their courses; it was just much bigger. Like them it had minimal central staff and like them it relied to a great extent on faculty to develop their own ideas, with little pressure to build on the work of others at other institutions.

MIT and Microsoft: In the first year of the agreement, there was a surprising tension between MIT and Microsoft, according to Dave Mitchell, who had been asked by Microsoft to be their leader on site. MIT's iCampus leaders and faculty wanted more engagement from Microsoft, Mitchell recalled, while staff at Microsoft Research didn't see that as part of their jobs. MIT wanted to share (but also tended to use their tools, often open source) while Microsoft staff were concerned about violating their own Non-Disclosure Agreements, and wondered why MIT projects were not sticking exclusively to Microsoft tools. The leaders of iCampus on both sides worked to bridge the gaps so that the research alliance envisioned by the agreement could actually work.

The six-member Joint Steering Committee (three members from MIT, three from Microsoft) also soon saw the need to elicit proposals from MIT faculty and students, proposals that would be educationally innovative and valuable from both MIT and Microsoft's perspectives. It was also important to find leaders who would actually complete their projects. (In this there may have been some institutional memory of the high rate of incomplete Athena projects a decade earlier.)

The iCampus projects have been far larger than the Athena projects. By early 2006, when over \$24 million of the original \$25 million had been allocated, iCampus had awarded about \$21.1 million¹¹ for faculty projects and about 1.65 million dollars to 30 student projects; student projects were allocated an average of about \$55,000 each.

It's a bit harder to count the faculty projects, since one large group clustered in what iCampus saw as one gigantic project – iLabs – which received about \$5.8 million over the years. The remaining 26 faculty projects totaled about half a million dollars per project, and the typical project was funded for 1-3 years, sometimes longer.

A recent profile of iCampus divided its projects into three categories: active learning and classroom transformation; learning services; and emerging technologies. Within those broad categories, iCampus funded a wide variety of projects, some quite exploratory, some operational; some new starts and some contributions to ongoing efforts. Over the seven years of its work, iCampus probed in many different directions.

Active learning and classroom transformation: Three of the faculty led projects in this category will be discussed in detail in this report: Technology Enhanced Active Learning in physics (TEAL), online presentations and homework for computer science (xTutor), and software to allow faculty and students to 'quote' from video in their projects, papers and discussions (Cross Media Annotation System – XMAS). In addition to those three, iCampus classified eleven more of its faculty-led projects and three of its student-led projects in this category. A few examples of these projects:

¹¹ All figures were supplied by the iCampus office. MIT deducted its negotiated overhead rate of about 63% of direct costs from these projects. So a faculty request for \$100,000 of direct costs would have an overhead of about \$63,000 tacked on, for a total grant from iCampus of \$163,000. All the figures in this paragraph include this MIT overhead.

- Conceive Design Implement Operation (CDIO). About the same time that iCampus was beginning, MIT's Department of Aeronautical and Astronautical Engineering began a thorough rethinking of its undergraduate program and facilities. The goal: to educate engineers who could do more than just analyze. The strategy involved extensive curricular change, as well as extensive physical renovations, in order to educate students in the full range of activities of creative, effective engineers. The resulting initiative, called CDIO, now involves twenty other institutions as well.¹² iCampus contributed to this ongoing effort, with, for example, support for using personal response systems (PRS).
- Classroom Learning Partner: Personal response systems, such as those used in CDIO and TEAL, usually involve small consoles: students can respond to multiple choice questions by clicking on a key, and the results from all students are quickly displayed as a histogram for the faculty and the course. PRSs are an exciting and promising area of innovation, and several iCampus projects explored this idea, including one student-led project that used mobile phones as PRS devices. Classroom Learning Partner focused on a different kind of student response. In fields like computer science, in small classes at least, all students can go the board to write or draw their solutions to a problem. Then everyone can see if all students are thinking in the same way, or if there are different approaches to the problem. But what about large enrollment classes? Kimberly Koile and Howard Schrum wanted to know if tablet PCs could be used. If students all wrote their own answers on a tablet, could the right kind of software rapidly scan all their solutions, automatically put them into a few categories, and then display those categories of response to the faculty and the class? Initial tests of the idea with small classes (less than 20 students) produced encouraging results. The software worked, and assessment showed gains in learning, especially for students who might otherwise have done poorly in the course.¹³
- Games to Teach: This project worked on 10 different educational game concepts for teaching science and engineering concepts in college and high school. Unique among iCampus projects, this effort had co-PIs from MIT (Henry Jenkins) and from Microsoft Research (Randy Hinrichs, Microsoft's on-site representative for iCampus at that time.)¹⁴
- Next Generation Mobile Classroom Design: This student-led experiment developed a system so that students in a lecture could communicate anonymously with one another, and with a TA, using PDAs. For example, instead of sitting politely (but silently) when confused, the student could use the PDA to ask the question. PDAs could also be used to explore materials being used in the class, such as PowerPoint slides.¹⁵

Learning Services. This second category of iCampus projects is rather similar to the first. Twenty-one projects were supported in this area (8 faculty, 13 student). Two of these are featured in this report: laboratory experiments that a student could design and run from a web connection (iLabs – the biggest of iCampus' efforts by far) and iMOAT, a web-based approach to managing

¹² CDIO consortium: see <http://www.cdio.org>

¹³ Classroom Learning Partners: see <http://icampus.mit.edu/projects/clp.shtml>

¹⁴ Games to Teach: see <http://icampus.mit.edu/projects/GamesToTeach.shtml>

¹⁵ Next Generation Mobile Classroom: see <http://icampus.mit.edu/projects/NextGenMobileClassroom.shtml>

the large-scale assessment of student writing. Here are a few of the other projects that iCampus categorized in this area:

- OpenCourseWare and DSpace: OpenCourseWare (OCW)¹⁶ has huge amounts of external funding to put MIT course materials online where they can be freely used by educators and other learners around the world. iCampus provided funds so that OCW materials could be automatically archived, organized and made available through DSpace, MIT's open source software package for the management of digital archives.¹⁷ DSpace is becoming a standard, so, by relying on DSpace, OCW materials can be used in a wider variety of ways.¹⁸
- iLearn (later .lrn) is an open source learning management system originally developed by MIT's Sloan School of Management. It is now supported by a consortium of institutions. Its web site¹⁹ says that it has half a million users and is the most widely used open source, enterprise-level learning management system in the world.
- ShuttleTrack – this student-led project developed a web service that members of MIT can use to see where the various campus shuttle vans were, with projected arrival times at various stops. As a web service, its output can be read on mobile devices, PCs, and public displays.²⁰

Emerging Technologies: This final category of iCampus projects includes eleven projects, four led by faculty and seven by students. Perhaps because these projects are considered the most exploratory and because the primary goal of The TLT Group's study is factors affecting adoption, none of these projects was chosen for analysis in this report. Here are a few representative projects.

- Natural Interaction has experimented with new forms of human computer interface for educational purposes. Its best known product, known as "Magic Paper," enables the user to sketch a physical system on a tablet PC (e.g., for example a ball dangling from a spring and swinging back and forth as it bounces against a wall), draw an arrow to describe the direction of gravity, and then 'turn it on,' to watch the ball bounce and swing.²¹
- Web-based wireless sensors for education (iDAT). To free students to go into the field and do research, it could help enormously if sensors were small, wireless and extremely inexpensive. Then it would be much easier for a class of students to fan out, gather data in the field about temperature, pressure, salinity, light or hundreds of other variables, collect their data, and analyze the data for their work. The goal is for iDAT sensors to be used for purposes as varied as ecological studies or measuring the acceleration of a

¹⁶ OCW is now supported by, and supports, a multi-institution consortium for making course materials freely available online: see <http://ocwconsortium.org/>

¹⁷ For more information on DSpace, see <http://www.dspace.org/> .

¹⁸ iCampus project on OCW use of DSpace: see <http://icampus.mit.edu/projects/dspace.shtml>

¹⁹ iLearn: see <http://dotlrn.org/>

²⁰ This student grant was completed and is one of several examples of iCampus projects that are still in operation at MIT. See <http://shuttletrack.mit.edu/> .

²¹ Magic paper, see <http://icampus.mit.edu/MagicPaper/>

pianist's fingers as she plays her instrument. iDAT is a cousin of the iLab projects discussed in this report.²²

- International Genetically Engineered Machines (IGEMS) Competitions. Today scientists can create simple systems that can operate within living cells. The goal of IGEMS is to run competitions among student teams from universities, each developing standardized components such as biofilms. The most recent competition (Nov. 2006)²³ attracted 450 faculty and students, competing as teams from 37 institutions around the world.
- Spoken Lecture Processing: Transcription, Tagging, and Retrieval. This experiment is developing procedures for making recordings of spoken lectures more readily usable online. Using speech recognition, the software analyzes a lecture and tags its significant sections in order to allow users to search audio recordings by content.²⁴

Here are the funds allocated by iCampus for the projects on which this study focused; these totals in some cases include targeted funding for outreach:

iCampus Budgets for Selected Projects²⁵

iLabs (labs, shared architecture)	\$5,778,265
TEAL	\$928,000 ²⁶
xTutor	\$682,535
XMAS	\$472,840
iMOAT	\$378,886

Structures for Support

Over the course of the iCampus program, Microsoft Research worked increasingly closely with iCampus and its projects. After an early laissez fair period, Microsoft put Dave Mitchell to work on the MIT campus and other staff followed, with still others allocated in Redmond to work with iCampus. Their aim was to help Hal Abelson and the MIT leadership to cultivate good projects and work with them, ideally helping them to use Microsoft tools in the process of developing educationally significant projects.

²² iDAT, see <http://icampus.mit.edu/projects/iDAT.shtml>.

²³ IGEM: <http://www.igem2006.com/>

²⁴ Spoken Lecture: see <http://icampus.mit.edu/projects/SpokenLecture.shtml> for information on the project and <http://web.sls.csail.mit.edu/lectures/> to see the demonstration systems.

²⁵ These totals represent the sum of iCampus grants awarded to each project area. Several of these projects, notably TEAL, also received substantial funding from other sources inside and/or outside MIT. In all five of these cases, projects received multiple grants over the life of iCampus. The dollars represent grant awards, not necessarily dollars spent.

²⁶ iCampus was a 'minority investor' in TEAL. MIT's d'Arbeloff Fund provided substantial startup funds around the same time that iCampus did, and the Institute invested around \$2 million more in renovating and equipping classrooms for TEAL use.

Abelson wanted to run iCampus with minimal ‘overhead’ so that as much of the money as possible could go to projects. There was no centralized staff of iCampus programmers, for example; no staff office devoted to dissemination or evaluation. Instead when a need was seen, Abelson and his assistants would do the work or outsource it. This didn’t always produce satisfactory results, from the iCampus point of view. For example, iCampus allocated funds for MIT’s Teaching and Learning Laboratory to do studies of iCampus projects. Some studies were done, but other funds were eventually returned unused because the Laboratory did not think it wise to hire additional staff to do the studies.

The projects were for the most part regarded as the territory of their faculty principal investigators, with the Joint Steering Committee occasionally receiving reports on progress. Abelson also took a personal interest in a number of the projects. Efforts were made to organize symposia and other gatherings of iCampus project directors, with mixed success. In some cases however, the iCampus leadership took an intense interest in project progress. iLabs is perhaps the biggest example of proactive leadership by iCampus, as will be discussed in more detail in that chapter of this report.

As often occurs with funding programs, the leadership’s biggest influence on the work came through the process of soliciting and funding projects. Because iCampus had been defined as a collection of projects to be led by MIT faculty and students, there was inevitably a great variety of topics. But the leadership was on the lookout for projects that would in one way or another:

- Foster active learning;
- Make use of web services;
- Collectively span many departments; and
- Make ambitious steps forward educationally.

As the early years of the 21st century passed, Microsoft’s representatives on the Joint Steering Committee began arguing more strongly for benefits that could be seen beyond the boundaries of MIT, a goal that was more implicit than explicit in the original agreement. That led to, among other things, the establishment of an Outreach Program that would attempt to promote wider use of the most successful iCampus projects both inside and outside MIT, and, later, to this study.

Brief Profiles of the Projects Under Study

iLabs

An iLab is a piece of laboratory equipment that can be controlled over the Web. Students need not be in the same room with the equipment in order to design the experiment, gather or analyze the data. In a traditional science or engineering laboratory course, all the students usually come to the same room for a scheduled period (often two hours) where they find a large number of identical laboratory setups: one for each student or each small group of students. The experiments they do must be completed in that two hour period. The equipment then is idle. In contrast, with experiments that can be configured as iLabs, students can design and carry out experiments at any time, and from any place. One piece of equipment can be used by the whole class, one after another. Where iLabs are feasible (and especially when they can run 24 hours a day, 7 days a week), they have considerable advantages:

- Students have more opportunities to do a series of experiments in order to carry out an unfolding inquiry, using the results of each experiment to design the next trial
- One piece of equipment can serve a much larger number of students

- Undergraduates can be assigned experiments requiring equipment that would have been out of the price range of labs that had to buy 20 of each piece of equipment in order to incorporate an experiment.
- Institutions could share laboratory equipment, so that each faculty member could have access to a diverse set of laboratory opportunities

In phase I of iCampus funding, faculty in several different MIT departments worked with student programmers to develop iLabs. It soon became apparent that these laboratories would be difficult for faculty to share with colleagues elsewhere, and expensive to maintain once grant funding ended. So a new project began, to develop a Shared Architecture that would centralize many of the administrative functions.

How far has adoption of iLabs proceeded? It depends on how the question is defined. MIT at this writing has not yet committed to continued maintenance of the Shared Architecture, without which iLabs would soon devolve to use only by faculty members who have the graduate students and equipment to maintain the labs themselves. Some iLabs designed before the Shared Architecture project are still in use, and some have already faded away. The Shared Architecture Project can now support ‘batch’ laboratories but we know of only two such laboratories actually in instructional use, one at MIT and one at the University of Queensland. But iLabs have attracted more public attention than any other iCampus project and discussions about large-scale use in countries like India are going on.

iMOAT

The iCampus MIT Online Assessment Tool (iMOAT) is an online tool for managing the assessment of the writing of large numbers of students. It was developed for, and is used by, a consortium of institutions led by MIT. Its primary use is assessing the writing of newly admitted students to help the university decide on course placement. The student can download a typical academic assignment (e.g., readings and an assignment to write something in response to those readings) and then several days later upload the resulting assignment. iMOAT then helps assign those essays to groups of human readers, and also helps manage the resulting data.

iMOAT is a substantial step forward in making the assessment of writing more ‘authentic.’ The kind of writing often done for placement is not much like the writing students do in first year courses. By giving students more time to read and write, as well as the ability to use a word processor instead of a pen, and to write in a more comfortable setting, iMOAT can help a university produce more valid assessments of student writing.

iMOAT is currently in use in about seven institutions, who pay for their participation in a self-supporting consortium.

TEAL

Technology Enhanced Active Learning (TEAL) is MIT’s version of an approach to teaching first year physics that is often called ‘studio physics’ or ‘SCALE-UP’ (the name of the model most directly adopted by MIT from North Carolina State University). Like other studio physics programs, TEAL deemphasizes lectures in favor of spending most class time on group work on conceptual questions, laboratory experiments, and simulations. TEAL differs from other studio courses in its emphasis on the use of simulations and in the well-equipped classrooms that make it easier for small student working groups to use computers and laboratory equipment together.

TEAL was developed in response to low attendance in introductory physics courses and research that showed that, nationally, students were not mastering fundamental concepts in physics, even at highly selective institutions. Evaluations of early uses of TEAL in electricity and magnetism

showed dramatic gains in conceptual understanding, advantages in student understanding still apparent years after TEAL ended, which is quite extraordinary. Thus far, the evaluations of first term physics (mechanics) have been less convincing. Attendance is much higher in TEAL courses than was the case in traditional MIT physics. But some students resent TEAL precisely because classroom participation is heavily weighted in grading.

It appears that TEAL's influence outside MIT has been significant but mostly indirect. The director of SCALE-UP reported a dramatic increase in adoptions after press reports of MIT's adoption. Fewer than five institutions have directly adopted elements of the TEAL approach, so far as we have been able to discover. The expensive, dramatic design of the TEAL classrooms has drawn large numbers of visitors to MIT, but the price tag of the TEAL approach, the rigor of its materials, and the desire of selective institutions to be seen as unique all seem likely to restrict wholesale adoption of the TEAL model by other institutions.

XMAS

The Cross Media Annotation System (XMAS) was originally known as the Shakespeare Video Annotation System. Like many of the other most successful iCampus projects, this line of work did not begin with the initial iCampus grant. Professor Peter (Pete) Donaldson had worked earlier in the 1990s to develop a much-publicized system to allow students to view and create video clips from movies of Shakespeare plays, clips that did not violate copyright. But the system was so expensive that Donaldson and a colleague at Stanford were the only users. The iCampus grant helped Donaldson get a new start and then, when that didn't work, another new start. The result is XMAS, a tool that faculty and students can use to include video clips in presentations, projects, and online discussions, without violating copyright.

Donaldson's proposal attracted iCampus attention in part because of the potential for students in different universities discussing plays through video clips. However, XMAS is now used almost exclusively in standalone courses. An initial evaluation at Vanderbilt showed impressive results. More importantly, the software has begun to spread into film courses. And it seems to be useful in almost any setting where users want to comment on clips from DVDs (e.g., someone's performance is recorded on digital video and then the performer or a coach reviews the video and then writes a critique of the performance illustrated with selected clips).

XMAS has had great success in promoting adoptions. There are several reasons for this that are explored in the case study. The most important is that Donaldson's research and teaching are closely tied together. That, combined with his prior successes in this line of work in the 1990s, made it natural for him to contact colleagues across the world (many of whom had attended earlier workshops by Donaldson) and suggest that they might want to try his new software for free.

xTutor

xTutor is software that in some ways resembles a course management system. It was designed as a response to two inter-related problems: a) how to free more class time for discussion by moving at least some lecture materials online, b) how to make homework more productive for students and less burdensome for faculty and TAs to grade, so that they could spend more time on less mechanical parts of teaching. The developers were particularly troubled by the fact that students could do homework assignments only partially correctly all term, giving up where they hit roadblocks, still getting partial credit and still passing the course. They wanted homework assignments and grading that would be more directly educational.

xTutor provides a platform for storing annotated lectures and course materials. It has attracted some users who like the content of the stored lectures. Where xTutor differs most substantially

from course management platforms like WebCT or MIT's Stellar is in its tools for creating and grading homework in computer science. Students can be given relatively authentic programming assignments. xTutor then runs the student's program and automatically assesses it; if the program doesn't run correctly the first time, the program provides hints.

It is difficult to be sure how widely xTutor course materials are in use because no registration is required. We did study one instance of use, at the University of Queensland, where faculty are quite happy with the Scheme course developed with xTutor. In the only instance we have found where someone at another institution attempted to use the xTutor platform to develop a different computer science course, the adopter abandoned the effort because that version of xTutor was too difficult to use. A new version, designed to be more user friendly, is just being released.

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Chapter 3: iLabs - Experiments in Education

“The idea came in 1998. I teach microelectronic devices...I was frustrated – all chalk and talk. As an engineer and experimentalist I was frustrated.” Jesus del Alamo

Introduction and Summary

An iLab enables a faculty member to incorporate laboratory work in lecture courses that have no laboratory space or budget. The student gains flexibility in when to do experiments, and how much time to devote to them. The more such labs become available online, the more choices faculty would have among laboratory equipment and experiments for their students. Although not all labs are suitable for use as iLabs, colleges with minimal laboratory facilities locally and distance learning programs might both find the need to rely heavily on iLabs, if more become available. For reasons such as these, international interest in iLabs seems strong, especially in Australia, China and India.

Despite this appeal, it's about been eight years since the work began at MIT on Professor Jesus del Alamo's first iLab. In the six plus years since its first grants, iCampus has allocated almost \$6 million for developing iLabs, for making them easier to use and share, and for disseminating them. It's been four years since iLabs Shared Architecture development began (intended to make it easier for faculty to share their iLabs with others). Although the resulting labs and software have been discussed in many venues, at this moment (late 2006), only a handful of MIT-type iLabs are in use under the Shared Architecture, shared by faculty at perhaps a dozen institutions, and serving perhaps 2000 students a year or fewer. The Interactive experiment feature of the Shared Architecture is, as it has been for many months, behind schedule but almost done.

Is the iLab glass half-full and filling? By 2011, will this innovation be spreading across the world? If so, will it spread directly (or at least indirectly) from seeds planted at MIT? If remote labs like this do spread, what will be their major patterns of use? While not finding conclusive answers to these questions, there are some hints about factors encouraging and inhibiting the spread of iLabs. Drawing on those bits of evidence and conjecture, we will make some suggestions at the close of this essay.

Genesis

“All Chalk and Talk!”

Jesus del Alamo is an experimentalist and physicist who, in 1998, was teaching courses on microelectronic devices to juniors and graduate students in MIT's Department of Electrical Engineering and Computer Science (EECS). He was frustrated with traditional 'chalk and talk' course formats that did not allow students to do hands-on experiments in his courses.

Then he had an idea, one that seemed “a bit crazy” even to him: to allow students to create and run a real experiment, not just a simulation, by using a Web browser to control the apparatus. When we asked del Alamo where the idea came from, he recalled that it was already becoming common for students to use lab instruments by programming a computer sitting next to the instrument, without ever touching the instrument itself. Software called LabVIEW, developed by National Instruments, is commonly used for this purpose. The Web was a hot topic in the late 1990s. So, if the student isn't touching the instrument anyway, why not control it over the Web?

In a traditional laboratory course serving, say, forty students, students might come for two hours and work in pairs on experiments. So 20 identical equipment setups might be needed. This

expensive equipment would be set up for students in advance (20 setups for each class session) and then would lie idle. And lab assignments could only be done during the class period allotted for work in the laboratory.

In contrast, an iLab would allow students to use a single piece of equipment, one after the other, 24 x 7. For lecture courses like del Alamo's, a remote lab would enable true experiments to become part of the course's homework. Del Alamo realized he could give his students access to expensive research equipment.

Del Alamo talked with two visiting Microsoft engineers who encouraged the idea; ultimately Microsoft gave him \$3,000 and a computer to start. In March 1998, he used the money to hire an undergraduate student through the Undergraduate Research Opportunities Program²⁷. This student, Lane Brooks, designed the architecture for web control of a Microelectronics Device Characterization Laboratory in just a few months, using expensive equipment from del Alamo's research to do the actual experiment and the donated computer to control the experiment.²⁸ For the iLabs effort this was the first time, but not the last, that an undergraduate would play a key role in developing an iLab.

Impressed and excited, del Alamo decided the new laboratory setup was reliable and solid enough to use that fall (1998) with "Integrated Microelectronic Devices" a graduate student class of over 30 graduate and undergraduate students from EECS and the Materials Science Department.²⁹

In spring 1999, del Alamo was using an improved version of this lab with an undergraduate class of about 90 students, Microelectronic Devices and Circuits (6.012³⁰). Although reactions were somewhat mixed and students had discovered new ways to break the lab, del Alamo was encouraged. He applied for funds from the MIT Alumni Fund for Educational Innovation program and received \$20,000 to continue his work in developing web labs. The success of his first lab also enabled him to apply successfully for a donation of \$76,000 of equipment from Hewlett Packard. This equipment donation allowed him to run his web labs on a different machine than was used for his research. The results of this foray encouraged him to delve more deeply into evolving the idea.

iCampus – initial grant and early cohort of separate labs

In 1999, soon after MIT received the iCampus grant, del Alamo and colleagues from several other departments submitted an ambitious preliminary proposal to develop an I-Lab³¹ suite of related "web labs," along with software that could be used for laboratory creation. The new software would also allow for the integration of laboratories, simulations, and interactive

²⁷ MIT has an extensive program to encourage faculty and others to engage undergraduates in professional work in exchange for money or academic credit. About 1/3 of all MIT's undergraduate have at least one such UROP (Undergraduate Research Opportunities Program) project.

²⁸ At the time, and for some years thereafter, del Alamo and others most often called this equipment the WebLab, and that name appears occasionally in quotes in this chapter. "WebLab" wasn't descriptive enough, however, so recently it was decided to call this particular lab the Microelectronics Device Characterization Laboratory. We will use that label throughout this narrative, for clarity.

²⁹ Materials from this and most other courses mentioned in this report can be found online in the MIT Open Courseware (OCW) collection. See <http://ocw.mit.edu/OcwWeb/index.htm>.

³⁰ Each MIT department has a number. EECS is Course VI, so all of its courses' identifying numbers begin with 6. MIT students usually refer to courses by number rather than by name.

³¹ The name was later changed to iLabs, to parallel iCampus.

tutorials; the two latter themes would fade and the projects would ultimately focus on using the web to control experiments.

By the time of his proposal, del Alamo saw additional advantages of such web-controlled laboratory equipment:

- One lab setup could sometimes suffice for large numbers of students. Labs could become a resource of abundance, not scarcity, almost like the impact of the Internet on ‘libraries.’ It was a fitting innovation for MIT which, in the nineteenth century, had pioneered making science laboratories available to undergraduates.
- This abundance could allow a much wider variety of experiments to be offered to students in each course, especially if several faculty could collaborate, so that the students of each could share the experiments of all;
- Institutions without the money for such experimentation could use free time on a faculty member’s equipment.

At some point, del Alamo and others also realized that, with an iLab, each student could choose to take more time to work on a longer chain of experiments, more time than a traditional lab period would allow. Use of iLabs for distance education was not mentioned.³²

Five of the proposed iLabs were funded with separate iCampus grants, each to a different faculty member, including del Alamo’s work in electrical engineering, a heat exchanger experiment in Chemical Engineering, a polymer crystallization experiment in Chemical Engineering, a “flagpole” sensor experiment and a “shake table” experiment in Civil Engineering. Because the developers of these early projects made their own decisions about design, their programs for doing common tasks (e.g., creating accounts for students, storing results of experiments) were each developed independently and in different ways. Time has not allowed us to explore all of these projects in equal depth so our narrative will focus mainly on del Alamo’s work.

The early experiments were of three types:

1. **Batch experiments** that students would design and then submit to the experiment. These experiments often took much longer to design than to run -- some would run in only a few seconds – so a single machine could serve a very large number of students in a 24x7 week. Batch experiments using an iLab can potentially serve thousands of students (depending on just how long it takes to run the experiment, how many of those students want to run an experiment at the same moment, and what the maximum time is that a student could wait for results – short waits enable students to do a series of experiments, with the results of one experiment influencing the design of the next.) It’s estimated by MIT that batch labs can expand the productivity of research equipment that might otherwise be lying around by a factor of 100 (two orders of magnitude).
2. **Interactive experiments** where the student has to adjust parameters as the experiment unfolds. Because each student, or student team, would need to occupy the machine for a

³² In contrast, a recent review of the role of the laboratory in undergraduate education, Feisel and Rosa (2005), discusses the use of the web to control laboratory experiments *only* in the context of distance learning and, because of the lack of face-to-face contact in many forms of distance education, describes such labs with a noticeable lack of enthusiasm. Feisel and Rosa appear to be unaware of the iLabs project. Prof. Zhu at Zhejiang University in China has, as we’ll see, developed 60 electrical engineering iLabs to support a major distance learning program.

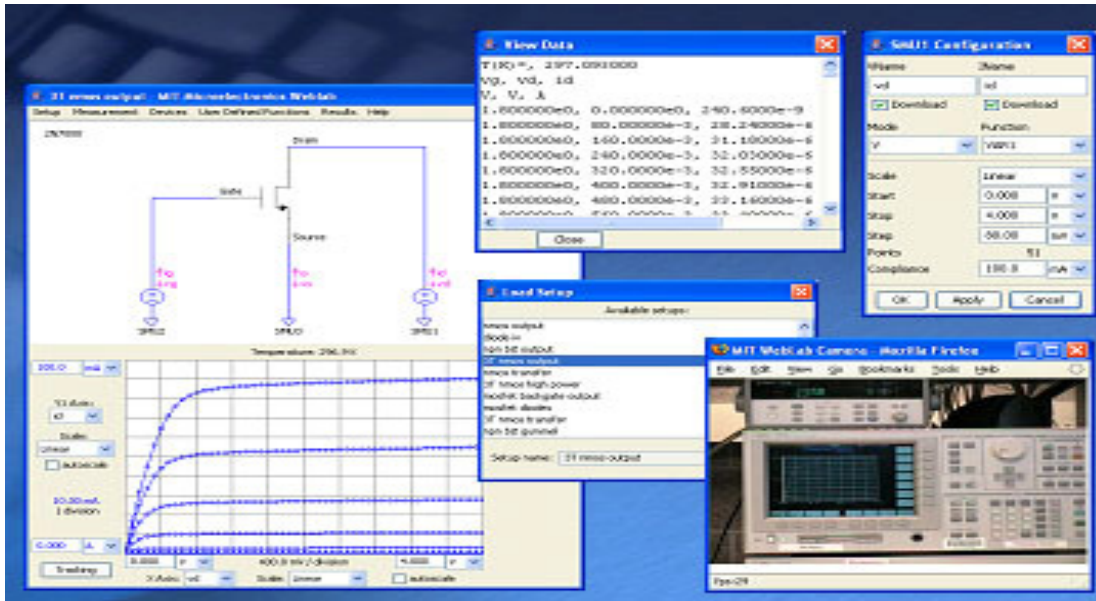
significant period of time, scheduling was needed, and there was only limited capacity to share an experimental set up with students at many institutions.

3. **Sensors** – The flagpole in front of MIT’s main building was instrumented in several ways to allow students to study stresses and resulting movements on the structure. This type of iLab is not about student-designed experiments, per se, but does enable students to study real world data.

Del Alamo and his students were not the first to develop a lab experiment that students could control over the Internet. The proposal cited two other instances of use of the Internet to control remote laboratory equipment for educational purposes, one at Carnegie Mellon and the other at the Beckmann Institute of the University of Chicago, Chicago Circle. The latter did, and does, offer K-12 students opportunities to control a scanning electron microscope. But there does not appear to have been much effort to create common tools or design solutions.

Initial Experiences with the Microelectronics Device Characterization Laboratory, including Evaluation Results

Much of the research on iLabs has focused on del Alamo’s first lab, the Microelectronics Device Characterization Laboratory. A picture of the interface is shown in Figure 1.



Results from initial uses of web-based labs in classes at MIT were encouraging. Professor Charles Sodini thinks he may have been the first faculty member teaching 6.012 to follow del Alamo’s example and try using the Microelectronics Device Characterization Laboratory. He had to overcome a reasonable reluctance first. “The real question on your mind is ‘What’s the support level? What if it breaks? If someone doesn’t have a chip in the lab, what if it doesn’t log in everybody?’ I didn’t want to be first. The support issues are important. It’s why I like to use commercial stuff rather than homebrew things that you don’t know precisely how they’ll work. The iLab is beyond that startup phase now and is well-supported within the Institute. So I said, after Jesus did it once, I said, ‘ok I’ll try it.’” Sodini was pleased with his initial use of the Lab and designed his own assignment using the equipment, for circuit design, to follow on an earlier assignment patterned after del Alamo’s.

The evaluation by Mitchell, Fischer, and del Alamo (2006) clearly charts the increasing use of the lab in the introductory circuits course (6.012) from Fall 2004 to Fall 2005, and shows how the

software and assignments continued to improve during this period. Complaints from students decreased during this period as the developers improved the software, and educational results improved during the same period. By Fall 2005, the Microelectronics Device Characterization Laboratory was being used in over half the homework assignments in the course (six of the eleven); a year earlier it had been used in only one assignment.

This evaluation report focused, quite properly, on how the students used the lab and the pros and cons of that experience from their point of view. The following excerpts from the report give some hints of that experience by Fall 2005, when many of the earlier bugs had been worked out and student feedback had become sharply more positive:

“Students reported that as they were collecting data, they reasoned mentally about the behavior of devices, and to a lesser degree visualized how devices work. They also thought about the relationships among variables, and applied concepts discussed in lecture or readings.

“Data analysis took longer, and required more thinking. Most students reported that the analysis was straightforward, often helped by clear instructions, but many described the data analysis as “tedious.” Students reported that when analyzing data, they also applied concepts discussed in lecture, visualized how devices worked, formulated concepts about the behavior of the devices, and used intuition to understand the devices. They also thought about relationships among variables, and how lab experiences related to material that they had previously learned.” (Mitchell, Fischer, and del Alamo (2006) , p. 15)

“WebLab provides students with an opportunity to develop skills of critical and creative thinking. One student said, “I definitely took stuff away from WebLab I couldn’t have taken away from just problems. In other problems in the assignment it seemed like you found the right formula to match the problem, plug in the numbers and got the solution. With WebLab you actually thought about the problem and how to set it up.” Another student commented, “Even when I was working on one of the problems not requiring WebLab, I could approach the problem in a more logical way, because I already had a picture of the sort of graph to expect.” (p.16)³³

“Faculty also were impressed with the savings in time and effort for students, and also for instructors. One instructor described WebLab as “80 percent of the experience for 20 percent of the effort.” Another observed that WebLab “takes the hassle out of a lab.” Several commented on time wasted in [traditional] labs because of faulty or broken equipment. With WebLab, students had more time to think about concepts, and faculty had more time to think about teaching and learning concepts.” (p. 25)

One way in which iLabs developers have tried to create powerful learning experiences is by designing interfaces that make it easier for students to understand and analyze their data, easier than it would have been using displays on traditional equipment in a laboratory. This appeared to be helpful in 6.012:

“The graphs generated by the program were thought to be particularly helpful as aids to analysis. Nearly everyone liked the WebLab graphing feature, calling it “absolutely necessary,” “the best part,” and “very valuable.” Several students commented that “a picture is worth a thousand words,” with one person adding, “And that’s very true, even in things that are so mathematical.” Others thought the graphs were a good way to check

³³ That last sentence is an interesting example of a student reporting that she or he had transferred what had been learned from the lab to another kind of problem. That sort of thing is valuable, less common than one might think, and worth further investigation.

whether they were on the right track or not, or to see if their data was in the right range.”
(p. 16)

The judgments of students about how the use of the lab had affected their learning was reasonably positive, as reflected by this table of statements with which students were asked to agree or disagree. An average of 7.0 would mean that students were unanimous in agreeing as strongly as possible, an average of 4.0 would mean that, on average, students were neutral, neither agreeing or disagreeing with the statement, and 1.0 would indicate the maximum disagreement.

	Spring 2005			Fall 2005			%Change
	Mean	SD	n	Mean	SD	n	
Understanding							
Behavior of the devices	4.30	1.73	37	5.42	1.17	33	+26.05
How to characterize a device				5.45	1.15	33	
Differences between theory & application	4.22	1.49	37	5.55	1.03	33	+31.10
Developing intuitive (?) on how devices work [sic] ³⁴	3.81	1.66	37	5.00	1.20	33	+31.23
Related lectures and assigned readings	3.62	1.52	37	4.82	0.88	33	+33.15

So, for example, student agreement that using the lab helped them understand the behavior of devices increased from spring 2005 (about 4.3, a little over neutral) to Fall 2005 (about 5.4 – a more solid agreement with the statement). Another example: regarding development of intuition about how devices operate, students had disagreed (on average) that the lab had been helpful in spring 2005, but by fall 2005, after the lab had been improved, the new class of students agreed solidly that the use of the lab was helpful. The same swing from negative to positive occurred when students were asked whether the use of the labs had helped them understand the lectures and readings. Keep in mind that del Alamo had been working with iLabs for over five years at this point; it’s a lesson about how difficult it is to make an instructionally effective innovation, especially as technologies themselves are in flux. For example, according to the report, the documentation and the assignments, for good and ill, had a lot to do with students’ judgments about the value of the lab.

There were also many complaints, even in the fall of 2005, and some students who did not experience the lab as faculty might have liked. To choose just one striking example,

“Several [instructors] said they were not sure that all the students believed they were testing real devices. Students occasionally asked, “Are we actually testing real devices? Is this real data?” (pp. 26)

³⁴ In the spring of 2005, this question was worded differently: “Developing an intuitive feel of how to model”

Heat Transfer

Space does not allow us to profile all the other iLabs supported by iCampus, but it's important to take a quick look at one of the interactive experiments, developed by Prof. Clark Colton of Chemical Engineering and his colleagues. The experiment was originally called Heat Exchanger and later, after being reconfigured to support more kinds of experiments, renamed "Heat Transfer." We will use the latter name to refer to it.

Jesus del Alamo suggested that Colton, too, develop a proposal to iCampus. Up until then, Colton had had little experience with computing this area but his group had put some simulated experiments online.

In his interview with us, Colton thanked Jesus and iCampus. "This would never have happened without funding and the funding produced ideas that led to things. Did it conquer the world? No. Did it produce worthwhile things? I think so and it got a lot of people thinking. It required somebody to take the lead, and Jesus took the lead on this campus and got other people interested. The presence of the funding got a nucleus to get things rolling and you'll never know what will come of it. Omnibus programs like this, I think, are good."

In a year or so, Colton's experiment went into use in "Transport Processes" (10.302), an undergraduate core course that Colton teaches with Kenneth Smith and Bill Dalzell.

Colton's experience has illustrated the difficulty of developing laboratory experiments. In an interview, Colton talked about new experiments that he and his colleagues were developing for a class coming up in several weeks. Colton remarked, "It takes an awful lot of work to get these things operative, [work that has] nothing to do with the computer. It has to with the [laboratory] equipment itself, and understanding what's going on. ... These are real life experiments and they don't behave like you expect. We used equipment that was developed by others so we are kind of stuck with the non-idealities that they built into the system. Every time we start [developing] a new experiment we gotta find out what's going on. Why doesn't it work like it's supposed to work? Why doesn't the theory fit the data?"

"There's a certain element of excitement but we're growing weary of it," he laughed. "It's like a complicated technical consulting problem. We and the TA had to figure out what was going on. It was very educational and I think it's produced some good problems."

Colton's lab has also been used by Prof. Barry Johnston to teach "Process Control" (10.450), an elective class. Colton asked for Johnston's help in setting up the equipment. Colton recalls, "I went to him and said, 'I've been playing around with this and the dynamics are complicated, counter-intuitive, and I don't know any control. I don't know what I'm doing.'" Johnston helped with setting up the experiment. Later Colton suggested to Johnston that the experimental setup might be even more interesting for Johnston's students in Control than it was for Colton's students. Johnston responded quickly to the suggestion and set up his own version of the iLab, using the same equipment for a very different kind of experiment.

Adoption happens along lines of relationship. Another relationship that played a role in iCampus dissemination was the Cambridge-MIT Initiative (CMI). This program, funded by British corporations and Her Majesty's Government, supported a variety of kinds of collaboration between the two universities, including a student exchange program that resulted in several Cambridge students studying chemical engineering at MIT, while several MIT students studied chemical engineering at Cambridge (not an easy plan to develop because MIT's program is for four-year degrees, while a Cambridge degree covers three years). One of those students, Richard West, spent a term in Colton's class and helped with his iLab. The student suggested that a professor back at Cambridge might be interested in the iLab. Colton knew that CMI provided funding so he contacted the professor, Markus Kraft and suggested they submit a joint proposal.

The resulting grants have funded several years of use of Colton's equipment by students at Cambridge. The iLabs project staff pitched in as well; programmer Phil Bailey from MIT's Center for Educational Computing Initiatives (CECI) assisted the Cambridge work. In one sense, the Cambridge adoption was 'third order': they adapted Johnston's process control assignment from 10.450. This use by Cambridge of Colton's equipment continues in 2007, a year after CMI and its funding ended.

Colton has suggested to a number of others that they use his experiments or build their own versions. He hasn't kept close touch with these other institutions, however.

iLabs Shared Architecture

Sharing came with a price: administrative burdens such as creating accounts for students of other faculty to use the machine in one's own lab. The passage of time also brought home a familiar message: software that isn't actively maintained and redesigned quickly ceases to operate, as a result of accumulating changes in its operating environment (e.g., updates to the Windows operating system). A faculty member might, with iCampus help, create an iLab but the burdens of maintaining the software in operation and sharing the lab with other faculty, would probably result in early extinction of the product, perhaps within just a year or two of the cessation of funding. This problem is not unique to iLabs. It has dogged educational software developers for decades. iCampus had to consider how some of the iLabs programming and software might be centralized, to lessen the burdens on faculty both for maintaining software (if they had developed it) and administering the iLab (if they were sharing their equipment with other faculty).

By this time, MIT's Center for Educational Computing Initiatives (CECI) had become involved with iCampus. CECI was directed by Steve Lerman, former director of MIT's previous big computing initiative (Project Athena) and former chair of the faculty at MIT. CECI is a "soft money" operation, supported by administrative fees from the grant-funded projects it supports. CECI was already providing design support for several other iCampus projects (e.g., iMOAT, TEAL).

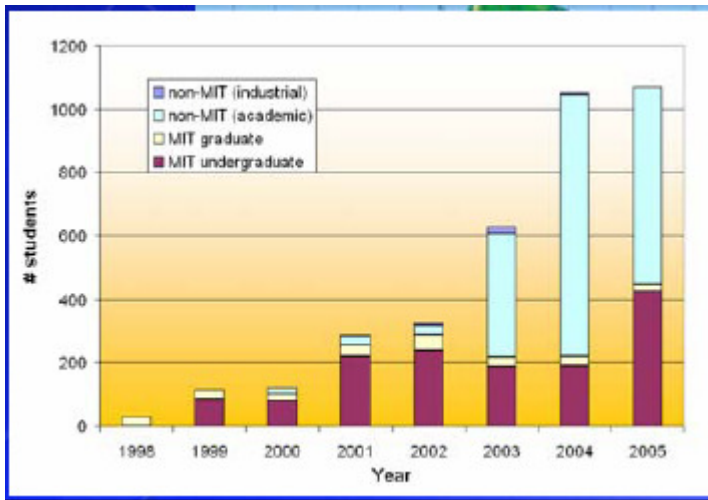
In spring 2002 Lerman and del Alamo teamed up to propose development of a software architecture that would centralize the support for iLabs, a strategy that would be especially useful if multiple institutions were sharing labs. The goal of the project was to develop a software system that would take the burden of faculty who wished to share their labs with other faculty at other institutions, and to ease the task of maintaining iLab software over the years by centralizing key functions. Each participating institution would usually need its own service broker to manage functions for all its iLabs. The Service Broker authenticates students, checks on their authorization to contact a particular lab server, accepts an experimental design sent by the student, and waits to retrieve the result from the laboratory equipment.

The Shared Architecture would thereby free experiment developers from a number of tasks, including the need to develop and maintain services for user authentication, authorization, experiment storage, and scheduling.³⁵ On the other hand, it would require developers of any existing remote labs, at MIT or other places, to rewrite their software. The development team focused first on batch labs, in order to speed dissemination and then, a couple years later, took on the even more complicated task of writing code to support interactive labs and sensors.

At this writing, in late 2006, the batch version of the Shared Architecture has been in use for some time, and has been adopted by, for example, the University of Queensland and OAU in Nigeria.

³⁵ The iLabs architecture project is described in Harward et. al. (2004)

Impact of the batch version of the Shared Architecture: Jesus del Alamo reports that the Shared Architecture has had several quite positive impacts on his ability to share the microelectronics device characterization lab with other institutions, as this figure hints:



The Shared Architecture made it easier to manage use by a number of other institutions. It has also simplified the development of other iLabs, as we'll see in the discussion of growing iLab use in a core course in EECS on circuits, 6.002, below.

The shared architecture for interactive experiments is due for operational release shortly. Like many innovative software projects, the process has taken much longer (a year or two longer) than initially expected. Colton believes that at least one institution turned away from the iLabs effort when the development of the Shared Architecture for interactive experiments fell far behind schedule.

The development of the Shared Architecture was delayed so long for many reasons, one of which was that development of architecture for managing interactive experiments turned out to be far more conceptually challenging than had been expected. It also appears to us that, as large as the grant support was, it couldn't fully support the ambitions of those who saw the future in wide sharing of experiments (batch experiments) versus those interested in interactive experiments (where the major pedagogical emphasis was on providing local students in lecture courses with laboratory homework). For whatever reason, the batch architecture, which was a simpler challenge, was finished first, and then the interactive experiment challenge was tackled.

Interestingly enough, so far as we can tell, the question was never raised at iCampus of whether to abandon the effort to support interactive experiments in order to devote more resources to implementing more batch experiments and fostering wider spread adoption. That is probably the result of the goal that most people had for iCampus of fostering research. The development of the ability to manage interactive experiments was carried on *because* it was technically difficult. The delay was evidence of the challenging nature of the problem. The acid test question in the end will be, what was achieved by doing this research? Does it lead to mass use of interactive iLabs? Did the designs created for this purpose generate new insights into other kinds of control/sharing problems? It is too early to answer those questions.

Efforts to Promote Adoption of iLabs and the Shared Architecture

Inside his department, del Alamo had a ready made channel for trying out iLabs in full view of his colleagues. EECS is a large department and 6.012 on microelectronic circuits is a course large

enough that it must be taught with multiple sections. In EECS, there's a rather unusual and interesting style for teaching such multi-section courses. Among the frequent features:

- One faculty member is usually in charge of the course, with authorization to make final decisions about the course; other faculty can play a variety of roles (discussion leader, laboratory supervisor). Graduate Teaching Assistants and, sometimes, undergraduate TAs provide support. In addition to the regular class meetings, this group meets weekly.
- In the normal processes of teaching the course, faculty and students each have plenty of opportunities to observe others in their teaching roles, and to observe innovations in action
- Members of the group are committed to being open to feedback, even critical feedback, about innovations and practices, and then to demonstrating to students that feedback from students has been heard and has often resulted in changes in the course.
- Over time, faculty members often change roles, generally moving from less responsible to more responsible positions.
- Students are seen as important actors in the improvement process; their opinions of innovations are sought and used. In at least one case, undergraduates representing each section also participated in the weekly meetings. Undergraduate participation strikes us as potentially quite important.
- The group is committed to improving the course and to adapting the course design and teaching to changing conditions, not just to repeating the way the course was taught in previous years. Over time, innovations are tried in the course, sometimes initially in just one section. These changes in content and methods are closely observed.
- Over the years there is a flow of faculty and students through the cadre, which (as a side-benefit) helps introduce and spread innovations. Because the membership of the cadre changes and because a large department may have a number of large courses, all taught by cadres with (over time) overlapping membership, the cadre system may considerably accelerate the refinement and spread of innovations.

Although this system hasn't resulted in any faculty using an iLab in a course where del Alamo hadn't first pioneered it – so far as we know, only three electrical engineering courses at MIT have ever used an iLab – the system has helped other faculty become comfortable with iLabs, develop their own style of using them, and use iLabs in courses like 6.012 even when del Alamo wasn't participating in the course.

The system also has resulted in a quite a few of del Alamo's colleagues knowing about iLabs, which may have helped ease the way to the use of iLabs in one of the department's four core courses, 'Circuits and Electronics.' (6.002). As its name implies, Course VI (EECS) includes both electrical engineering and computer science. Anyone majoring in this department must take 6.001-6.004, two of which are in electrical engineering and two in computer science. So it was an important step toward institutionalizing iLabs in the department to begin using them in one of these core courses. After two terms of 'apprenticeship' during which he began to phase in some iLabs use, del Alamo became the lead lecturer in 6.002 in Fall 2006. Three different iLabs are being used in the course, to support many different assignments: the Microelectronics Device Characterization Laboratory, the Dynamic Signal Analyzer (originally developed by a lecturer in

the department and now maintained by del Alamo), and a lab based on National Instruments' Educational Laboratory Virtual Instrumentation Suite (NI ELVIS).³⁶

The Singapore MIT Alliance (SMA)

With del Alamo's isolation from other developers and users outside MIT, it helped to have some kind of scaffolding around which an adoption relationship could take shape. The first was furnished by MIT's educational program with the National University of Singapore. A colleague was teaching microelectronic devices in the program, which gave del Alamo the idea of using the Microelectronics Device Characterization Laboratory in the program. This use of del Alamo's equipment by students in Singapore began about the time that iCampus funding commenced.

Dissemination via conferences and talks

Del Alamo had no previous engagement with colleagues outside MIT when it came to education. He didn't know what conferences to attend and, in one interview, told us that he still really doesn't know what conferences in general would be the best places to find others interested in iLabs. Like many faculty we talked with at MIT and other institutions, del Alamo feels reluctant to appear pushy when it comes to innovation. He'd prefer to discuss what he's been doing, and, if someone volunteers a question about whether they might share the lab, he can respond.

With some help from iCampus, del Alamo did find a number of venues where he could give talks about his work on iLabs, notably the International Conference on Engineering Education, which helped him make contacts with interested faculty in other countries. For example, he discovered that faculty at Chalmers University in Sweden had developed their own iLab so he asked if he could use it, and offered use of his. The Chalmers faculty had lost outside support for their work, so MIT never was able to use it, but the Chalmers faculty began using del Alamo's lab. Del Alamo reports that iCampus was of great help here, too, not only through travel support from his grant but by directing attention his way. The Outreach Director for iCampus always headlined iLabs in his talks around the world. One result: del Alamo's Microelectronics Device Characterization Laboratory is being used by Chalmers University (Sweden), National Technical University Athens (Greece), University of Parma and University of Pavia (Italy) as well as three institutions in Africa, described in the next section.

iLabs in Africa

One of the outgrowths of the CECI work on the Shared Architecture was a proposal to the Carnegie Corporation of New York to support collaborative work on iLabs with three large universities in Africa: Obafemi Awolowo University (OAU) (Nigeria), The University of Dar es Salaam (Tanzania), and Makerere University (Uganda). The project provides another kind of scaffolding around which adoption can occur. The interaction has been two-way, stimulating changes in MIT's iLabs and also the development of an operational amplifier iLab at OAU.

University of Queensland

Sometimes the adoption roles of iLabs and iCampus as a whole were mutually reinforcing. iCampus has been pursuing a hub-and-spokes dissemination model, identifying particularly interested institutions for favored treatment, in exchange for their playing a dissemination role for iCampus with their peers. The greatest success of this strategy to date has been with the University of Queensland. As described in Chapter 8, UQ was initially most attracted by the opportunity to develop and share iLabs, internally (where labs are important and under-funded), with other institutions, and with high schools (where UQ saw them as leverage to help both

³⁶ For more on this equipment, see http://www.ni.com/academic/ni_elvis/

improve high school education and UQ recruitment). In turn that UQ commitment of funds and energy attracted still more help for them to work with iCampus projects, including, especially iLabs.

The effort had gotten started but was moving slowly until an undergraduate, Joel Carpenter, demonstrated that a talented, relatively unsupervised student could download the software available from MIT and, in just a few months, develop an iLab that would work with the Shared Architecture. He did so without much help from either UQ or MIT. Carpenter's achievement encouraged at least one UQ faculty member, Gary Tuck, to undertake his own iLab work, because Carpenter had demonstrated its feasibility.

iLabs in China

The adoption of iCampus projects was promoted mainly through person-to-person contacts. One surprising and effective set of existing relationships exploited by iCampus was MIT's program for sending interested undergraduates to China.

MISTI – MIT International Science and Technology Initiatives – manages a variety of study-abroad internship programs for MIT students, including its MIT-China Program. Since 1997, one element of the MIT-China Program has been the China Educational Technology Initiative (CETI).³⁷ CETI sends small teams of undergraduates to China to work in high schools and colleges. Some of these teams focus on briefing educators on MIT's OpenCourseWare Initiative materials. According to Sean Gilbert, program administrator, iCampus put time and money into supporting MISTI students who would help institutions adopt projects such as iLabs and xTutor. Abelson, for example, spoke on this at a conference in China in the summer of 2004.

Undergraduates in the MISTI program discovered that a professor of electrical engineering at Zhejiang University, Shanan Zhu, had developed about sixty web-controllable laboratories for distance learning.

In an interview with us, Prof. Zhu reported that he had been developing labs for distance learning for about six years. The iLabs team followed up, and, at this writing, is trying to arrange a working meeting with Prof. Zhu. They are impressed by what they have heard so far of his work and hope that, in the future, funding can be secured so that a modified Shared Architecture can include the efficiencies of Zhu's approach with features of the MIT approach.

Prospects in India

A visit to India in mid 2006 has sparked serious interest in iLabs. The visitors were Phil Long, iCampus Outreach Coordinator, and Mark Schulz of the University of Queensland (an iCampus hub institution, described in chapter 8). According to Long, two or three collaborations between MIT and organizations in India are currently on the horizon. Andhra Pradesh, a state of over 76 million people, is a focus of interest. This state alone has over 275 institutions with programs of engineering education, many of which have no laboratories. A public-private organization called the Institute for Electronic Governance (IEG) has already downloaded iLab code and set up a service broker. A working meeting is scheduled within days of this writing to decide which labs should be developed initially. IEG may also seek major corporate funding for this effort. This use of iLabs bears a striking resemblance to Prof. Zhu's own web laboratories in China:

1. The labs are being developed for students who would otherwise have little or no lab experience (unlike the students for whom iLabs were originally designed; their lecture

³⁷ For more information, see <http://web.mit.edu/mit-ceti/www/projects.htm>

course homework was enriched with labs but they also had hands-on laboratory work in other courses).

2. A centralized unit is funding, creating and administering the labs for a large population of students. This also is different from the peer-to-peer lab sharing at MIT and its collaborating institutions.

An iLabs Consortium

The various participants in iLabs, at MIT and elsewhere, have talked from time to time about creating some kind of iLabs consortium. Several functions have been suggested for such a consortium, such as:

- Helping assure that the Shared Architecture evolves with the times yet keeps enough unity that it can be used by different institutions sharing the same iLabs
- Attracting grant funds for iLabs development
- Encouraging the development of needed iLabs
- Assuring the 24x7 availability of shared iLabs

These discussions appear to be on hold, perhaps until the end of 2006.

Analysis

We have already discussed the goals of iLabs and summarized what we know of their successes. To understand why the concept is not already taking the world by storm, it's important to take a look at some special factors inhibiting their spreading use:

- A. **Curricular specificity**: For curricular software like iLabs to spread, somehow a faculty member who values using this particular iLab must communicate with a faculty member teaching one of a limited number of subjects and persuade him or her to try the idea. The communication might be direct (e.g., in a meeting or e-mail exchange) or indirect (faculty member #1 writes something for a publication, web site or digital library that faculty member #2 later sees and reads). With iLabs the difficulty is probably even greater than, say, for XMAS because iLabs is designed to be easiest to use when the local institution supports its own service broker. But many institutions might not consider that unless several of their faculty demanded it. So iLabs may face chicken-and-egg problem: which comes first – the coincidence of several faculty members who each want an iLab, or an IT department that installs a service broker and then tries to find faculty to use it. Yet, as Professor Sodini remarked, taking advantage of an iLab may first require significant curricular changes undertaken in the trust that, when the iLab is tried, it will work faultlessly.

However, once there are several users, a service broker, and some kind of local support, then it should become easier to expand the use of iLabs locally. That series of events has occurred at a couple of institutions so far, with help from the iCampus Outreach program. At the University of Queensland at least, this is leading to the relatively rapid development of more iLabs.

An easier way for iLabs to spread would be if an institution with a relatively centralized instructional program, or a polity accustomed to providing services for all its educational institutions, invested centrally in developing a large number of iLabs for use by its instructors. As we have seen, this is the path being followed in China and in India. This strategy to some degree bypasses the curricular specificity bottleneck described above.

- B. Faculty values and preferences: The faculty we have interviewed had very different ideas whether, and why, students should do experiments in their courses. They also differed on whether an iLab was a real ‘hands-on’ experience: some argued that it is, while for others it was more akin to a simulation (but more of a bother than a normal simulation). So an iLab designed for a particular course is not actually likely to appeal to the few faculty members teaching such a relevant course at any one university. It will fit the values of some, but not of others. This complicates an already difficult dissemination challenge.
- C. Lack of familiarity with relevant communications channels: Del Alamo had not been active in the American Society of Engineering Education (ASEE) or in other associations with sessions and publications focusing on the teaching of courses for which he and his colleagues were designing laboratories.
- D. Lack of appropriate dissemination materials. During this period of development, MIT has done relatively little to broadcast the availability of specific iLabs such as the Microelectronics Device Characterization Laboratory on its web site. Nor has it developed dissemination materials and instructions aimed at typical faculty members and IT support staff at other institutions. Instead, the dissemination activities have been carried out through interpersonal interactions involving the principal investigators and the Outreach Coordinator.
- E. Lack of a connection with a publisher. MIT has been relying thus far on the open source model. Some initial discussions have occurred about involving a publisher to sell iLabs, or iLabs support materials.
- F. Lack of a consortium or web site that would help potential iLab providers and users to find one another.
- G. Lack of institutionalization at MIT. There is no local commitment to spreading the use of experiments and experimental research as an important undergraduate teaching/learning activity at MIT. There is no program of workshops and publication to help faculty consider how they might use such techniques in homework. So far as we know, no departments have committed to the long term support of iLabs in the curricula. And there is, as yet, no long-term commitment by MIT’s internal information technology unit to support iLabs Shared Architecture; that’s important because most faculty members would not consider reworking part of their course by using a technology that could unexpectedly disappear in a year or two.

Three Visions for the Future of iLabs

There are several different visions for how iLabs should be created and used, each with somewhat different implications for next steps for the program.

1. A **relatively small number of developer-instructors make labs available to their own students and to students of selected colleagues** (probably at other institutions). (e.g., Jesus del Alamo and Clark Colton at MIT; pole balancing experiment at the University of Queensland; OAU experiment shared with MIT). This use of iLabs would be centered on individual faculty and their personal associations. When labs could run in batch mode and without supervision (evenings, weekends, local holidays) or involved sensors, then the sharing might be widespread. The challenge here may be how interested users could find out about the labs, but perhaps disciplinary associations would establish some central points for advertising ‘labs to share.’

2. **A consortium of institutions develops a suite of labs that are then shared as a reliable service among its members.** We assume that such a consortium would probably rely mainly on batch labs and sensors; interactive labs are less scalable. Although discussed over the last two years, this development has not yet begun and we have not yet seen any clamoring for it. It might help if, once a reliable large-scale source of iLabs was created, a publisher or publishers helped spread the word as a way of selling laboratory equipment, textbooks, or both. To make such a strategy work, it seems reasonable to start by identifying a constellation of laboratories for which there might be great demand, in order to simplify the task of making such a consortium, or consortium-publisher, arrangement self-sustaining as soon as possible. iMOAT (chapter 4) provides one model of creation of such a consortium, but it is an example that provokes caution as well as hope: iMOAT appeals to a cohesive set of potential adopters (Writing Program Administrators) who are in a cohesive communications network. Yet the iMOAT Consortium has grown only slowly. In contrast, each separate iLab may need its own communication network; the task of spreading the word and finding adopters is more daunting for iLabs than for iMOAT.
3. **A single, very large university or government program creates labs for distance learners or other students who would otherwise not have such labs.** Zhejiang University, China uses remote labs for distance learning and has already developed 60 different labs, not using the MIT architecture or ideas. India has expressed interest in iLabs. This idea seems to us most likely to serve large numbers of students in the short run, since a single entity could control the development of the labs, support their integration into the curriculum, and the support of students. At the higher education level, such sustainable applications seem more likely to occur in other countries. For high schools, some states might decide to develop and subsidize the operation of such labs.

Recommendations: Next Steps for Research and Action on iLabs

Despite the current extent of adoption, it seems fair to say that iLabs is still a relatively innovator-centric (or perhaps “developer-centric”) project. The focus has been on the original faculty innovators and on the task of developing software that would work for them (and for others).

We suggest that faculty associated with iLabs, and MIT as an educational institution, give special attention to two possible uses of iLabs:

- a) as part of a departmental and institutional effort to explore wider, deeper use of experiments and experimentation in many undergraduate departments. We return to this option in Chapter 10, Recommendations.
- b) as part of MIT’s contribution to international collaboration, working with countries such as Australia, Africa, India and China where the work has attracted attention. Most of these projects might be comparatively centralized, in the way that Zhejiang University has created 60 experiments for its own distance learning program, rather than decentralized. If centralized development projects such as these create a large number of widely used iLabs (including curricular materials, assessment tools, scheduling infrastructure, and the like), that resource could help set the stage for increased sharing of iLabs among peers in the United States, Europe and elsewhere.

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Chapter 4: iMOAT – Using a Coalition to Build a Consortium

“We propose to develop a suite of IT and content services that will allow colleges and universities to administer cost-effective, valid, and educationally relevant online writing evaluations.”

- iMOAT proposal to iCampus, 2001

Compare the opening sentence of the first iMOAT³⁸ proposal to iCampus, quoted above, with the following first sentences from proposals for other projects that are being analyzed in this study:

- “I-Lab is a new educational environment for science and engineering education.” (del Alamo, 1999)
- “There is abundant educational research supporting the view that students learn best if they are actively involved with the material they are studying. We propose to establish a technology enabled active learning (TEAL) environment for large enrollment physics courses at MIT, which will serve as a national model for such instruction.” (Belcher, 1999)
- “In this project we will develop a new class of educational materials and subject formats (initially in the EECS core and header subjects) that promote active learning of engineering and physical sciences by pervasive use of hands-on, constructive activities.” (Lozano-Perez 1999 proposal that led to xTutor)

In contrast with other iCampus projects, iMOAT was developed explicitly for use by many institutions: adoption was a fundamental goal. Principle Investigator Les Perelman prepared for his iCampus project by recruiting other institutions to help MIT design the software so that it could work well for them, too. iMOAT differed from other iCampus projects in at least one other important respect: iMOAT is described as a service, not just as software.

This case study will summarize how this happened, how Perelman’s work with his community of writing program administrators gradually led to the development of sustainable software and service.

Groping Forward – Step 1

Change in academic institutions usually involves trial and error.³⁹ Les Perelman had already led the development of an online service for supporting writing assessment at MIT in the years before iMOAT, and the successes and frustrations of that earlier effort had a substantial impact on the iMOAT project.

MIT’s incoming first year students are required to arrive several days before the formal beginning of the fall term for an extensive orientation program. In the 1990s, one block of that orientation program was occupied by a writing assessment, used to determine whether each first year student would need to take a composition course and, if so, which one. Students would write two essays

³⁸ The software now referred to as iMOAT was called TestWrite earlier in its life. For simplicity’s sake, we will use the term iMOAT throughout this case study.

³⁹ See, for example, the Ehrmann (1978) historical study of a department of civil engineering in a research-intensive institution much like MIT. It was common for initial responses to fail or at the least to require significant modification before they succeeded in attracting the students or research dollars that the faculty had been seeking.

in two hours: one narrative essay and one argumentative essay. MIT used every large lecture hall on campus and assigned them to rooms alphabetically. These essays were then graded ‘holistically.’

In 1997, Leslie (Les) Perelman was Director of the Writing Requirement and Associate Dean, Office of the Dean for Undergraduate Education. One of his many duties was to serve on the Committee on Undergraduate Admissions and Financial Aid, a committee chaired that year by Hal Abelson. Abelson asked Perelman why the students were all being asked to write with pens when almost all of them were more accustomed to writing with computers. Abelson, who was interested in developing educational uses of the Internet, suggested to Perelman that the writing assessment be done online, during the summer. Students could work with familiar tools and perhaps receive feedback on how to improve their writing, instead of simply hearing that they would need to take a writing course later on.

Perelman and Madeline Brown, Director of Writing Initiatives, immediately saw the appeal. Using the web to move writing assessment into the summer wouldn’t just be a convenience. Perelman believed the assessment could be more valid as a predictor of freshman performance if it were done this way. In contrast to hurriedly writing in a bluebook with a pen, freshman writing involves a variety of formats, one of the most frequent of which is responding to readings by spending hours using a word processor⁴⁰ to craft a complex argument.

The assessment would be more valid if it were more ‘authentic,’ that is, if it more closely resembled the kinds of writing that students would most frequently be asked to do. That condition would be fulfilled if the students were given reading to do (and plenty of time to do it) and then asked to write an essay (with plenty of time, and familiar tools, to do that.) All that would be easier to schedule if the student could do the reading and writing over a period of days during the summer. Because this is a relatively ‘low stakes’ assessment, a proctor wouldn’t be needed, just a student’s pledge that the work had been done without help. The readings and the writing task could be downloaded during the summer and, a few days later, the student would upload his or her essay. Then the essays would be rated holistically by graders sitting around a table at MIT. Perelman also realized that, if the assignments were done over the summer and online, there would be time to provide feedback for students on the strengths of their writing and how it might be improved.

The Dean’s office decided to support the effort and, in Spring 1998, assigned a student programmer to create the “MIT Online Essay Evaluation System” that would run on a computer in the Registrar’s Office.

The new online system was popular: half the incoming class participated in the pilot, three-quarters of the first year students participated in the second year. The other incoming students waited until they arrived at MIT and did MIT’s traditional bluebook assessment.

Writing Program Administrators – A Consortium for Instructional Improvement

The system attracted the attention of other writing program administrators in Perelman’s professional network of Writing Program Administrators, an organization which provided him with several channels of communication including its annual conference, its listserv, and personal

⁴⁰ The thinking skills for writing with a word processor are, for most people, substantially different from those of writing with a pen. The latter is more akin to sculpting in stone, the former to sculpting in clay. Thinking while writing with a word processor allows the writer to discover patterns of thought by writing, and then critiquing and remolding the writing. The traditional methods use of a pen, and a short period of time, requires a very different kind of thinking, different from modern academic and professional writing.

communication with people he met through WPA. Perelman was soon receiving requests from other institutions about whether they, too, could use the MIT software.

However, Perelman recalled, “It was a completely idiosyncratic system. And also we had a problem with their server [in the MIT Registrar’s Office], which was not fault tolerant and went down. So I wanted to move it to a server farm. Neither of those could be done because [the designer] didn’t use standard software (for) the backend database. To get another copy to put somewhere would have cost \$25,000. The other problem with the system was that the registrar (part of the Dean’s office) had built it to do what *they* wanted to be done. I had all these people interested from other schools. I wanted to make a very robust system that could be used in lots of different ways and work at other universities.” The system had other bothersome characteristics: it wouldn’t accept late papers, for example, and it required the submitting computer to have an MIT certificate.

In 2000 Abelson supervised a small feasibility test of doing this kind of writing assessment with web-based services. The test results showed it could be done.

Perelman was stimulated by other institutions’ interest in “the MIT model” to develop a service that many institutions could share. He used the WPA listserv to invite a group to meet at the Conference on College Composition and Communication in Denver, in March 2001, and then began about a year of work with representatives of this nascent consortium to create specifications for a new system. In January 2001 Perelman had submitted a proposal to iCampus and in September 2001, Perelman received over \$350,000 for a two-year project to develop a web services approach to managing writing assessment.

Round 2: iCampus

The software itself was initially developed by a master’s student, Mark Walker, with supervision from Microsoft’s onsite representative, using the new .Net platform. What was unusual about the development effort was how thorough a break it was from the previous version. Like Pete Donaldson’s XMAS program, the software was redesigned from the ground up, conceptually as well as in code. But unlike any other iCampus project we’ve seen, the new version was designed for multiple institutions to use, while the earlier version had been designed just for MIT.

Perelman recalls, “Rather than developing it here, alone, I advertised on the Writing Program Administrators listserv, which is what everyone who does what I do is on. [I said] that I was looking for about four or five other universities to partner in the development of this. What they would get was two years of free use, as well a chance to help design it. I specifically selected four other universities that were very heterogeneous.”

The original five institutions whose writing program administrators participated in the design of iMOAT were:

1. MIT;
2. Cal Tech, which similar to MIT in some ways but significantly smaller (and being smaller was significant for iMOAT, as we’ll see)
3. The University of Cincinnati (which then had eight different colleges ranging from an open admission junior college to an honors college);
4. DePaul University in Chicago, which has a lot of mature students, older students, and a lot of satellite centers; and
5. Louisiana State University (a large, public, ‘flagship’ university),

The team members created the requirements collectively working via phone meetings as often as every two weeks, sessions at their shared national conference, and two annual meetings at MIT funded by the grant to work out the requirements document. After the first version of iMOAT had received some use, the team met again to work on the requirements for version 2. (iMOAT is in version 3, at this writing.)

By developing the specifications and the interface with these diverse institutions, Perelman wanted to assure that the resulting system would have more uses, and more users. For example, each institution had its own chunk of the iMOAT server, with its own name in the URL (e.g., <http://caltech.iMOAT.net>) and pages that used that particular university's logo and design look, so that students would feel that they were on home turf. (That didn't always work, as we'll see below.)

Because Perelman's focus was on the use of the system at other institutions, not just MIT, let's take a look at what happened at four rather different institutions:

- Cincinnati, which uses iMOAT for placement purposes, as MIT does;
- Louisiana State, which invented a very different use for iMOAT;
- CalTech, which left the consortium, developed its own software and then, after several years, abandoned its software and returned to the consortium; and
- Cornell, which considered using iMOAT and decided against it.

University of Cincinnati

Each of the participating institutions was distinctive in some way. The University of Cincinnati is an unusually decentralized institution. It consists of five colleges, each with its own English department, dean, and faculty. The colleges aren't even all in one place. Three of them are on the main campus in the city (with three different English departments) while the two branch campuses are each in other locations. The College of Arts and Sciences provides courses that fulfill the English requirement for most of the BA colleges; they have worked closely with Marlene Miner, chair of the university-wide composition committee and an English professor in the University's two-year college, in the development of iMOAT. Miner knew that iMOAT would have to be designed to cope with that diversity of procedures and needs.

Like Perelman, Miner and her colleagues built on a foundation of previous work. In UC's case, this was a systematic study of the kinds of writing prompts that could produce the most valid essays for placement purposes. That study had gone well and produced university-wide buy-in to a single approach to assessment. Then came Perelman's invitation to help design iMOAT, at no cost to the University (other than people's time) and with no obligation to use the software. As Miner recalled the meeting to discuss Perelman's invitation, "No one asked what it would cost. That was amazing. I put in the presentation that we would have a role in designing the system, in conjunction with other institutions. When I mentioned the list of schools and the free part, they were on board from the beginning. We met at national conventions where I was going anyway. I went once or twice to MIT and the grant paid for that."

Miner remembers the exacting work of design. "It was a learning experience for me. I'm not a technical person. The conference calls –we were talking not only about what we wanted the system to do but about how we do placement. We talked about what the students would see. When we met at MIT we looked at what [the system] would look like...I needed custom codes for our colleges, which no one else did. I know we went over each screen, what would we see, what we would be able to do, what to upload, download, how to manage the password. We also

talked about how we needed to have a place to have a reading, multiple writing assignments... You can then have multiple assessments, for example 2-3 assessments. Or one now, and another one later.”

Development of the system brought out the inevitable bugs. “For one,” remembers Miner, “we had too many students using it and it froze on it as they were downloading. It was a test. I called Les, it got straightened out, and there were no real problems. And it wasn’t as easy as it needed to be to navigate. That was fixed by the second version. By that time we had hired graduate students to staff the help line. They kept good notes and found bugs.”

The help service was just one way in which different universities had to adapt themselves to iMOAT, as well as vice versa. Miner recalls that MIT initially provided help for its own incoming freshman by giving them Perelman’s cell phone number. Miner said, “Our students had many more technical difficulties. They are using computers that are pretty old, would time out, would disconnect via a phone modem. And they weren’t as skilled at doing anything online as they now are. So we were glad to have 3 [UC] graduate students staffing the phone help line, and the e-mail help line. It was staffed at set hours, 11 am to maybe 4 pm and then again in the evening 7-11.”

Because of UC’s participation, the iMOAT software had to be developed to handle UC’s unusual administrative diversity. That, and the fact that one of the colleges within the University is a community college, both helped iMOAT attract new users in later years.

Louisiana State University

Irv Peckham, Director of the University Writing Program at Louisiana State University, was another of the original team convened to design iMOAT. At the time iMOAT went into development, LSU was admitting about 5,000 first year students annually. It used a hybrid system for assessment, assigning initial placements based on SAT or ACT scores, but allowing dissatisfied students to challenge that placement by writing an essay during orientation week. The procedure was quite disruptive, resulting in students switching courses and section for a week or more into the term. Peckham looked for a system that would allow students to write essays more like those that they would write in classes, using the Web so that the writing could occur during the summer.

After finding out what Perelman was intending to do, Peckham wrote a proposal to his dean. Peckham recalls, “I needed to get the provost behind this. I wrote a proposal, arguing that the current situation was disrupting courses for 7-10 days as students moved and other students were moved to maintain class sizes. I was able to show the provost that by doing this [assessment and placement] before the term, he could save quite a lot of money in the process of keeping all classes full. He gave me a \$10,000 grant to run this for a couple years.” So LSU joined the consortium designing iMOAT. Peckham also had to get others behind the project, including the chair of the English department. Later when a new Dean of Arts and Sciences was appointed, he needed to be convinced; again ‘saving money’ was a winning argument.

LSU’s participation helped make iMOAT more robust. For example, LSU uncovered the aggravating detail that the first version of iMOAT was programmed in MIT’s local time so that an essay due before “midnight” would actually be rejected if it was submitted after 11 PM in Louisiana’s time zone. Once discovered, the problem was soon fixed, to the benefit not only of LSU students but also of MIT incoming students who were living in other time zones.

LSU was one of the iMOAT institutions that seriously studied outcomes of its use, discovering little correlation between SAT/ACT scores and the scores assigned by iMOAT reviewers to

academic essays. In other words, the standardized tests were very, very poor at predicting how well students would write in response to authentic academic assignments. This helped justify spending time and money on this more valid form of assessment, at least for students who believed that standardized test scores had incorrectly described their writing skills.

iMOAT came along at a time when accreditors were pressing institutions to improve assessment, which prompted Peckham to develop an entirely new use of iMOAT. “The key to success at LSU was to use iMOAT to assess writing at the end of the semester.” In other words, all students in different sections of the same course would be given the same readings, and the same writing assignment to end the term. Instructors would all be trained to grade the essays, not knowing which student’s essay they were grading, or which section that student had been in. iMOAT would be used to manage the process for giving and grading this final assignment at the end of the first year. Peckham recently wrote that, “Our purpose in the semester assessment was to improve course coherence, motivate student and teacher performance, and respond to the perennial charge of grade inflation.” (Peckham, 2006) In an interview, Peckham asserted, “The University is always being pressed to assess learning. We get a lot pressure from SACS⁴¹ to run assessment. By my doing this at the end of the semester, that put us way ahead and got us a lot of attention from senior administrators. I hate to use the term ‘cutting edge,’ but we were leading the university.”

Building this new end-of-semester assessment was a gradual process, Peckham remembers. “[For placement of entering students] I didn’t have to work with the instructors because they weren’t involved in the placement, other than the six I hired to do the reading [of students challenging the results of the ETS/ACT scores]. Where I really had to get [instructor] buy-in was in doing the assessment at the end of the semester. I was assessing writing for all the teachers in the program. Teachers are notoriously threatened by outside assessment of student writing because it reflects indirectly on their teaching. I piloted it for four years. I kept talking about it and getting people to gradually accept it. It was voluntary to take part in the pilot. More and more did. We kept talking about what to evaluate. [Participation in iMOAT] became an important part of teacher inservice.”

Just as saving money was key to administrative acceptance, assuring faculty that they could improve assessment without spending more time was important. “What was key to that was to construct an environment where I wasn’t asking the teachers to do more work.” Peckham also used faculty to develop the assignments and procedures for assessment, so that the process wouldn’t seem to be an administrative imposition. “We have a dead week at the end of the semester where we give no new assignments, before finals. I got our program excused from giving finals and used iMOAT to create a writing situation for all the students. So the faculty could use that dead week to do training [on how to assess this particular assignment] and the scoring in finals week. When [iMOAT assessment at the end of the term] became mandatory in this last fall semester, it helped me address a million problems including the charge of grade inflation.”⁴² When teachers are systematically grading their students at levels higher or lower than

⁴¹ The Southern Association of Colleges and Schools, which accredits LSU.

⁴² It’s interesting to compare the LSU experience with this required end-of-semester writing assessment and the MIT experience with the virtual requirement that students take the TEAL form of physics (see Chapter x). LSU worked four years to get participation from a growing number of instructors. MIT told students after two years of piloting that they would have no choice but to take TEAL and to attend most of the classes. At LSU training of faculty in writing assessment was a priority. At MIT, we heard relatively little about educating students in the arguments for and against TEAL-style instruction. Helping students become conscious of, and test, their theories of learning almost certainly happened in some sections, especially early in TEAL’s history, but it’s not clear whether this practice was institutionalized across TEAL sections.

those same students' iMOAT assessment, Peckham can use the data to create an occasion for faculty development.

Meanwhile iMOAT software development had been completed, and Peckham had to find the money to begin making a financial contribution to the consortium if LSU were to continue using the service. A previous provost had backed his participation in development, but now there was a new provost and new policies. "Our program had had to fire 30 of our 65 instructors. That was quite a political disaster. It had to do with our trying to make LSU a higher ranking institution nationally, which you can do by changing the instructor:student ratio. At that time iMOAT was about to cease to be free – it had been free first three years. So I had to make the case to make the case for \$10-15,000/year fee. The new dean would be the one to provide the money. The original way of saving money, placement, was not going to appeal to the new dean because he hadn't seen the old situation. But I could show the new dean that he would save \$45,000 /year for the end of term assessment. When we scored the student essays, 3800 students, we initiated a protocol for exempting students who scored high from taking second term composition. By tracking that for two years in the pilot, we were saving \$35-\$40K in instructor costs."

This pattern seems common with iMOAT: writing program administrators who like the program because it provides a more valid, successful way of placing and assessing students and therefore try to develop ways of using iMOAT that can persuade provosts, deans and others that the university is saving money. Of course, improving education and saving (or spending) money are not directly linked, but the motivation to do the first can sometimes drive people to save money in order to get the backing they need. That was the case at LSU.

One other theme came up in this case study that must be mentioned, because we heard it so often, in so many cases: the importance of human help from the iCampus project at MIT. "Shannon Larkin (who initially managed iMOAT" was crucial, absolutely crucial," Peckham recalled. "And Chris Felknor (who now is charge of iMOAT programming and technical support) is pretty quick to answer the phone. All these situations that crop up during the semester assessment with 3700 students and the time frame is the same for all of them. Lots of things can happen. I ask [Chris] a question, he gets right back to me, and we solve it. I don't try to call him at night unless it's absolutely critical and I don't remember if I've ever done that. But [Chris is available] at least 8 hours a day, five days a week. I frequently, every so often have to make a case to the dean. And this happens in all our schools, the dean says 'why don't I send you to IT and have them develop [a system like this so we don't have to pay every year]?'. Chris Felknor is my answer. When it's such high stakes, you don't want this thing to roll under. You can't depend on IT in any university." This turns out to be a key theme in the story of Cal Tech's participation in the iMOAT Consortium.

California Institute of Technology

Cal Tech is the smallest of the institutions in the original consortium and, even with a lowered price, still faced a higher charge per student than other institutions. So Stephen Youra was more than open to the idea, once the original development was complete, of having a Cal Tech programmer develop a local, 'free' version of online assessment software.

Steve Youra had come to CalTech from Cornell recently in order to take over the writing program. He had already known Les Perelman for a long time at that point, something that was often the case in successful adoptions. "When I used to run the communications program at Cornell, I visited MIT once and met Les, maybe 20 years ago. We got to know each other through conferences and mutual interests. We went to some of the same conference talks. When I edited a special issue of a WAC journal, Les submitted a piece. And he was on an outside evaluation team that came to review the program I was running at Cornell." This theme of a long history of slowly developed confidence in mutual interests and values shows up repeatedly in cases of successful

iCampus adoptions. The Cal Tech case helps illustrate why this kind of shared trust can be important, as the adoption process hits bumps in the road.

As at MIT, entering Cal Tech students had spent an hour writing a blue book essay in order to find out what writing requirements awaited them. Youra recalls, “What was at stake was placement into ESL section of writing or a composition course, both of which were precursors to writing-intensive humanities courses. We tried to avoid language of ‘passing and failing’ but students saw placement into ESL or composition as stigma. What in effect it meant was doing extra work in the curriculum because they had to pass those before they could take the humanities courses. I saw it as problematic from the start.” Before Youra’s arrival, Cal Tech had had no writing specialists. The bluebooks had been graded by humanities faculty, who were not in love with the task. “And I was faced with a line of students down the hall the next week, students who were challenging the outcome of this writing assessment thing.”

Youra heard about the iMOAT project from Perelman and was interested in joining. Aside from some questions about potential cheating, there was little resistance from his colleagues; pointing to Cal Tech’s honor code and the relatively low incentive for students to cheat were sufficient to get past that objection. At CalTech it is humanities faculty who rate the students’ work, the faculty who will be teaching those same students later on. Their reaction to shifting from hurried grading of bluebooks to summer grading of word processed essays has been largely positive. Says Youra, “Because they are not being paid for their time and they’re not writing specialists, they don’t want to spend a lot of time on this exercise. They see it as an obligation and some do it with hesitation. They want to do it quickly and efficiently. The other thing they like is that the papers are word processed and have fewer stray errors and are more legible than the blue books.”

Using iMOAT had one other impact on writing assessment at Cal Tech. Now all students use word processors, even if they are doing a ‘makeup’ assessment on campus when they arrive in the fall.

Youra worked with network people at the university in the initial implementation of iMOAT. When iMOAT’s grant ended and it was time to either pay for the service or withdraw, Charlie Hornberger of the Cal Tech IT staff told Youra that it would be less expensive to develop their own software than to pay \$5-10,000/year to participate in iMOAT. “Charlie developed a system that worked well for us. He still had to do some things behind the scenes. The interface was beautiful for 80-90%. If I needed a print out, he would send me the file to print, for example. It was quite beautiful, and some functions I prefer over iMOAT. I love iMOAT but I have some problems. It has some instructions hardwired in that are really geared for MIT. It says “essays” while we have only one. And the security certificate says “MIT.” I can’t tell you how many emails I get from students suspecting that this is an MIT hack on Cal Tech. Stuff like that has been an ongoing, minor irritation. Chris [Felknor] has been really good too; when I ask him to do X, he usually can do X.”

“Charlie had done something 80-90% complete and then left to take another job. That was great for him but not great for us. We’d used his system for a year or two, but we couldn’t continue to support it without more software development. What iMOAT also provided was 24x7 help and support, which we couldn’t provide. We did buy a server with RAID redundancy but it required Charlie being on call, and I don’t have another Charlie.” So Cal Tech rejoined the iMOAT consortium.

“The devil is in the details.” Institutional context can make a big difference in how attractive or troublesome a service can be. Youra points to the difficulty of using any online writing assessment at Cal Tech. “Timing has been an issue for us. I don’t how that would work at other institutions. I don’t get the information about the incoming students in May and we have to run this in June, when the faculty are still here and willing to do this. ...Students don’t commit until

May 1. Then there's a week before they get the acceptance letters. This year I ran into the problem that admission didn't want the first piece of correspondence to admitted students to say, "Welcome to CalTech, take this writing assessment." So our narrow window got narrower. We sent out the e-mail and a hard copy letter only two weeks before iMOAT went live, with apologies for the late notice. Then Admissions updates the information as new information becomes available, address updates, new students."

This case makes it clear that institutionalization of iMOAT involved the widespread recognition that iMOAT is a service whose maintenance requires paying for human beings and a reliable server farm, not just the creation of software.

Meanwhile Cal Tech continues, somewhat reluctantly, to pay for the service, aware that they are paying far more per student than other members do, because Cal Tech only uses iMOAT for assessing incoming students and because there so few of those incoming students. iMOAT charges an annual fee per institution (varying somewhat by size of institution) and most of its costs are fixed, so the more institutions join the consortium, the lower the fee per institution. So Cal Tech has more incentive than any other institution in iMOAT to find more members. I asked Youra whether this was a priority for him. "Last summer Les and I did a joint presentation at the WPA [Writing Program Administrators] conference. Do I actively promote it? When the subject comes up among colleagues, I describe iMOAT and encourage people to consider it. But I haven't been an evangelist, a salesperson for iMOAT. It's not because I have reservations. We use and we're happy with it, but I haven't been promoting it. As I told you, at the WPA meeting, I talked enthusiastically about this approach but at that time I was using our own system to demonstrate it. The real message is that the assessment should match the task which the students will find themselves in. Incidentally it's not as though there are many competing systems out there. So advocating this issue is next to advocating for iMOAT."

When interviewing Youra, I thought I heard a rather negative tone of voice when he said that he wasn't a "salesman for iMOAT" and I asked him about that. "You're touching on a very good point," he replied. "It's partly because it's a product, not an approach. I have a self-interest in lowering the cost. It could feel like Amway. I'd be suspicious if someone else approached me. So I'm of two minds. It's a great tool and certainly helped us, but putting on a loudspeaker and promoting it, there's a certain self-interest. Particularly academics aren't used to it. Unfortunately it has a connection with Microsoft that doesn't have the best image in the world, so it can be perceived as being an agent for Microsoft. Les points out that this was developed on .Net and other institutions may not have that server and the expertise to support it. It's not just shareware that you can spread around. The taint of Microsoft, the specialized platform, the significant costs—that's not to say that, in an e-mail list if the topic came up I wouldn't be an enthusiast. That's the extent. I wouldn't travel around the country trying to promote it. I wouldn't make it a special mission.

"In the early days I had imagined that by now that there would be 20 institutions. We were not involved so I don't know why it hasn't grown. Maybe occasional conference presentations and e-mail mentions aren't enough. This is more of a change than that, and there is resistance. I talked with Joe Martin, my colleague at Cornell who heads their writing workshop. They looked at it and decided for whatever reasons that they weren't interested in iMOAT. You should ask him."

Cornell University

Only a few years ago, Perelman and his colleagues were anticipating rapid growth of the iMOAT consortium to perhaps 50-60 members by the end of 2005. In fact, in late 2006, the consortium is now earning enough money to cover its operating expenses, but it has only 9 members at this time, with 5 members who were not part of the original consortium. Cornell University provides

one example of an institution that seriously considered taking part in iMOAT but decided against it.

Joe Martin is Director of Cornell's Writing Program. In a recent interview, he recalled, "I went to a couple meetings with Les Perelman and investigated iMOAT's implementation. It would certainly make part of my fall semester much easier. I do an onsite assessment during orientation weekend. It's a lot of time in the office and a lot of settling to get students in the right room and getting people to read the essays. The project itself seemed ideally suited for creating a writing situation that mimicked the actual writing process. So I investigated it.

"One reason I didn't go with it is because of scale. At MIT and at Cal Tech, the online project is required of the entire incoming class. I can't do that at Cornell. I only assess 4-500 students in a class of 3000. This wasn't worth the investment of money to do that. [Author's note: Cal Tech, which is a member of iMOAT, assesses fewer students than Cornell, but they do also complain about the cost.] I can do the on site assessment at a fraction of the cost of iMOAT. I like the program. It gives them an assessment that is a better assessment than a one shot on site assessment." Martin also commented that LSU faces different assessment pressures, and different expectations from students about assessment, so that it was unlikely that Cornell would use iMOAT as LSU does, for a required assessment of writing at the end of the freshman year.

The iMOAT Consortium

By 2002, an aggressive growth plan had been developed for the Consortium, featuring strategies for widely publicizing the work (conference presentations; journal articles; listserv posting; encouraging an article in the *Chronicle of Higher Education*). The plan called for rapid growth to 60 participating institutions, and a self-sustaining consortium with a budget of \$500K/year by Dec. 2005. That budget was based on the assumption that iMOAT would require a completely freestanding organization in its own off-campus facility. As it turned out, that wasn't necessary.

What turned out to work well for iMOAT was a lasting relationship with MIT's Center for Educational Computing Initiatives (CECI). CECI provides many of the facilities and services that iMOAT needs and, because it shares them with a number of grant-funded projects, the price is low. For example, Chris Felknor, the iMOAT programmer, is shared with other projects, and is now teaching another CECI staff member how to support iMOAT software. This reliance on CECI substantially lowered the operating revenue iMOAT needed, and enabled iMOAT to become self-supporting.

The iMOAT consortium may have grown to self-sustaining size and it is still growing, but it is rather small: fewer than 10 members at this writing. Prices are still relatively high (\$5-\$10,000/year) because there are so few members. As noted above, it doesn't appear that the current members have put a high priority on recruitment, even though it would lower their own costs. Marlene Miner attributes the slow growth of the Consortium to the priority given writing placement by most institutions. "I would guess the problem is, the problem with placement everywhere, is that it's a low priority item, a cost. If a test can be cheaper [than assessing actual student writing], that's what they'll do. It takes some convincing, an institution that is committed. Fortunately I didn't need to fight the battle of whether to see student writing. That was already part of the tradition here [at UC]."

Conclusions

Perelman's strategy of developing a software program for MIT with the help of a consortium of fellow users is unique in iCampus and unusual in our experience internationally. Three of the other projects we have studied – iLabs, XMAS, and xTutor – had at least two separately funded stages of software development (XMAS has had about five different platforms). In each case the

phase I software was so successful functionally (despite its limitations as software) that fresh funding was attracted to do a complete redesign. But only the iMOAT rewrite employed a consortium of potential adopters to help assure that the resulting product would be easy and appropriate to use in a variety of settings. In order to do that, some of the money that might have otherwise gone to iMOAT software development (or to other iCampus projects) was spent to bring the consortial representatives together periodically. And iMOAT staff spent considerable time with these representatives in a design and development process that had to have been frustrating at least occasionally. But the bet paid off: the software was robust enough that new consortium members have been attracted by features that MIT, on its own, would never have developed. iMOAT is now supported by a dues-paying consortium of institutions that use it in different ways. And additional institutions may also be inspired by its example of authentic assessment.

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Chapter 5: TEAL⁴³: A Campaign to Improve Conceptual Learning in First Year Physics at MIT

“I am a profound admirer of John Belcher. He got more change out of that department than any other reasonable person could have achieved.” – Frequent visitor to the MIT Department of Physics

Problems Facing Physics

There had long been dissatisfaction with freshman physics instruction at MIT. All majors at MIT, even in social sciences, management and humanities, are required to take two terms of physics. Various designs and experiments had been tried over the years to improve these physics courses, occasionally with two or even three variations of the course being taught simultaneously.

Meanwhile, since around 1980, change was in the wind nationally. For over two decades, physics education research had been yielding convincing evidence that a) students even at highly selective institutions such as Harvard and MIT were failing to master some of the most basic ideas in introductory physics, even when lectures and problem sessions were accompanied by traditional laboratory experiments. In the mid 1990s, a PBS television documentary, “Minds of Our Own,” drew on this research to dramatize problems in American education. Time and again these programs showed graduating seniors from MIT (and Harvard) still in their caps and gowns, giving ridiculously wrong answers about concepts in physics and other sciences that had been taught repeatedly in school and at MIT.

Perhaps the single most important development in this campaign to understand and improve learning in physics was the development of the Force Concept Inventory by David Hestenes and his colleagues. This multiple choice test of conceptual understanding was carefully designed to reward conceptual understanding and to reveal the most common misconceptions. Many faculty members, from selective institutions to community colleges, were shocked by their students’ poor performance on an exam that, beforehand, these faculty members had assumed most of their students would pass. This lack of understanding had previously been hidden from both faculty members and students by the students’ ability to apply mathematics in routinized ways to routine problems found in problem sets, quizzes and exams. As Eric Mazur wrote in 1992⁴⁴:

“For the past 8 years, I have been teaching an Introductory Physics course for engineering and science concentrations at Harvard University. I used to teach a fairly traditional course in an equally traditional lecture-type of presentation, enlivened by classroom demonstrations. I was generally satisfied with my teaching during these years—my students did well on what I considered pretty difficult problems, and the feedback I received from them was positive.

“About a year ago, however, I came across a series of articles by David Hestenes of Arizona State University, which completely and permanently changed my views on teaching. In these articles, Hestenes shows that students enter their first physics course possessing strong beliefs and intuitions about common physical phenomena. These notions are derived from personal experiences and color students’ interpretations of material presented in the introductory course. Instruction does very little to change these

⁴³ For iCampus’s basic web material on TEAL, see <http://icampus.mit.edu/teal/>

⁴⁴ Quoted in Richardson (undated)

'common-sense' beliefs. Hestenes provides many examples in which students are asked to compare the forces of different objects on one another. When asked, for instance, to compare the forces in a collision between a heavy truck and a light car, a large fraction of the class firmly believes the heavy truck exerts a larger force on the light car than vice versa. My first reaction was, 'Not my students...!' I was intrigued, however, and [tested my own students]. The results of the test were undeniably eyeopening.

"I spent many, many hours discussing the results of this test with my students one-on-one. The old feeling of satisfaction turned more and more into a feeling of sadness and frustration. How could these undoubtedly bright students, capable of solving complicated problems, fail on these ostensibly 'simple' questions? Slowly the problem revealed itself: many students concentrate on learning 'recipes,' or 'problem-solving strategies' as they are called in textbooks, without bothering to be attentive to the underlying concepts...

"Just a year ago, I was entirely oblivious to this problem. I now wonder how I could be fooled into thinking I did a credible job teaching Introductory Physics. While several leading physicists have written on this problem, I believe most instructors are still unaware of it. A first step in remedying this situation is to expose the problem in one's own class. The key, I believe, is to ask simple questions that focus on single concepts. The result is guaranteed to be an eyeopener even for seasoned teachers." (Mazur, 1992)

Hestenes and his graduate students had helped other faculty discover that common-sense misconceptions were preventing students from developing an intuitive understanding of Newtonian physics. Perhaps this should not have been surprising. After all, years earlier, Thomas Kuhn (1963) had developed the concept of paradigm shift to describe just how difficult it was for professional scientists to change their world view.

As Hestenes' Force Concept Inventory (FCI) gradually spread from one faculty member to another, the story told by Mazur was often repeated. One of the authors of this report talked years ago with a physics faculty member at a community college. That faculty member recalled that, several years earlier, he came across the FCI. After he looked it over, he was confident that anyone passing his physics course could also pass this seemingly simple test. So he administered it to his class at the end of the term. He was stunned at how low his students' scores were. "I've been teaching physics for twenty years," he told us, "and I'm a damned good lecturer. So I had to conclude that you cannot *tell* people physics. It cannot be done." With the help of a test that he had administered to his own students, he was going through a paradigm shift as profound as he was hoping to see in his students. In his case, the paradigm consisted of his assumptions about how students learn and how faculty should teach. He and Mazur had reached some of the same conclusions. One of them was that, to be effective, a good instructor needs to continually study his own students, using tools drawn from the physics education community of inquiry.

The good news: this same stream of physics education R&D was demonstrating that non-traditional approaches to teaching could yield better understanding of those fundamental concepts.

The National Science Foundation and private foundations invested for years in the search for better approaches to physics education. That funding, and the resulting stream of encouraging findings and new program designs, helped leaders in the physics education movement gain in prestige. Their work began to draw favorable notice in publications from the National Academy of Sciences and other authoritative groups. Investment in research was leading to documented improvements in learning. Some departments (though relatively few in institutions considered to be first rank research institutions) began to include a physics education specialist among their physics faculty. That is becoming more common, and more noticeable in the wider world of physics. Recently physics research was rocked by the news that Carl Wieman, a relatively recent

and still young Nobel Laureate in Physics (2001), had moved to the University of British Columbia, where he was shifting his research completely to physics education.

MIT Encounters Physics Education Research

Decades earlier, MIT was a leader in physics education reform in high schools in the wake of Sputnik. But the new wave of physics education research seems to have had relatively little impact on the Institute for a number of years.

This did not mean MIT's physics faculty members were satisfied. Poor attendance rates (around 40%) at lectures were all too common at MIT, an institution where many students boast that they can carry heavy course loads, including courses that meet simultaneously, and still get A's; they could skip classes because lectures and textbooks duplicated one another and the tests mainly focused on the kinds of knowledge that could be absorbed from textbooks and simple problem sets. But failure rates in physics (7-13%) were judged by some faculty in Physics and in other departments to be too high. It was rumored that members of the MIT Corporation (the Institute's board of trustees) were complaining about the failure rate in 8.01 and 8.02 – the first two terms of physics.

John Belcher, a professor of astrophysics without much previous background in teaching undergraduates, lectured second term physics (8.02, including electricity and magnetism, relativity, and related topics) for three years in the early 1990s. Although he received extremely good ratings from students by the third year, Belcher, too, was dissatisfied because of poor attendance, a failure rate of 10-15%, and a sense that he was not reaching students. His response after the first year was to take acting classes, so that he could project better and make a better impression, and thereby increase attendance and understanding. That did not work.

So Belcher attended a conference of the American Association of Physics Teachers (AAPT). He learned that, for at least a decade, pioneers in physics education research had already been tackling these problems, and with some success.

Electricity and magnetism are among the topics in science that are most difficult to teach effectively. Students whose skills of reasoning and visualization have helped them succeed in the first term of physics often have problems with the complex and abstract visualization needed to master E&M.

Belcher was interested in applying his own ideas about making electromagnetic fields more visible and comprehensible to undergraduates. He wanted to do this by giving them simulations of fields, simulations that they could examine closely and manipulate.

Belcher submitted a major proposal to the US National Science Foundation, to develop computer simulations of electromagnetic radiation for use in 8.02. In a move that would have profound implications for physics instruction at MIT, NSF turned down Belcher's proposal but offered him a planning grant on the condition that Belcher team up with an expert in physics education research. So Belcher joined the physics education research community. His chosen expert was Bob Beichner of North Carolina State, who was already at work developing SCALE-UP.⁴⁵ (Brehm, 2001)

NC State's SCALE-UP stood on the shoulders of earlier programs such as Priscilla Law's development of workshop physics at Dickinson College, Rensselaer Polytechnic Institute's studio

⁴⁵ For an introduction to SCALE-UP, see their web site at <http://www.ncsu.edu/per/scaleup.html> (noted May 27, 2006).

physics, and an earlier program at NC State called IMPEC. IMPEC was an integrated approach to freshman engineering for which Beichner had developed physics instruction.

SCALE-UP was a departure from all of these in its goal of handling sections of 100 students at a time. Earlier efforts were designed for sections of 20-70 students, which meant that their laboratory centered approaches could still have relatively high costs per student.⁴⁶ To reduce costs per students to acceptable levels, SCALE-UP developed an approach that could support large sections that were nonetheless focused on experimentation, debate, and problem-solving. To perfect its approach, the SCALE-UP team systematically tried solution after solution, taking data, and adjusting its approach (e.g., on the design of worktables). Belcher would follow many of SCALE-Ups procedures for organizing large sections of students to do active learning, while using a different textbook, problems, and new simulation tools for visualizing electromagnetic fields.

By 1999, interest in educational innovation at MIT had increased further. Alex d'Arbeloff, recently named chair of the MIT Corporation, had managed to persuade MIT that his \$10 million gift to the Institute should be for projects in educational innovation, not for a new building.

Belcher was already deeply involved in discussions around changing introductory physics. His development of computer simulations of E&M fields for undergraduate instruction had begun to win him support from MIT, including a class of 1960 Fellowship. In September Belcher was named one of the first members of the new Council on Educational Technology, co-chaired by Hal Abelson, which would provide advice on d'Arbeloff grants and, soon, on iCampus funding.

In October 1999, the Microsoft gift to MIT was announced. After two public meetings, the new iCampus program issued request for proposals to MIT faculty. In December 1999 Belcher proposed to develop an experiment-based, collaborative approach to teaching 8.02 plus “software [that] will consist of tools for the analysis of experimental data (including video analysis), 3D visualizations of phenomena to help make the unseen seen (e.g., electromagnetic fields in 8.02), and Java-based interactive simulations of the experiments.” The Physics Department, said the proposal, was committed to convert physics instruction to the TEAL model if the prototype succeeded. Belcher had agreed with the Department that, once operational, TEAL not consume any more staff time than traditional physics instruction. The Department wanted better results but it did not feel capable of investing more operating resources in order to attain them. With that commitment from Belcher in hand, the Department put its backing behind TEAL. Many factors probably figured in the Department’s commitment, including the issues already mentioned in this essay and the fact that MIT, although a pioneer in laboratory work for undergraduates in the nineteenth century, had abolished required laboratory work in freshman physics several decades earlier.

In 2000 both iCampus and d'Arbeloff grants to TEAL were announced and work, including a search for adequate space for the 100 student sections, began.⁴⁷ Curriculum development began for 8.02, the second term of physics that focused on electricity and magnetism. The first offerings of the new format would occur in the fall term (most MIT students took first term physics in the fall and second term physics in the spring, but a mix of first year and other students took second term physics in the fall each year, giving Belcher a nice sized pilot group.) If the

⁴⁶ The iLabs cluster of iCampus projects takes a complementary approach to this problem of lab costs by having students work on the equipment one at a time, 24x7; iLabs is discussed elsewhere in this report.

⁴⁷ The department, then and later, did not intend that 8.02T be the only option for physics. Students could also choose a more calculus-intensive version of physics, 8.011/8.012, which continued to be taught in a lecture-dominated fashion.

program succeeded in this pilot phase a few times, it would be implemented for all undergraduate taking 8.02, and work on 8.01 (mechanics) would begin.

Around this time, Belcher's work received another endorsement from MIT when, in June 2000, he was named one of six new MacVicar Fellows, to assist his efforts to improve undergraduate education.

Institutionalization factors: By this time, MIT had invested heavily in these experiments – d'Arbeloff and iCampus money were complemented by multi-million dollar investments of Institute funds in the creation of TEAL classrooms -- in part because the Physics Department had asserted that, if the experiments succeeded in improving physics learning, TEAL would be institutionalized.⁴⁸ This promise was essential for justifying the investment of approximately \$2 million of Institute funds in the facilities (over and above the iCampus and d'Arbeloff grants). The Department would have an escape route if the evaluation results were not good, but a heavy commitment had already been made to moving forward with TEAL for a period of years.

Space plan: The resulting plan and facilities mark a paradigm shift in physics instruction for MIT. To choose a single element, a TEAL classroom has no 'front', no well-equipped, protected place from which an instructor customarily lecture. In TEAL it's expected that the instructor will move from group to group for much of the class time. A second element: TEAL classrooms are a far cry from traditional classrooms where students are equipped only to take notes, or perhaps to use a laptop. TEAL's space is designed to help small groups share work and thinking with each other and the larger class: personal response systems, screens and easels to make it easier for students to share equations, simulations, and ideas.⁴⁹



The TEAL Pilot in 8.02 and the Evaluation Results

Only a little over a year was available to develop 8.02 (TEAL) before its first prototype offerings scheduled for Fall 2001 and Fall 2002. This preparation went without much public attention, with one exception. TEAL would need an unusual classroom, one big enough for students to work at about 10 tables, each roundtable big enough to hold 3 groups of 3 students and their equipment. It became known that the top floor of the Student Center, a popular student study

⁴⁸ iCampus asked that all proposals include a statement about sustainability.

⁴⁹ For a short video of the TEAL classroom being used for physics, see <http://icampus.mit.edu/teal/>. As of October 2006, a button in the upper right of this page led to the video.

area, was being considered for conversion to classroom space, which aroused a vigorous student reaction. MIT quickly dropped that idea and the Physics Reading Room was selected for conversion. Later, when other reasons for student opposition arose, some people would remember that TEAL had already been a villain once.

The new classroom drew heavily on the design R&D work done for SCALE-UP at North Carolina State. For example, NC State had experimented with several different sizes of tables before setting on the design that they, and later MIT, used. MIT's version of the SCALE-UP classroom was developed with far more money than NC State's.

The first prototype version of TEAL was offered to 190 students (40 more than the 150 originally planned) in Fall 2001. Most students take 8.01 (Newtonian physics and mechanics) in the fall, and 8.02 (electricity and magnetism in the spring). But each year smaller numbers take these courses in the opposite terms. So the new course design received its first test with this smaller number of students who were taking 8.02 out of phase. Learning from the Fall 2001 and Fall 2002 TEAL versions of 8.02 were later compared with the Spring 2003 8.02 (taught via traditional lecture techniques).

The early 8.02 sections produced dramatic improvements in student conceptual understanding. Students were given a pre-test of their insight into fundamental physics concepts, and divided into three groups. As the following table indicates, all three groups gained substantially from 8.02 taught through TEAL.

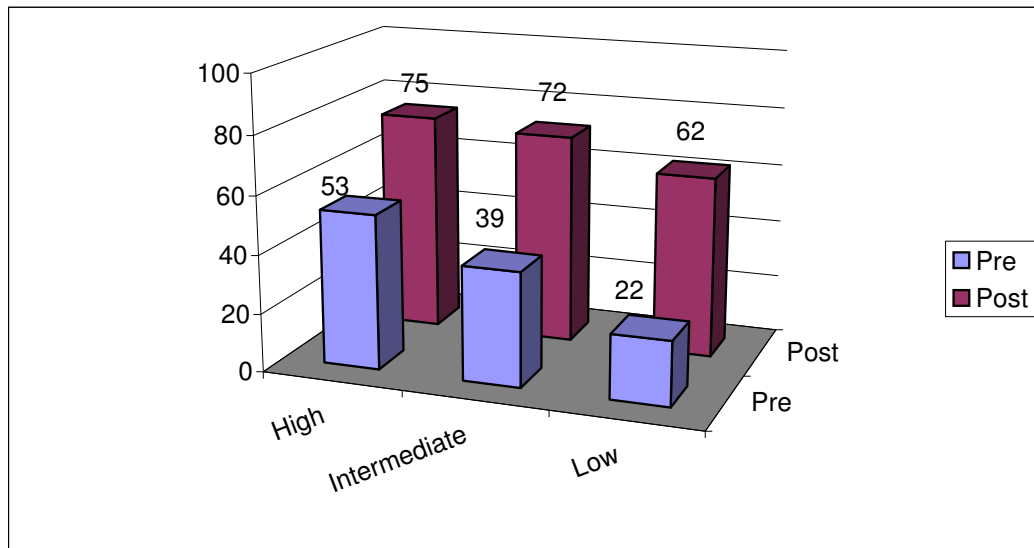


Figure 1: Pre- and Post-test Results For Spring 2003 8.02

Many faculty wondered whether TEAL would achieve the kinds of gains in conceptual understanding being achieved by other reform efforts. Richard Hake pioneered the most widely used method of making such a comparison (Hake 1998)

$$\langle g \rangle = \frac{\%Correct_{post-test} - \%Correct_{pre-test}}{100 - \%Correct_{pre-test}}$$

Sometimes called a Hake gain, this statistic allows comparisons across groups by comparing what students actually gained from pre-test to post-test, with the maximum they could have gained. The type of approach used by TEAL is called “interactive engagement” (IE). Hake studied 48

examples of interactive engagement in physics and found that the average gain across those examples was .48.

The table below compares the first full-scale implementation of TEAL in 8.02 (spring 2003) with the very first prototype run of TEAL (fall 2001) and the final lecture-style offering of 8.02 (spring 2002). Students in the scale-up of TEAL in spring 2003 (.52) did far better than the lecture group (.27). This doubling of gains from traditional methods is also typical in other universities when IE methods are compared with more traditional lectures and laboratories.

Group	Large-Scale TEAL spring 2003		Prototype TEAL fall 2001		Control Group Lecture/Recitation spring 2002	
	N	Gain	N	Gain	N	Gain
All	514	0.52	176	0.46	121	0.27
High	40	0.46	58	0.56	19	0.13
Intermediate	176	0.55	48	0.39	50	0.26
Low	298	0.51	70	0.43	52	0.33

Table 1: Normalized Gains for the Pre- and Post-testing for the terms shown

In addition a study was done of 8.02 and other courses using the new classroom in order to make suggestions for improving the facility. (Breslow, Lipson and Tervalon, 2002)

By this time, the TEAL version of 8.02 had taken on a distinctive shape. As Belcher described the course in a 2003 article,

“In the TEAL classroom, nine students sit together at a round table, with a total of 13 tables. In five hours of class per week (two two-hour sessions and one one-hour problem-solving session led by graduate student TAs), the students are exposed to a mixture of presentations, desktop experiments, and collaborative exercises.

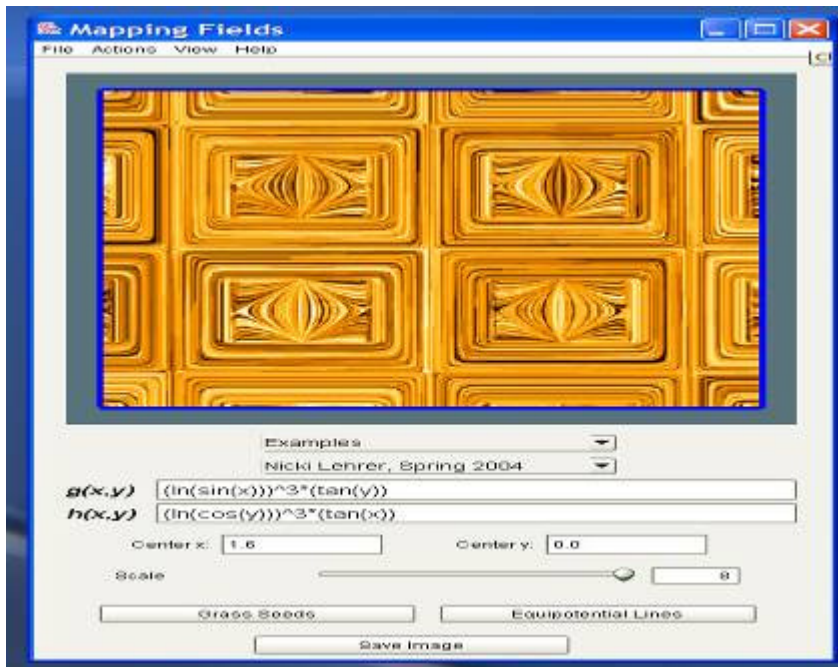
“The course was broken down into six sections. A physics faculty member, assisted by a physics graduate student, an upper-level undergraduate who had previously taken the course, and a member of the Physics Demonstration Group, taught in each section...

“Students were assigned to groups of three and remained in those groups for the entire term. In the two prototype versions of the course, we assigned students to groups based on their score on an electromagnetism pre-test, discussed below, using heterogeneous grouping (i.e., each group contained a range of student backgrounds as measured by the pre-test score). In spring 2003, because of the logistics of dealing with over 500 students, we assigned students to groups randomly.⁵⁰ The grade in spring 2003 was based on: inclass activities, desktop experiment summaries, and worksheets; standard weekly problem sets; questions about reading assignments that were turned in electronically

⁵⁰ SCALE-UP uses heterogeneous groups, changed several times during the term, to maximize the degree to which students learn from one another and to minimize the degree to which group discussions become social interactions rather than problem solving. MIT later changed these procedures to conform to the SCALE-UP model.

before each class; three one and one-half hour exams; and a final. Three-quarters of the tests were made up of the standard “analytic” problems traditionally asked in 8.02; one-quarter of the tests were made up of multiple-choice conceptual questions similar to questions asked in class and on the pre- and posttests. Students typically score lower on these multiple-choice questions because they test concepts that may not be well understood, and because there is no partial credit. The course was not curved. In other words the cut-lines for the various letter grade boundaries were announced at the beginning of the term. Because collaboration is an element, it was important the class not be graded on a curve, either in fact or in appearance, to encourage students with stronger backgrounds to help students with weaker backgrounds. *Also, the cutlines in the course were set in such a way that a student who consistently did not attend class could not get an A.* [emphasis added] This was a deliberate policy to encourage attendance, based on the belief that at least part of the reason for the traditionally high failure rates in 8.02 is the lack of student engagement with the course.” (Belcher, 2003)

The tools for simulating electromagnetic fields, developed by Belcher, figured prominently in TEAL. They were designed to help students learn to visualize the fields that, previously, had been represented only by equations⁵¹:



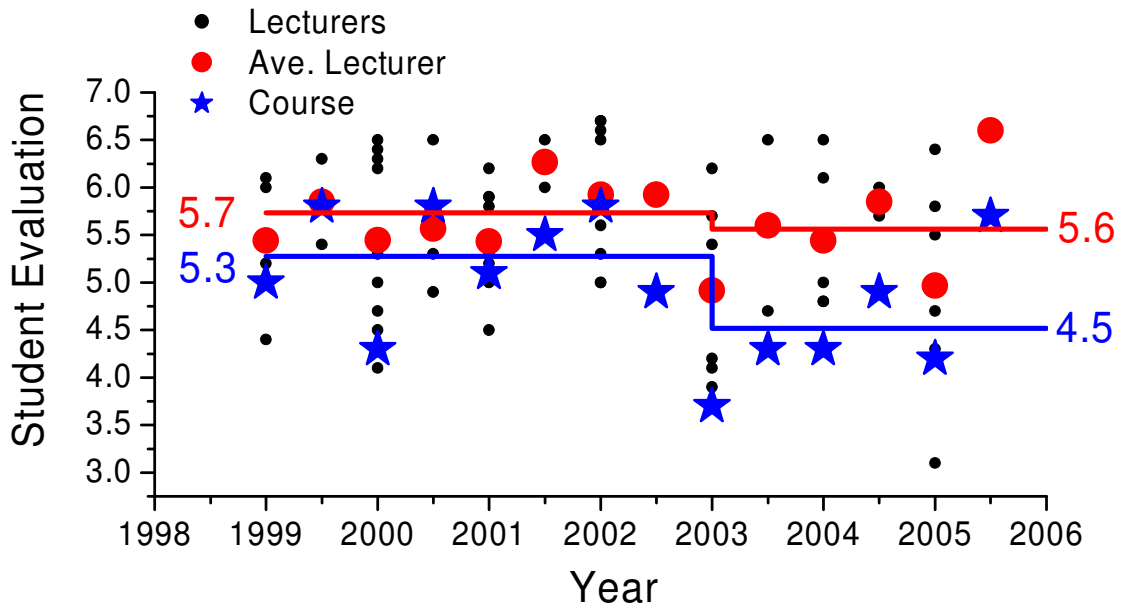
After the developmental period in which the TEAL version of 8.02 was taught only in the fall with 100-200 students, the next step was to offer it during spring term, for the 500+ students. It was around this time that iCampus funding ended and a proposal from Belcher for additional support was turned down. Belcher recalled later, “iCampus said you did it two years and it was well-received and we’re not going to fund you anymore. I said they were nuts and it could go down the drain 10 minutes. And then we went from 180 students to 500 and six new faculty who had never taught it before. That was spring 2003. That was the spring that will live in infamy. It was the worst academic term of my life.”

⁵¹ To see these materials, funded by the d’Arbelloff Fund for Excellence in MIT Education, iCampus, and NSF, see <http://web.mit.edu/8.02t/www/802TEAL3D/>.

Resistance to TEAL

The TEAL version of 8.02 (electricity and magnetism) was well-received until, in spring 2003, it became the required way for most students to take physics (students planning to be physics majors usually took another version, 8.022, which was both lecture-centered and more abstract and mathematical). The first year that TEAL was required, its leaders had to deal with several simultaneous challenges: involving many more of their colleagues as leaders of TEAL classes; shakeout problems with a scaled-up program; and resistance from students who were now compelled to take the course.

The first observation to make about this rather well-publicized student resistance is that it has been far from unanimous. The only source of systematically collected data, end-of-course student evaluations, suggests that the problem was temporary, and linked to problems in the first term of full-scale reliance on 8.02 (a term in which we have seen that gains in physics concepts were dramatic). This table of student evaluations of 8.02 was assembled by Prof. Eric Hudson.



The figure charts student responses to two questions:

- Overall rating of the course on a scale from 1 ('very poor') to 7 ('excellent'), and
- Overall rating of the instructor, on a scale from 1 ('very poor') to 4 ('average') to 7 ('excellent')

The figure shows a dramatic drop in student evaluations of 8.02 at about the time that 8.02 went exclusive to the TEAL format, from 5.3 (about half between 'average' and 'excellent') down to 3.7 (a little below 'average') for the first offering of TEAL as a required format.

After the initial sharp decline, however, there is a steady upward trend. By Spring 2005, 8.02 evaluations (the course) are as high as they ever were before TEAL (around 5.7 or 5.8), and

evaluations of the 8.02 faculty⁵² were higher than at any point since 1998 (around 6.5 compared to a previous, pre-TEAL high of around 6.3). That's true even though TEAL was 'forcing' students to attend whereas students who didn't find lectures valuable had not been around to fill out their survey forms; the TEAL data come from about 80% of the enrolled students while the lecture version of the same course drew ratings from only about 40% of the students. Hudson found that the 1998-2005 course evaluation average for 8.01 was 4.8 (mostly pre-TEAL) and the long term average (again, mostly pre-TEAL) was 5.7. In other words, judging from course evaluation data, teaching in TEAL didn't affect evaluations of 8.02 faculty much, and evaluations of the course, which dropped sharply in the term when it was first taught as a requirement, have now risen to levels higher than they were in pre-TEAL days.

Nonetheless, complaints from students who don't like TEAL have periodically reached the ears of the student newspaper, reinforcing the impression that TEAL is less popular than its precursor.

So let's focus on the nature of that reaction. We have no way of knowing what the breakdown of opinion has been, and it almost certainly has varied from class to class. A recent study of student opinions of TEAL by Murthy (2006) includes the observation that most comments were mixed, illustrated with this quotation that will satisfy neither TEAL's advocates or its opponents:

□ "I think the format could be more effective, but for a required course it's okay I guess."

Some of the origins of this resistance are probably common to all studio physics at selective institutions. Students have been accustomed to excelling by practicing certain forms of problem solving in high school physics, and to being the best in the class. In TEAL and other studio courses, students not only find that this previously successful mode of thinking fails: they may find themselves confidently stating wrong answers in front of their peers, some of whom are outperforming them. In a studio course, it can be embarrassing, or impossible, to wait for someone else to commit publicly to answer and see what the right answer is, before saying, "Yes, that's what I was thinking, too." Perhaps this 'embarrassment factor' is greater at MIT where students are only months removed from being unquestionably the brightest students at their high schools, and virtually always right.

Clash of the SCALE-UP model with MIT culture? The opposition to TEAL at MIT seems to have been greater than at the many other institutions that also adapted the SCALE-UP model from North Carolina State or other sources. If so, one reason may be that relatively consistent attendance (in order to participate in collaborative activities) is required to get an A. As Belcher asserted in the article quoted above, this move was taken after some thought, as a reaction to high levels of absenteeism in physics. Studio physics courses try to foster deeper conceptual learning through student discussion, debate, and collaboration in problem-solving. The more students are absent, the more it hurts those students who come to class, as well as those students who miss the discussion. But for decades at MIT, freshmen would boast that they could get A's in courses (and carry heavier loads) by simply reading the textbook, doing problem sets, and then "acing" exams. So the discomfort of TEAL's pedagogy was multiplied by a sense of outrage at what seemed an arbitrary requirement that students participate in at least some group work in class in order to get an "A."

There may be other reasons for lower ratings, too. One faculty member in the MIT Department of Physics has suggested that there are so few good teachers among the 80+ faculty in the Physics Department that TEAL's demands will inevitably result in less popular lecturers, dragging down the average rating of TEAL sections.

⁵² Hudson used figures from the 8 largest sections of pre-TEAL physics to calculate the pre-TEAL statistics in this chart.

Whatever the reason, in spring 2003, students complained wherever they could; 150 students signed a petition to make TEAL, at most, an option for freshman physics. According to a story in “The Tech,” the student newspaper, “8.02 TEAL does not provide us with the intellectual challenge and stimulation that can be expected from a course at MIT. We feel that the quality of our education has been compromised for the sake of ‘trying something different.’ We strongly advise that the traditional 8.02 course be reinstated as soon as possible.” (LeBon, 2003)

Student ratings and happiness may have been low at first, but learning of physics concepts had improved, as had attendance or pass rates in the course, according to the research being done. So the Department went ahead with its plans to expand TEAL to include 8.01: first term physics. A new classroom was developed, at a cost of almost \$2 million more, so that the Institute would have adequate capacity for its new standard for physics instruction.

8.01 is still undergoing major modifications. Early evaluation results were not as strong as those for 8.02, for reasons that are not yet clear. But the Department remains committed to its development. TEAL has shown good educational results overall, and, as one faculty member commented, when the chairman of the Corporation puts his own money on the table, it’s hard to backslide.

One other impact of TEAL on physics at MIT is important to note: Lillian McDermott of the University of Washington, a leader and pioneer in the field of physics education research, has recently been added to the Department’s Visiting Committee. This is the first time that physics education research has been considered important enough to warrant a role in oversight of the department.

Impacts of TEAL Outside MIT, Alone and via SCALE-UP

There’s a spectrum of impact that runs from ‘replication’ (when an innovation is copied or used in new settings in ways that closely resemble the original use) to ‘adaptation’ (when substantial changes are made in the new site) to ‘influence.’ Influence is almost always the most common of these and no more so than in the case of TEAL. TEAL’s combination of elements: its challenging content, expensive facilities, unusual pedagogy, and the content of physics itself make replication quite unlikely and even adaptation unusual. We saw a number of instances of influence in our interviews, even though we weren’t seeking them specifically: faculty who mentioned that they’d glimpsed TEAL and were inspired by its vision of active learning; instances where TEAL classrooms were used in other disciplines.

The following paragraphs deal with some instances of adaptation of elements of TEAL outside MIT. These are not the only instances of substantial adoption or adaptation of TEAL, but the page does describe most of the adoptions of which we are aware.

Wider Adoption of SCALE-UP: Bob Beichner, director of SCALE-UP, thinks that MIT’s adoption of SCALE-UP helped persuade many (dozens?) of institutions to pay more attention to the SCALE-UP approach. If he’s right, this may have been the principal source of adaptations stemming from TEAL, since TEAL and SCALE-UP share similar pedagogies and some similar facilities (the general space plans are similar, but the greater expense of the MIT rooms is due in large part to the extensive use of projection screens for sharing information among faculty and students.) Beichner is quite grateful to John Belcher for insisting continually that SCALE-UP be mentioned in the coverage of TEAL.

TEAL at National Chung Cheng University: NCCU in Taiwan has adopted TEAL, building a classroom along MIT lines. The classroom has a capacity of 100 students but in TEAL’s first two trial runs, 50 students have been in each class. So far, NCCU is the closest thing to a replication

of MIT's program but there are, of course, substantial differences. NCCU's budget for TEAL was spent mainly on physical facilities, so not much remained for buying equipment needed for student experiments. Budgeting for laboratory equipment is a priority. Other differences include the language, the textbook, and the length of the class (1.5 hours instead of 2 hours). Nonetheless NCCU is seeing substantial gains in student learning, up 25% from last year on a test based on the Force Concept Inventory (FCI). The professor, Jaw-Luen Tang, is also seeing increased student participation in conversation (unusual, he reports, for Taiwan where students are ordinarily quiet in class). Here are some pictures⁵³ of the NCCU TEAL classroom in action:



The left hand photo shows an experiment in progress, while a simulation of the experiment (showing the E&M field) is displayed on the screens in the room.

NCCU's experience is not the same as MIT's, of course, in part because of other contextual differences. NCCU attendance in traditional physics was already high, for example, so NCCU did not experience student resistance to attending class.

NCCU is a regional iCampus hub, disseminating the TEAL model to colleges and high schools in Taiwan.



The photos above show a TEAL-style classroom at Hu-Wei Senior High School. Their classroom is half the size of that at NCCU, holding about 50 students, with 4 projectors, 3 360-degree video cameras, and 5 student tables (6-feet long, each table seating 9 students). It is funded by Taiwan's Ministry of Education.

⁵³ All Taiwan photos were taken by Sheng-Chien Chou and Ming-An Tsai, students of Prof. Jaw-Luen Tang of NCCU.

With support from NCCU, National Dong Hwa University is also planning to build a TEAL classroom. Ren-Hung Hwang, director of the teaching center and coordinator of ‘hub’⁵⁴ activities at NCCU, reports on other elements of NCCU’s support for adoption of the TEAL model. “Concordia Middle Highschool (Chia-Yi, Taiwan) [has] organized a program based on TEAL’s courseware for their physics-talented high school students. We have also just submitted a proposal to Ministry of Education to request budget to promote TEAL to universities in our region (about 17 universities/colleges in our region). If this proposal is granted, we will have a second TEAL classroom in CCU, and several TEAL classrooms in other universities, and we will also have more human resources to work on courseware and lab design... We offer training courses for instructors that interested in TEAL, and host conferences to introduce TEAL and our work on TEAL... Currently, we have funds from Ministry of Education, Taiwan to promote TEAL via purchasing more equipments for labs, designing labs and courseware, and spreading the experience of TEAL to other universities. (budget allocated to CCU TEAL project is around \$US 0.3 millions).”

Worcester Polytechnic Institute (WPI) use of simulations: Assistant Prof. Carolann Koleci has been working with John Belcher, Peter Dourmashkin, and others at MIT in trying out visualization tools from TEAL in physics courses at WPI.

Koleci, whose Ph.D. is in Physics Education Research, had originally heard about TEAL at an AAPT meeting, from Sen Ben Liao, a professor then holding a visiting appointment at MIT. His poster session was next to hers at the meeting, and they started talking about physics innovations. The conversations ultimately led to a Fall 2004 study of the usefulness of visualizations in physics learning at WPI. A subsequent MIT-WPI study integrated Belcher’s visualizations into Mastering Physics instructional materials and tools (also used in TEAL at MIT).

WPI’s use of TEAL ideas and products seems to be limited to Koleci at this point. WPI differs from MIT in many respects: WPI’s seven-week term, its small size, and emphasis on learning by working on projects among those differences.

SUNY Stony Brook use of Content: A continuing theme in this report is how unlikely and, often, uncomfortable it is for typical faculty to talk with peers, especially at other institutions, about how to improve a particular course that they both teach. Koleci at WPI happened sit beside a TEAL representative at AAPT (a meeting that neither might have attended had not both been committed to physics education research). Gene Sprouse, an award-winning teacher at SUNY Stony Brook, discovered TEAL because he is an MIT alumnus and heard a presentation about TEAL at his 30th class reunion. He discovered that TEAL curricular materials were available through MIT’s OpenCourseWare Initiative (OCW) and began using them, a bit more each year.⁵⁵

Sprouse’s story illustrates both the multi-faceted nature of TEAL and also the pragmatic way in which effective faculty try to improve their courses. After several semesters of using bits of TEAL material,

“This semester (spring 2006) I bit the bullet and decided to use a lot more material from OCW. I don’t have a TEAL classroom. I picked the visualizations. I use them a lot. This semester I also used the problem solving sessions that were available on OCW. The way I

⁵⁴ MIT has agreements with a number of institutions around the world to serve as ‘hubs’. In exchange for extra support from MIT for their own activities, these universities have agreed to promote iCampus projects to other institutions in their region. For more detail on one of these hubs, see Chapter 8 of this report.

⁵⁵ As an example of OCW offerings, here are the TEAL materials from the spring 2005 offering of 8.02: <http://ocw.mit.edu/OcwWeb/Physics/8-02TSpring-2005/CourseHome/index.htm>

The site includes TEALsim simulations as well as other materials.

teach the course, I have three 55-minute lectures, one 55-minute recitation, and one two-hour lab every week. I use the Mastering Physics homework system⁵⁶. I'd done that for the last three years, since it first became available. The recitation section – the Mastering Physics does a lot of the tutoring – so I would use it to clean up problems that students had trouble following. There weren't so many of those. So I decided to use my recitation time to do the problem solving sessions. In a "problem solving session" the students work in a group of three. The problems that are on OCW are usually things you'd do as a derivation in a lecture. But if you force the students to work through it themselves, it's a challenge. It's not a physical experiment. It's a thought problem. The first one is using line integrals to do surface integrals. It's something they may not have seen yet in calculus. It scared them when they heard about it but at the end of the hour, when they had solved it, it meant something to them. And you need that in order to talk about Gauss's Law, Faraday's Law. That was just one of the sessions. [The students] loved it. They liked talking with each other. It's the nature of young students. They work on a problem together, talk about it, teach each other, kid around. They like the relaxed nature of it. The TA and I walk around the room and answer questions. It's very informal. That's something I lifted from TEAL that I really like."

Windward School: The Windward School in Los Angeles has been studying TEAL closely, using it as a guide for renovating a classroom for Fall 2006 and to help design two new academic buildings: a math/science building and a learning center/library. Eric Mandel, a teacher of history and Director of the Middle School at Windward, joined the Windward team on its second or third visit to MIT, and his thinking about his own teaching was abruptly changed when he saw an MIT physics class learning in a TEAL classroom. "It was the notion that really the whole class was based on an active learning model, as the name suggests. So that, to me, was the notion that students can be taught in a way, that they can get what they need from the lesson without having the professor, sage-on-the-stage model." Mandel was struck by how the professor could organize a large piece of a class by assigning students to work in groups on a complex task, using tools at their table. He also was excited to learn about the potential of personal response systems. Mandel is one of the first Windward teachers to use their renovated TEAL-style classroom, and he is using it to teach "Introduction to American Government" to seventh graders.

A Chemistry TEAL: The TEAL classrooms attract a steady stream of visitors to MIT. One of those people who has studied the MIT work quite closely is Prof. Peter Tregloan, a chemist from the University of Melbourne in Australia. The evolving chemistry subject at Melbourne is similar to TEAL at MIT in some ways, and quite different in others. That's not surprising: replication is rare in higher education. Adoption almost always involves adaptation. Aside from the most important difference (chemistry versus physics), here are a few other ways in which the Melbourne work differs from that at MIT:

- At MIT, lecture and recitations (problem sessions) have been combined, while at Melbourne, only the recitations are being transformed. Previously they were held in a small lecture theater with banked seating. That facility has now been transformed into a TEAL-style classroom.

⁵⁶ This system of homework problems, homework checking and associated tutorials was developed by Prof. David Pritchard of MIT, without external funding and independent of TEAL. In contrast to the open source distribution of TEAL (no charge to users, nor revenue to authors or distributors), Pritchard licensed his material to a commercial publisher and the body of materials has steadily expanded. Mastering Physics materials have been used with great success in the TEAL versions of physics at MIT.

- Because Melbourne space was small, their new Learning Laboratory is about half the size of TEAL classrooms at MIT. Its capacity is 40 students, seated in five zones. As indicated in the schematic below⁵⁷, each zone is at a different level, to help students work in small groups.
- Like TEAL student groups will work on solving problems designed to improve their ability to apply concepts. Unlike TEAL they will not use personal response systems, nor will chemistry lab work be done in the space.



Use of the TEALsim Tool in Other Fields: After six years of almost full-time, exhausting effort on TEAL, John Belcher is no longer active in teaching introductory physics. But he retains a strong interest in using simulations to improve learning. He currently is using the TEALsim software to create a protein visualizer for a chemistry course.⁵⁸

Summary of Factors Affecting Adoption of Studio Physics Models

The most important driver of studio physics has been the field of physics education research. Early work showing unmistakable signs that even good faculty had been fooling themselves about student learning helped draw in enough funding over the years for some talented physicists to shift their research partly or wholly to physics education. These pioneers in turn could become centers of outreach, sometimes receiving grants to help other institutions move forward, as Bob Beichner of SCALE-UP did. The R&D of physics education, receiving endorsements for

⁵⁷ Our thanks to Peter Tregloan for providing this architect's rendering of the new classroom.

⁵⁸ For more on TEALsim, see <http://jlearn.mit.edu/tealsim/index.html>.

authorities as respected as the National Academy of Sciences, was crucial for drawing faculty support from MIT for this dramatic shift.

Other factors can favor the adoption of various studio models. At RPI, for example, according to Brad Lister one reason for the institutionalization of the studio model is that many Physics faculty prefer teaching in a studio. We know that some MIT Physics faculty prefer this style, too, but we have no data on how many faculty feel this way.

Adoption of elements of TEAL at some institutions described above has also been driven by the content: the simulations and problem materials.

TEAL and SCALE-UP are unusual kinds of innovations. Most improvements in teaching are done one course at a time, one faculty member at a time. Each faculty member can make his or her own choices, expecting not to be pushed by anyone else. But studio physics, to maintain traditional levels of costs/student, requires large numbers of students and large numbers of tenured faculty: those expensive classrooms have to be used by many courses in order to justify the investment. So an unusual degree of consensus is required. The struggle to achieve such a consensus can be bruising. .

Recommendations for TEAL

The evidence we have seen convinces us that the TEAL approach currently embodied in 8.01 and 8.02 is a) a substantial step forward in teaching physics concepts, and b) an unfinished transformation. We say that it is unfinished not just because of resistance by some students and faculty but also because of the importance of physics in so much of what MIT seeks to teach.

‘Forward’ can best be defined as a process of intentional, evidence-based improvements in teaching and learning. Among the most important goals, in our opinion, is that students in all majors be able to apply ideas and techniques from introductory physics to issues they will face in their professional and personal lives; that they come to appreciate the idea of elegance in physics; and perhaps gain some sense of the field’s history.

1. Sources of Ideas

One source of input for such improvement is international literature on learning in physics, which requires that the Department invest in following that literature and sharing its most important findings and methods with staff. The attachment to this chapter is meant simply as an existence proof: other physics programs are doing exciting and effective work, and MIT’s Department of Physics has a responsibility to be aware of this state of the art, incorporating and improving on it as appropriate.

2. Faculty as Inquirers

MIT, and institutions like it, seem to be between a rock and a hard place. On the one hand, the physics faculty have a responsibility to undergraduates, to their faculty colleagues, and to the larger world to teach modern physics as effectively and efficiently as possible. On the other hand, the culture of departments such as MIT’s encourages the beliefs that a) time spent on teaching and on physics education research will likely damage not only one’s own research but also the department’s standing in the world and thus its command of resources, b) one can teach effectively by spending rather minimal time on that activity, c) command of physics content and the ability to speak reasonable English are the major skills needed for effective teaching, d) a certain rate of failure and drop-out are acceptable even with students of the caliber admitted to MIT. To summarize: it’s important to improve students’ learning but there is little time or support for doing so.

We don't see either of those changing anytime soon. So the question becomes, how can MIT faculty learn how to teach more effectively with only minimal time spent on the task? We have several suggestions, and hope at least a few of them will prove useful.

- **Continue to invest in the improvement of teaching.** Alex d'Arbeloff, when Chair of the MIT Corporation, had to persuade MIT to allow him to give millions of dollars for teaching improvement, at a time when some people at MIT would apparently have preferred money for a building. Raising money to help faculty improve learning in their courses ought to be a priority for the Department and for the Institute. One way to spend such money is on staff (postdocs and/or other professionals) who can engage in Physics Education Research and who can help interested faculty to develop new approaches and assess their outcomes and costs.
- **Research Program on Science Learning:** We suggest that the Department and the Institute invest in a program of research around General Institute Requirement subjects such as introductory physics. One focus: find or develop easy-to-use assessment tools and procedures that faculty (and researchers) can use to guide student learning. Another focus: in what instances are students who have passed these courses able, or unable, to apply what they have learned in later MIT courses? What can be done to improve these results?
- **Observe Colleagues:** We suggest that faculty frequently find the time to observe the teaching of their colleagues. At least one college in the US helps faculty announce to colleagues which days their classes are open to faculty observers. This practice is common in 8.01 and 8.02 already, and ought to be extended.
- **Staff meetings in multi-section courses should include students, and focus partly on improving learning:** We suggest that 8.01 and 8.02 staff meetings include faculty, teaching assistants, and undergraduates representing various sections. These staff meetings should not become totally focused on 'nuts and bolts.' They should analyze how the course has been going each week, gathering searching feedback from participants, before discussing how plans should be adjusted for the following week. Some of these meetings would also be appropriate for discussion of innovations and findings from other institutions.
- **Learning about learning should be a goal for 8.01 and 8.02:** Students often resist active and collaborative learning in part because they believe they learn best by listening to lectures, taking notes, and working alone on problem sets. 8.01 and 8.02 ought to help each student test whether or not that theory is correct, and under what circumstances. This can be done with little alteration of the curriculum. The 'natural experiment' is being performed all the time, but without any collection of data. Faculty teaching 8.01 and 8.02 could ask students whether each week they want to work alone, watch video lectures, etc. or whether they want to take part in the class's activities; the average score of all those who studied alone can be compared with those who engaged in active and group learning.
- **It Takes a Village...:** We suggest that the Department and MIT invest in widening exchanges and frequent communication with other institutions engaged in the reform of introductory math, science, and engineering courses, institutions such as RPI, North Carolina State, the University of Illinois, the University of British Columbia, and many others inside and outside the US. Such collaboration is important as a means of sharing knowledge and insight about new practices and the problems they cause. MIT is more likely to attract the resources and talent needed to make spectacular improvements in student learning if it works with other institutions.

Attachment to Chapter V – Brief Sketches of Several Other Innovative Physics Programs

In addition to the excellent SCALE-UP program at North Carolina State that has so directly inspired the work on TEAL, our research has led us to three other programs that seem worth attention from MIT and TEAL. We have selected these not because they are the best such programs and certainly not because we are experts in physics education research, but because they differ from one another, and from MIT, in interesting ways.

Rensselaer Polytechnic Institute (RPI) – Studio Courses Across the First Year Curriculum

One of the landmark developments was the adoption of research-based techniques (collectively referred to as a ‘studio course’) not only for all physics sections but also for much of the rest of the first year of instruction at Rensselaer Polytechnic Institute (RPI). Their campaign⁵⁹ began in the late 1980s, according to Brad Lister, Director of the Anderson Center for Innovation in Undergraduate Education where much of the studio work has been headquartered. Lister said in an interview that the studio work didn’t yield institutionalized practices and definitive evidence of educational gains on a large scale until about a decade after the work first began. RPI is now 15 years into its Campaign, and working on second generation studios; the new work focuses more on the online assignments and interactions that occur before class time, helping both students and faculty to prepare for class. Meanwhile, Lister reports, about 10-15% of RPI students feel that studios ‘aren’t for them.’ Nonetheless for physics and a couple of other courses, studios are the only way the courses are offered.

University of Illinois: “Avoid Burnout; No Heros!”

According to Gary Gladding, Associate Department Head at the University of Illinois at Urbana-Champaign, current efforts to improve physics instruction at the University got their start with a visit by Prof. Dave Hertzog to Tufts University (not far from MIT). Hertzog brought back ideas about predict-observe-explain laboratories that he’d learned from Ron Thornton and his colleagues. These labs focused on concepts, not instruments, and often involved students working in pairs: predicting what the experiment would show before doing it, taking data, and then interpreting what the data meant in terms of concepts. When Hertzog implemented the Tufts-style labs in his algebra-based physics course, the results were remarkable. Students at Illinois are routinely asked to rate the relative contributions of different elements of their physics course to learning; “Lab” was almost always at the bottom of the ranking for this course. In Hertzog’s course, using the new labs, the Lab was ranked #1, the single most important contributor to learning physics.

⁵⁹ Education/Technology Campaign is a term that we’ll define more formally in Chapter 10, “Findings.” Briefly, an Education/Technology Campaign aims to achieve a significant educational improvement at the programmatic, institutional or national level (typically), an advance that is to some degree defined by its use of technology. The Education/Technology Campaign(s) at RPI, at MIT (TEAL), at North Carolina State (SCALE-UP) and many other institutions are primarily aimed at increasing the power of introductory physics to teach fundamental concepts to a wide range of students by using active learning pedagogy supported by probeware, personal response systems, physics laboratory equipment usually in rooms renovated or designed primary to support group work by students. These rooms are usually called ‘studios.’

Within a few years, the Department launched a larger effort to rethink physics instruction in many of their courses. It was a large order: the department handles 2500 students per semester in introductory courses alone. As Gladding recalled the situation in a recent talk at a conference on the institutionalization of reforms in physics education, faculty in the 1990s saw teaching introductory physics as an exhausting obligation. The courses had changed from time to time, but the program didn't seem to be making any progress as a result. Gladding chaired a committee of 8 physicists commissioned to take a deeper look at the problem.

The guiding principle of Gladding's committee: "Eliminate burnout and need for heroic efforts!" They wanted to develop improvements that could be easily implemented without any unusual expenditure of faculty time or effort.

The committee work met regularly for a year, studying what other institutions were doing and adapting those ideas that seemed most promising to their own ways of doing things. The committee's year of collaborate research and planning also functioned as professional development and as team-building. They also decided that it was important to have a set of changes that, while individually easy, were mutually reinforcing. They saw "interactive engagement"⁶⁰ as a theme that could help these various changes reinforce each other and, together, improve learning. Changes that, done alone might be ineffective or eroded by the status quo, could help each other work. So one goal was to develop an efficient, effective infrastructure that could relieve faculty of as much busy work, stress and risk as possible. Two examples: effective departmental secretaries handle much of the routine administrative work. The faculty member can show up at the beginning of the term and be given handouts, a web site ready to go, etc. Another example: homework that can be automatically graded. Modest remodeling was also needed for the rooms to be used for discussion. Historically problem sessions had actually been mini-lectures. Now they were to involve group work, so desks were replaced with small tables and chairs.

The committee also developed a division of labor for teaching large enrollment classes. A team of faculty would run each such course: one or two lecturers, one overseeing discussion and training the TAs for their critical role as coaches, and one overseeing laboratories. The faculty together would create each exam (a typical course would have four exams during the term). During the planning period much emphasis was put on developing discussion routines, lab projects, homework and other material that would all foster interactive engagement and conceptual mastery.

Results have been good. For example, tests on questions common to both traditional and new exams showed gains on almost every question. Gains on the Hestenes Force Concept Inventory were good. And the number of TAs rated "excellent" by their students went from about 20-25% a term to around 70-80% per term.

An important, unplanned element of Minnesota's strategy was to develop a Physics Education Research Group in the Department. The program, led by Gladding, has graduate students and postdocs, and has lured Jose' Mestre, a noted scholar in the field, to take a half-time appointment in physics and a half-time appointment in Education. The program also has brought a succession of top notch experts to visit the program, experts such as Nobel Laureate Carl Wieman who now works full-time in Physics Education Research.

The reforms have been in place at the University for about a decade now and seem stable.

⁶⁰ To learn more about "Interactive Engagement" (IE), see, for example, Hake (1998).

The University of Minnesota: Innovations in Physics Instruction That ‘Fail Gracefully’

Ken Heller’s group at the University of Minnesota focuses on the implementation/adoption problem. Heller is Associate Head of the Department of Physics. A particle physicist, he also does some work in Physics Education Research. Minnesota, like MIT and many other large institutions, has to invest the time of many faculty and graduate students to the teaching of introductory physics.

In Heller’s opinion, many of widely-discussed innovations in physics education, including the family that includes workshop physics, studio physics, SCALE-UP and TEAL, have scored wonderful successes but also have one unacceptable characteristic. Heller has borrowed a term from engineering. When they fail, he says, they can fail catastrophically. “I know too many people who have tried this [dramatic restructuring] for a year or two and then dropped it.”

Heller and his colleagues have set out to develop innovations in physics that, when implemented imperfectly, ‘fail gracefully.’ In other words, even when the implementation is not quite (or not even close) to what the developer had in mind, it’s very unlikely that the results will be repulsive for students, embarrassing for faculty, or worse. There’s no cliff off which the unwary faculty member might fall.

So Minnesota sticks with innovations that are very close to what faculty and students are used to. They have retained the lecture, problem session, and laboratory scheduling, for example. Their approach is more like ‘putting new wine in old bottles.’ For example, a keystone of their approach is to emphasize use of problem sessions for collaborative problem solving, where students work on complex, context-rich problems in teams. They recommend abandoning the traditional requirement of graded homework, in order to free up graduate Teaching Assistant (TA) time. And many faculty have agreed to give up one lecture a week. Instead faculty and TAs spend more time together, and TAs are carefully trained and supported to do a good job of coaching students as they work in small groups on problems.

Heller’s hope for the future lies with those graduate TAs. He reports that colleagues at other institutions tell him that, when they’re hiring new faculty for their physics departments, they can usually tell whether a candidate has a Ph.D. from Minnesota, because of their interest and understanding of teaching.

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Chapter 6: XMAS - Spreading the Word Through an Invisible College

“I’ve known Prof. Donaldson for some time.” Kathy Howlett, faculty adopter of XMAS, Northeastern University

Pete Donaldson noticed how his children watched videodisc movies at home. The idea that became XMAS grew from that seed: first as a tool for presentation in his courses, then as a tool for students to create multimedia essays about filmed performance of Shakespeare, then Donaldson’s own scholarly work.

By the late 1990s Donaldson’s scholarship in this area was well-known. So, by the time he received his first iCampus grant, Donaldson already had an invisible college of colleagues already interested in his use of computers to bring performance into instruction and research. Through workshops and keynotes in his disciplinary association, Donaldson already had mailing lists and other communications channels to reach these people. That situation is typical for an MIT faculty member who receives a research grant, but it was not typical for many iCampus PIs who had little track record and no invisible college of colleagues interested in their educational work. For XMAS and a few other iCampus projects, however, the “funded research paradigm” was an appropriate strategy to promote widespread adoption.

Before iCampus Funding

In the 1980s, because the Donaldsons didn’t want their children to watch too much contemporary television, the family bought an early form of videodisc and a collection of classic films. These Capacitance Electronic Discs had a counter so that films could be accessed to the nearest minute. Donaldson recalled, “My children, then 8 through 14, could identify and extrapolate, have visual and verbal patterns that they found in the material, and formulate questions about narrative that were astonishing. The technology seemed to be contributing. So you would ask, ‘what’s the exact moment when Charlie Chaplin sees the blind girl and recognizes that she’s blind in *City Lights* and, later in the film, when does she see him and realize she’s doing well and he’s still a tramp? What’s the pattern there?’ They could do that, and talk about how the two moments related.”

This excitement influenced Donaldson’s decision to try using this technology with students. In the 1990s, he and his collaborators developed a HyperCard-based interface for accessing and annotating disc-based movies. Supported by a grant from the National Endowment for the Humanities, they developed the “Classroom Presentation System.” It used two Pioneer videodisc players so that two different versions of the same Shakespearean scene could be compared side by side. Although initially planned for classroom use, Donaldson discovered that just one clip or pair of clips could spark 20 minutes of conversation. So, ironically, the primary use of this “Classroom Presentation System” soon became student projects, done in a lab equipped with computers and videodisc players.

“Performance and film should be central to a Shakespeare teacher’s work,” says Donaldson, “not just fluff or an extra. Faculty used to say ‘at the end of the day you’d *watch* the film but first you *study* the text.’ We thought we could change that if we changed it from the top, by making an impact on the Shakespeare scholar community, embodied in the Shakespeare Association of America. We proposed and got a plenary in their 1993 annual meeting. I had published my book on close reading of Shakespeare in film, in 1990, *Shakespearean Film, Shakespearean Directors*.”

At their SAA session in 1993 Janet Murray of MIT talked about multimedia, Larry Friedlander of Stanford talked about performance, and Donaldson demonstrated the software. “I took a passage in Hamlet where there are two different versions that vary substantially from one another, when Hamlet meets the ghost on the ramparts. There are 15 lines that are in one early edition but not in the other. Hamlet is waiting for the ghost with his friends when the king drinks and the cannon go off. In only one version, then follows a dozen lines or so, “so oft it chances in particular men...” and the ghost appears when Hamlet talks about people losing their reason. So I took that well known difference between the two, and analyzed the difference between the Olivier and Zeffirelli/Gibson versions. I showed how, if you could move quickly enough between text versions and film versions, you could see things you hadn’t seen before.”

“It really took off,” Donaldson recalled. “It was a 25 minute talk with over 100 short videodisc citations from videodiscs shown over 100’ cable from players at the back of the hall. How we got that done is amazing to me. People recognized that. They didn’t know the technical marvels that our programmer did in putting it together. We’ve never done anything that complicated since! That was a signal success and got to be well-known.”

Donaldson’s scholarship began to change, too. He wanted to move the field of Shakespeare scholarship toward seeing each play as a matrix of text, performance, and related materials and events that change over time. Donaldson created a series of multimedia projects (many of them later converted to articles) that developed from close readings of various films and themes. In the process he also developed connections with dozens and dozens of scholars who attended his workshops and presentations. Like Donaldson, these faculty members believed that close reading of filmed performances offered a new avenue for both research and teaching. These connections formed a broad, firm launching pad for Donaldson's efforts to promote adoption of the software that had been developed for him.

Donaldson and Larry Friedlander also experimented with online collaboration in this period, with groups of students at Stanford and MIT having a live discussion of video clips online. But the technology was not up to the challenge and the work was soon abandoned. However, the notion of using online discussion of video clips later influenced Donaldson’s iCampus proposal and work.

Initial Grant - Purposes and Execution

In the first phase of their work, Donaldson, Belinda Yung (project manager), and Sarah Lyons (Shakespeare lecturer) initially relied on Microsoft Research to adapt the Microsoft Video Annotation System to their needs. This software adaptation was tested at MIT and at the University of Cambridge, but technical problems were substantial. Ultimately the team concluded that the gap between Donaldson’s needs and the Microsoft software’s capabilities was too wide to bridge. The programming work shifted to MIT students employed by Donaldson. This next phase of the work was called SVAS, the Shakespeare Video Annotation System.

SVAS was used more widely but it too was awkward to use for most people. The only successful outside use of which we are aware is that of Leah Marcus at Vanderbilt, our first case study below. The current, somewhat more user friendly software, is called XMAS – Cross Media Annotation System. The new name also reflects some growth of interest in use of the software for non-Shakespearean film. XMAS was released for use in 2005. Because XMAS has been used far more widely than any other previous version of Donaldson’s software, iCampus or earlier, our adoption analysis will focus on this version.

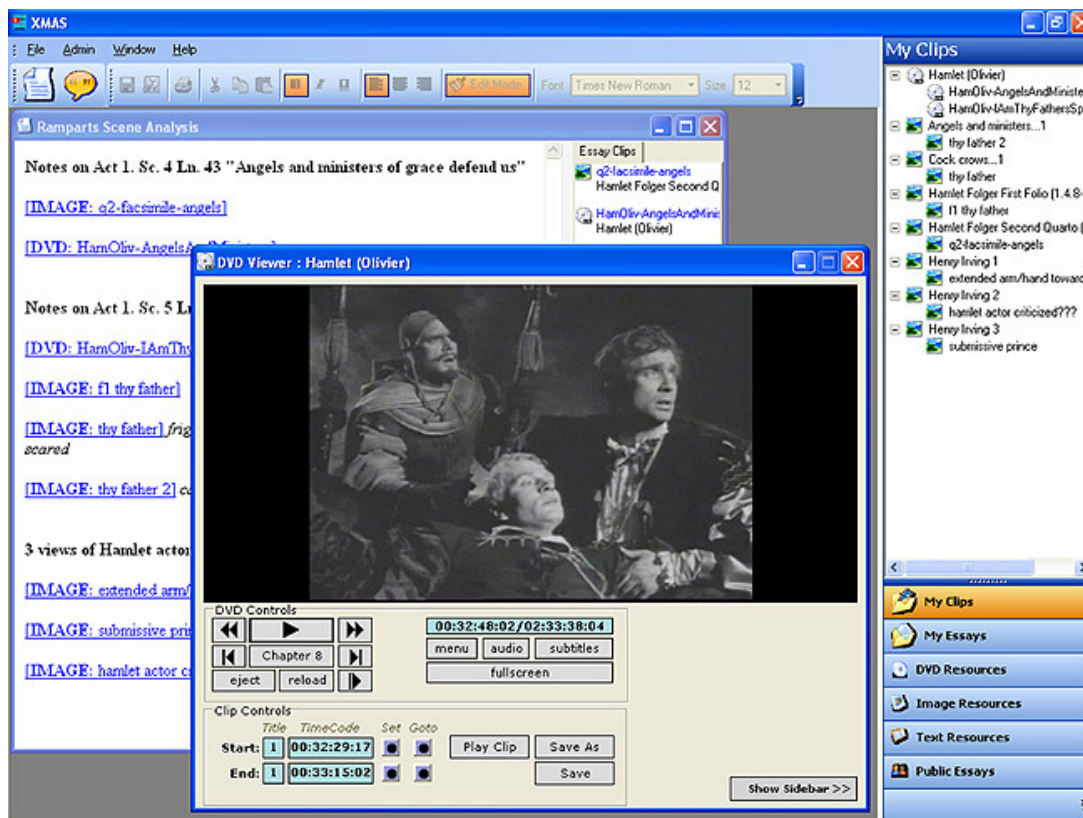
It is significant, and not unusual in the world of educational software, that it took at least three versions of the software, and five years (of the seven years of iCampus’s own life), before a version of the software was released that was valuable and viable enough to gain a foothold

outside MIT. Dating from the beginning of the work on the Classroom Presentation System, it was about 11 years before XMAS was even close to being ready for wider use.

How XMAS Works – The Basics

XMAS enables users to incorporate clips from DVD movies into presentations, notes, discussion posts, and other projects, without violating copyright. That's because no copy of the video is made. The user must have the DVD in his or her own computer in order to see a clip from that DVD embedded in a project, presentation, or discussion post. XMAS enables an author to define the beginning and ending of a clip from a movie; later the user can click and see just those seconds of the movie that the author has defined.

This strategy violates the preconceptions of many faculty and students, who assume that XMAS copies and pastes clips from a DVD housed on a server. That preconception is so strong that it has resulted in some inconvenience for adopters who realized only late in the game that they needed to acquire a legal copy of each DVD for each user (and DVDs can be expensive, hard to find or both). To make matters harder for the faculty member, each user must have the same version of that DVD.



XMAS software has two components:

- € Server software stores all the projects and presentations, information about DVDs, and other XMAS resources such as texts of Shakespeare plays. To repeat: the author's work is stored on the server, not on the author's PC. MIT makes the server software available for free download.
- € "Client software"(on the user's computer) manages the DVD (also on this same computer) and provides the authoring and editing tools. The client software is free and can be downloaded on the Web.

So when someone views a project (see figure above) from a PC, the text is copied from the server to the user's screen. Meanwhile, the video clip is directly coming from the user's own computer.

XMAS enables users to create presentations (talking points interspersed with video clips), projects (essays with embedded clips), online discussion (video clips included in posts). XMAS includes texts of all Shakespeare's plays as well.

Selected Adoption Case Studies

Leah Marcus – Vanderbilt University

Making the Connection: Prof. Leah S. Marcus, Edward Mims Chair of English at Vanderbilt, was one of the first adopters of the SVAS outside MIT. She received grant support of around \$10,000 from Vanderbilt and was one of a cadre of faculty doing innovative projects. The grant gave her funds to buy DVDs for her students and the obligation to do a formal evaluation of her pilot test. Marcus worked closely with a support staff member whom she valued so much that she said in an interview, "I won't tell you the name of our liaison because I don't want you to steal him. He's an excellent interface person, helping people get what they need."

Advantages and Disadvantages: In her April 2005 evaluation of this spring 2005 course, Marcus provides a clear explanation of what motivated her to use the new software, an explanation that would be shared, we're sure, by faculty members interviewed for this case. She wrote,

"I initially created the "Shakespeare and Film" version of the course because I was having a hard time convincing students that I was not THE authority on Shakespeare. Shakespeare is difficult, but at the same time a highly revered author. Students tend to lack confidence in their own ability to interpret the plays, and look to me as the professor to tell them what Shakespeare "meant." At the level of individual speeches, I can in fact contribute a great deal to their understanding. But in my students' eyes, my greater familiarity with Shakespeare's language, dramatic conventions, and historical milieu meant that I could be counted on to explain the plays to them.

"I, on the other hand, wanted to teach them that Shakespeare wrote for performance, and with the expectation that the meaning of his plays might be altered by differences in performance. In fact, we have ample evidence that this was the case even from Shakespeare's own period in the form of different printed versions of the plays that are often markedly different in terms of language and sometimes even setting and characters. I initially created the "Shakespeare and Film" version of E210 to try to show students how the meaning of even a single speech or scene could be altered through performance. During every class period, I showed clips from two or three different film versions of the same scene in order to give students a sense of the wide range of meaning that could be productively garnered from the Shakespearean texts

"I thought "Shakespeare and Film" worked well in bringing home to students the simple truth that the plays can mean many things, depending on performance and context. But students still seemed unduly dependent on my sense of the "correct" interpretation. I hypothesized that if students were to have their own access to the entirety of more than one film version of each of the plays, they might develop a deeper sense of the contingency of Shakespearean meaning and the importance of performance. I requested money from the Provost's office and the College of Arts and Science in order to create an "Interactive Shakespeare" course in which every student would use DVDs of important performances of the plays we were discussing in the hope that the new course design would cause students to assimilate more fully the importance of performance to the meaning of Shakespeare."

Marcus spent a year getting ready to use XMAS. She wrote in her evaluation, “At MIT the software had only been used by students outside of class to prepare materials to be shared with the class. At Vanderbilt I wanted students to be able to use the materials during class. ‘Interactive Shakespeare’ was taught in a computer lab, and allowed me to set up a problem by discussing specific scenes from a play, showing a number of clips that demonstrated how specific film actors and directors had solved the problem in their performances, and giving students time to discuss the materials among themselves and move beyond them to their own interpretive concerns. I used the grant money from the Provost and A&S to develop our end of the XMAS software and to buy 32 copies of every DVD we studied so that each student would have his or her own copy to view at home and use during discussion.”

Because XMAS is networked, with records and papers at the server (MIT) end and the interface at Vanderbilt, problems are sometimes hard to analyze and fix. But after initial installation difficulties were resolved, the software worked reasonably well.

In operating XMAS with MIT handling the server and administrative responsibilities, MIT had three major roles: keeping the server operating, registering any DVDs that Marcus might want to use, and providing accounts for Marcus’s students. Marcus was an early adopter and her experience stretched the system as it then operated. In an interview, Marcus recalled, “When I tried to use it last year, I couldn’t be listed as the instructor. At that time Pete was the default instructor. So they had to create a new version so there would be file sharing to me. Last year, if a student wanted to create a paper using XMAS, I had to do it through Pete. That’s not optimal, obviously. Supposedly they have file sharing now, so that when students sign in, they can enter my name, and then share their work with me.”

Outcomes: Marcus is the only adopter we have found who did a natural experiment, comparing her SVAS course with a somewhat similar Shakespeare course she was teaching at the same time, a course where she also used film, but not the software. As she wrote in her April 2005 report,

“In addition to teaching “Interactive Shakespeare” this spring (E210), I also taught a year-long Shakespeare course that was intended for more advanced students, primarily English majors (E209A and B). I taught that course in a more traditional way, showing frequent film clips, but not requiring students to view DVDs of specific productions as part of the class work. Since I was teaching the two separate Shakespeare courses, I was well situated to study the differences in student achievement by asking both groups to do the same things at the same time in a discussion of a given play, and measuring the differences in their responses... In a freewrite, I gave students a general topic, and left completely up to them what they chose to write about for five minutes.

“I asked for three different freewrites on plays that overlapped between E209 and E210. The first topic was “Sun and Shadow in Richard III.” The second topic was “The World of Fairies in Midsummer Night’s Dream,” and the third was “Black and White in Othello.” In all three cases, I tried to choose topics that were unavoidably obvious and about which everyone would have an opinion. I tried to create some parity between the two groups of students by showing both groups in class some of the same clips illustrating how specific performances on DVD dealt with interpretive questions raised by the topics. However, the E210 students were shown more clips in class; they also viewed two DVD productions of each play on their own. So both groups of students were introduced to the same interpretive differences, but the students in “Interactive Shakespeare” were more deeply immersed in those differences because they saw contrasting performances in their entirety and could explore the DVDs on their own.

“...What interested me was whether students showed signs of having assimilated my point about the importance of performance to interpretation and my corollary point that students could act more independently of the professor in formulating and studying interpretations of Shakespeare...”

“I was prepared to see differences in the E209 and E210 groups, but not for the degree of difference I encountered in their responses. Given that both groups were regularly exposed to more than one DVD performance of each play in class, it would not have been unreasonable to expect students in both groups to discuss differences between performances in their freewrites. But, as had been my previous experience in “Shakespeare and Film,” ...the E209 students did not really assimilate the lessons of the film clips shown in class.

“...It comes as no surprise that the students in Interactive Shakespeare were far more likely to mention film evidence in their essays than were the students in E209, the more traditional Shakespeare course. But I was surprised that so few of the E209 students mentioned film at all, given that I showed at least two clips relating to each of the questions and emphasized the variability of interpretation in the different productions we discussed. For the Richard III freewrite, none of the E209 students mentioned film, while 96% of the E210 students did. For Midsummer Night’s Dream, the corresponding figures were 90% and 3%; and for Othello, 85% and 11%. The steady rise in mention of film by the E209 students during the course of the year suggests that they were gradually assimilating it into their mental arsenal of equipment for discussing Shakespeare, while the E210 students were gradually becoming less likely to mention film, moving from 96% for the first film tested to 85% for the last. But the contrasts are nevertheless greater than I would have predicted. It appears that showing occasional clips does not have the desired pedagogical effect. In order to give students the learning experience I was hoping for, the greater immersion we used in Interactive Shakespeare is required.

“...[The next question was] whether or not in doing their freewrites students gave any indication of understanding that interpretation might be variable, given on specific performances or points of view. The gap between E210 and E209 is unexpectedly large: 74% versus 0% for Richard III, 85% versus 9% for Midsummer Night’s Dream, and 80% versus 11% for Othello. Here again we can see that the E209 students improved over time, but the gap was still telling, particularly given the differing sophistication in literary studies of the two groups of students.

“...Although these results are crude and preliminary, they are encouraging. Although I did not mention the fact above, my overall sense of the quality of responses was that the E210 students were doing better, more sophisticated interpretive work than were the E209 students, despite the greater experience of the latter group. The data shows unequivocally that Interactive Shakespeare students tended to write more about a given play within the small space of a five-minute freewrite, and tended to explore more widely in that they were more likely consider a range of possible interpretations. These results suggest that Interactive Shakespeare is worth teaching again, but with fewer technical glitches, a more finely honed pedagogy, and more attention to the historical milieu of performances.”

Peter Berek and Aime de Grenier, Mount Holyoke

Making the Connection: Peter Berek is an English professor at Mount Holyoke, currently nearing retirement. His principle teaching interest is Shakespeare and Renaissance drama. Berek “did a stretch as an administrator, including a period as provost” of Mount Holyoke in the 1990s. “I found out about XMAS when Pete Donaldson sent out an e-mail (in 2004), saying he was

working with new software for using DVDs for teaching Shakespeare. I hadn't done anything with MIT's Shakespeare project before, but I'd been using videos and discs to teach Shakespeare since the 1970s."

Low Threshold? "Getting involved was extremely easy," Berek recalled. "It was a matter of some e-mail exchanges with Donaldson. I talked with one of our technologists here, Aime de Grenier, with whom I'd collaborated in the past. I asked if she was interested and she was.

"I'm an instructional technologist," said de Grenier. "I work in library information technology group, a merged library and IT group. I am the humanities liaison to the faculty. I also help manage the faculty resource center, a 10 station faculty development lab. I have a long-term wonderful working relationship with Peter Berek, who is using XMAS. We've been working together on learning the tool for three semesters." Berek asked de Grenier to contact Donaldson and find out more about how Donaldson used XMAS in his own teaching. De Grenier went on, "Very quickly in the conversation I started asking questions about how the tool was served, what kind of installation was required, how were the DVDs managed."

Donaldson put de Grenier in touch with Belinda Yung. Recalled de Grenier, "It took only one or two e-mails. The tool is not very complex. We saw how to work with it, and how to reach out if we had questions. Belinda was fantastic to talk to and work with." The initial design had been "clunky," said Yung. "It wasn't until the second version came out, a year later, that Peter decided to use it (Fall 2005)." Around this time, Peter Donaldson and Belinda Yung came to Mount Holyoke to demonstrate the system. In retrospect, this visit was crucial in reigniting Berek's interest.

The learning curve may have looked simple but when people are working with a technology only casually, it can take a long time and progress is neither continuous nor linear. For example, recalled de Grenier, "'at some point in fall 2005, they said 'oh by the way, we can add DVDs any time you want.' That really broadened our understanding of the tool."

Prof. Berek said, "Aime, Pete, Belinda, and I arranged to download a copy to Aime's computer and mine. I got a sense of how it worked. The version that we used in Fall 2005 required a little manipulating as you installed it. Nothing she thought was any big deal. The December 2005 version I installed myself on my own computers and it's like installing any other MS/Windows software. You click, an install shield comes up, and it does it."

Advantages and Disadvantages: Aime de Grenier recalled Berek's use of XMAS in his fall 2005 seminar, "He hoped that the students in his course would use XMAS to write and annotate papers, but pretty early on he fell back. He was concerned about the reliability of its being served across the Internet. The first time he used it in the classroom, it didn't work right. We went back to Belinda. It was a bug that XMAS had already documented but that I didn't catch on to, a bug in installation. Then we had networking problems the first times we used it. The speed of the DVD, and the needs to serve it across the Internet, requires a certain kind of machine."

Prof. Berek concluded that it was safer to use XMAS as a lecture aid for his fall 2005 seminar. He explained, "As you probably know, using DVDs in a lecture class is a pain in the ass. Finding the specific moment you want to show is not always easy. You end up showing a bigger clip than you wanted, or students have to suffer through you finding the right spot.

"So XMAS has the attraction of allowing you to create the clip in advance. That's good. I like that. However, the way the software works means that each time you do that, you have to go back to a small screen. It's not big enough to project for a group of students, then you start the clip, then XMAS makes a loud noise, makes a window, asks you about a big or small screen, and finally the big screen. This intermediate stage of warning you that you're about to make it bigger and how to make it smaller, makes it somewhat less attractive.

Once the initial problems were resolved, XMAS remained a little awkward for Berek to use. “When you click on the help button, nothing happens,” said Berek. “Belinda sent me a couple pages of typed documentation, and that was very good, but it’s the kind of thing you learn to use by playing with it. Frankly I haven’t played with it enough. If I had been teaching a seminar with 15 students, I’d have made it a point and I’m absolutely confident that, if I’d spent a couple days, or even a couple consecutive hours, I’d have gotten comfortable enough. But it’s not perfectly simple. There are different modes, essay mode, clip mode and so on. It’s like learning to use a different word processor, not hugely complicated but not automatic either. Learning to use it is a matter of playing with it. The things I am now comfortable with are inserting a DVD and making clips. Inserting clips into an essay is something I haven’t done yet, though I have no doubt that I could do it.”

In Spring 2006, Berek for the first time asked students to use XMAS to do projects. This entry-level course on Shakespeare enrolled 43 students; it is by far the largest course offered by the department. “It seemed extremely risky to assign XMAS the first time, with this large a group. So I asked if anyone was interested in the films we were watching. They’d seen me using XMAS in class so they knew it existed. I was somewhat surprised that only two students took me up on it.

“Learning to use the tool was easy, they told me, but learning to think about a brief visual moment was harder than they expected, which strikes me as good news.” Berek was pleased with this initial student use by students but his own part in this assignment was more frustrating. “The thing that I found least satisfactory about the tool, and it may be my own fault, was the process of reading and commenting on the papers was awkward. Reading them was easy. We loaded them into the public area of XMAS. But I couldn’t figure out a way to comment in the paper, the way I would use the Comments feature of Word. Reading the paper and not being able to make marks on it was a new experience and not altogether a happy one. I have to say, with some embarrassment, that I didn’t call Pete or Belinda, and ask them how to do it. There may be a way.”

Fostering further adoption: Berek hasn’t published any papers or done conference presentations in this area. “Pete Donaldson is a Shakespeare on film person; I’m a Shakespeare on film person.”

Mark Lawhorn and Mary Hattori, Kapi‘olani Community College

Making the Connection: By the time that Mark Lawhorn, an English professor at Kapi‘olani Community College in Hawaii, heard about XMAS, he had already used an earlier version of Donaldson’s software. So he moved swiftly to use XMAS in his courses. In a March 2006 interview, Lawhorn commented, “It was last spring, about a year ago, that I got an e-mail from [Donaldson], asking if I was teaching any classes where I might want to use XMAS. I said, “Yeah!”

Advantages and Disadvantages: We tried it out in the fall, last semester. I’ve noticed that students are immediately engaged and the ones who are more savvy can use it without instructions. The layout is self-explanatory.

“Having said that, there is a need to give them a few more detailed instructions, what to watch out for. For example, if you left-click [rather than right-click] on the fast forward button, the program would crash. Then you log back in and it pops back up quickly. But you definitely want to let people know that in advance. It’s always the people who don’t wait for instructions who do things like that.”

“Even in the short time we used it, there was a positive response from students. They would comment in student evaluations that they liked XMAS. I had that to go on, that and classroom observation, seeing them engaged. And the quality of the comments in using the program. That’s

probably a function of being able to save little clips, watch them over and over again, take a few notes, get them right down on paper, in the program, while they've got the clip running right there. It's partly the immediacy of being able to do that

“This semester they're still using it. My goal this term was for them to write a whole paper, using selected clips. Everybody in the class has to do a whole analytical paper, with a number of clips and post it in the public area. I've made plans to integrate this in a comprehensive way in my literature and film course in the fall. My plan is to do 5 works of literature and films that go along with them. In some cases, like the *Quiet American*, we'd use two different films in conjunction with the book or short story or play...I think that XMAS is potentially a really good tool for doing that. It's showing a lot of promise in the brief uses I've made of it in class. I'd like to see if it's useful in analyzing films with a little more complexity.”

Fostering Further Adoption: Lawhorn contacted a number of people at the college to get support, including Mary Hattori, coordinator of the college's Center for Excellence in Learning, Teaching and Technology.

In order to decide whether the Center should support XMAS, Hattori wanted to know whether other faculty could be interested in using XMAS, too. So she decided to help Lawhorn showcase his work. The Center sponsored two symposia where Lawhorn could 'show and tell.' The Center also was sponsoring a new service, "Open Classroom Days." Faculty at Kapi'olani could announce days in which they welcomed colleagues to come and watch them teach. Quite a few faculty members, including Lawhorn, decided to take advantage of the offer. And faculty, including Hattori herself, came to watch Lawhorn teach and to chat with his students afterwards. Hattori decided to use XMAS in a course she teaches on urban legends, in which students study films.

Analysis

As a case study for analyzing adoption issues, XMAS falls in the middle: it's not a perfect, easy-to-use, inexpensive, vitally important piece of software that will almost automatically achieve wide use. Nor is it an innovation with so many problems that wide use is impossible. These factors make it a good case study: it's attractive enough to attract attention but vulnerable enough to disruption to help us see the issues that can make a difference to adoption..

We begin the analysis by summarizing some patterns in the adoption cases we have studied.

Table 1 (below) summarizes the difference between direct faculty-faculty dissemination and iCampus mediated dissemination. In those XMAS adoptions where Donaldson was the conduit, the first point of contact in the adopting institution was an enthusiastic faculty member who already used video, knew of Donaldson's prior work, and had a strong interest in trying to make XMAS work locally. This person was then often aided by a) a local support person who sometimes worked quite symbiotically with the faculty member (e.g., Berek and de Grenier at Mount Holyoke; Lawhorn and Hattori at Kapi'olani). In contrast, where the connection was created by iCampus, it usually went through an IT person (e.g., Trent Batson at URI, Michael Starenko at RIT) who then had to find and interest a faculty member.

Table 1: How Adopters Heard About XMAS

	From Donaldson (directly or indirectly)	From iCampus Outreach
Adopters We Have	McJannet/Bentley	Goins/RIT

Studied	Lawhorn, Hattori/Kapi‘olani	Mundorf/Univ. of Rhode Island
	Dancer/MIT	
	Berek/Mount Holyoke	
	Howlett/Northeastern	
	Holland/Notre Dame	
	Marcus/Vanderbilt	
Adopters who seem least likely to use XMAS in the future	Howlett, Northeastern	Goins/RIT Mundorf/Univ of Rhode Island

Table 2 summarizes the variety of ways in which XMAS is being used. The bulk of use of XMAS is still with Shakespearean film, but it seems likely that that will change, since film courses and other courses that do close study of film (certain courses in culture, political science, sociology) greatly outnumber Shakespeare courses. That trend is probably dependent on whether and how scholars in film begin to use XMAS for research and when they begin offering their own talks and workshops using it.

Table 2. Major pedagogical use of SVAS/XMAS (each faculty member’s single major use of XMAS)

Faculty/Institution	Instructional Theme	Shakespeare Films?
McJannet/Bentley	students using clips in homework projects	Shakespeare
Howlett/Northeastern	students using clips in homework projects	Shakespeare
Lawhorn/Kapi‘olani	students using clips in homework projects	Shakespeare and non-Shakespeare
Hattori/Kapi‘olani	??	Non-Shakespeare
Marcus/Vanderbilt	student display and discussion of clips in a laboratory setting	Shakespeare
Berek/Mount Holyoke	faculty classroom presentations	Shakespeare
Dancer/MIT	student classroom presentations	Non-Shakespeare
Goins/RIT	student evaluation of XMAS	Non-Shakespeare

Table 3. Major Strengths and Weaknesses of XMAS That Adopters Mentioned as Affecting the Likelihood for Future Use of XMAS

This table is not an evaluation of XMAS. It is a summary of issues mentioned by adopters either as reasons for using XMAS, or as problems that diminished their interest in it.

Strengths of the current XMAS product

Allows legal use of DVD clips by students and faculty in research, presentation, and online discussion. Current law makes it almost impossible to make legal, organized use of video clips in any other way so XMAS is apparently the option for any faculty member or student who wants to do, and then share, a close analysis of clips from movies.

Compared to some other iCampus projects, the software is easy to use. No local development required. The client software can be downloaded to the users' machines.

Equipment for students is widely available (PC with DVD drive) and, if the student has the DVD and has no trouble downloading the XMAS software, any such computer can be used for XMAS.

XMAS works on Windows PCs, which are quite common

Enables the user to relate the video to a text of the plays, stored in XMAS

Problems with the current XMAS product

The author and the reader must each use identical DVDs in order to see the clips. This DVD must have previously been registered in the system. This can create difficulties especially in large classes and/or when the DVD is rare (e.g., out of print)

Unlike Donaldson's Classroom Presentation System of the 1990s, XMAS can only show one video clip at a time, making it more difficult for authors to contrast two different scenes. If a second clip comes from a different movie (e.g., a different film of the same Shakespeare play), the first DVD must be ejected and a second one inserted. This is true even for machines with two DVD drives.

Some complaints about user friendliness and interface design. The online help doesn't work yet. Although 1-2 users have employed XMAS with very little help, most benefited from (and perhaps required) both visits from Donaldson and Yung and internal help. At least one potential user (Mundorf at URI) seems to have been derailed by lack of internal help, remarking that, without help, XMAS was more trouble than it was worth.

In some instances it was a problem for the humanities faculty to find such classrooms and/or to refer students to reserve bookroom-like spaces that could lend DVDs and provide computers with DVD drives and with XMAS installed.

There is no version for Macintosh or Linux, so faculty whose students don't all use Windows, or whose students cannot all get Windows machines, are unlikely to use XMAS.

This feature thus far is only used in Shakespeare studies, not other films. One user complained about the version of Shakespeare used in XMAS.

The most obvious and, oddly enough, most difficult question to answer about these adoption attempts is "How many have really been adopted by their institutions?" In one sense, none of them have: their use is tied to particular faculty and their interests. Yet there is a chance of long term use in virtually everyone of these cases.

- MIT has Donaldson, Dancer, plus two more faculty who will probably use XMAS next year. The MIT library has installed a computer/DVD installation for XMAS users, a key factor in helping assure that users can share a limited supply of DVDs. Yet Donaldson is still using grant money to support Yung and the server: MIT's information technology service does not yet support XMAS.
- Kapi'olani is enlarging its pilot experiment to include more faculty and seems likely to continue moving ahead. They are considering whether to install an XMAS server
- Vanderbilt: Marcus continues to be the only user, but Vanderbilt has its own XMAS server.
- Mount Holyoke got off to a good start and has stable technical support for Berek, but Berek is nearing retirement and no other users have yet appeared.
- At Northeastern and RIT, the faculty adopters' decision about whether to use XMAS again seems to ride on whether their libraries establish a computer/DVD area with an adequate collection of DVDs. Northeastern is on its way to establishing such a facility so adoption seems likely and wider use is possible. At RIT the faculty member says that, if the library establishes a facility, she would use XMAS again. She is especially interested in its potential for including video clips in online discussion.
- Notre Dame was originally stalled because its Office of General Counsel insisted on seeing a license before allowing XMAS (open source software) to be used. That problem took enough time to resolve that the faculty member was unable to use XMAS that year. He intends to use it next year for the first time.
- At Bentley, McJannet is lukewarm about XMAS. All her students are assigned to analyze the same few movies and she is so familiar with the clips, she doesn't need to watch them (which makes grading papers much more efficient). Of the institutions we've studied so far, Bentley seems least likely to see wide use of XMAS soon; McJannet hasn't decided whether to use it again.

These cases suggest several important lessons for assessing and supporting future innovations.

The possibilities and limits of the research paradigm: Most important for adoption is the unusual nature of the innovation itself. Like most pedagogical innovations, XMAS is not an e-mail system or a word processor. So, like most pedagogical innovations it will have a relatively small group of faculty users at any one institution. To this degree, XMAS is typical of most iCampus projects we have studied, and of most software development by faculty at universities.

But XMAS is also a tool that its creator, other faculty, and students can use to analyze and interpret materials in the discipline. It's a good tool, especially in skilled hands, and unusual enough that it opens up fresh ground for experts and novices.

XMAS is the most recent of five or six technologies that Donaldson has used to help pioneer this field: the ground was ripe for adoption because Donaldson had already developed communications channels for reaching potential adopters: there were people who knew his work, and he knew how to reach them (e.g., mailing lists of participants in workshops he had led on this subject in the past.) This is not unusual for faculty in their research fields: MIT faculty tend to be well-known and well-connected in their research fields. It's a hidden asset for funders of faculty research: the invisible college to which the well-known researcher is connected, and which is likely to exploit any successful work emerging from the grant. Faculty research funding draws on an invisible, international network that surrounds MIT faculty in their roles as scholars – networks of collaborators, competitors and observers who are already accustomed to attending to what the MIT faculty member produces next. Each funder of a new research project makes

withdrawals and (they hope) deposits to that invisible asset for influence. That model is a good fit for Donaldson's activities. XMAS received relatively little outreach help from MIT in comparison to a set of projects like iLabs, in part because it's not in engineering or science (iLabs is headquartered in the MIT School of Engineering). Nonetheless, XMAS is one of the more successful iCampus programs when it comes to adoption. All but one of the adopters we have identified heard about XMAS from Pete Donaldson, and were aware of Donaldson's work in this area before he had received iCampus funding.

Technology Brevis, Education Longa: Nonetheless, it took Donaldson and his collaborators about a dozen years to get from the first version of the innovation to one that was even somewhat suitable for wider use. In other words, the effort to develop this kind of activity as an area of research and pedagogy has taken over five generations of technology to advance.

There's a lesson for funders, and for developers. The cost of implementing a new idea, in time and money, is often far greater than one might imagine when the idea first surfaces. In *Development Projects Observed* (1967), Albert Hirschman called the inevitability of unexpected delays the "law of the hiding hand" and asserted, having learned this fact, it might be wise to forget it or we would never do anything bold. But Hirschman also suggested that sponsors of such work would need to keep this fact in mind when deciding what to support, how much money to allocate for support, and how flexible to insist that schedules be.

Recommendation for XMAS

1. **XMAS outreach materials should contain better briefings on its pedagogical uses and its weak spots.** These outreach materials need to recognize the need to overcome persistent misconceptions by faculty and students (e.g., that XMAS involves making video clips from streaming video) and provide suggestions that are compatible with its weaknesses (for example, are there productive ways in classes of small, moderate or large size for students to be studying different DVDS? That could increase students' sense that they are doing original work; it might also increase the time required by faculty to grade student projects because the students' examples would more often be new to faculty.) The materials should also be suitable for the surprising variety of uses of XMAS: inside and outside Shakespearean studies, for lectures, for discussion in classrooms, for student projects.
2. **XMAS would spread more quickly if it had more faculty champions who used it in research, gave presentations at professional associations (e.g., film, cultural studies) and ran workshops.** Although Donaldson uses XMAS for research, we have not yet found other faculty who use XMAS in their own scholarship. We have no sense yet about a) whether this is important, and b) whether this is likely to change. Certainly, XMAS needs champions outside Shakespeare who will spread its use in their disciplines. If they used XMAS in their own scholarship, that might increase the energy and visibility of the outreach.
3. **Fix bugs in XMAS and make it more user-friendly.** The balance of user opinion seems to be that XMAS is pretty easy to use if and only if XMAS is important enough to be used frequently. If not, even faculty tend to forget repeatedly what they have been taught about XMAS and thus find it frustrating. More 'early and late majority' faculty would use XMAS if this barrier to entry were lowered a bit.
4. **Enable XMAS to use video from remote sources in cases where DVDs are rare, expensive or both.** Belinda Yung suggested this change and pointed out that attempts to date had failed. In watching a streaming video, the user must first cache the whole movie up to the point of the clip. The delays imposed by the need to create this cache have been unacceptable. But if this technical problem could be solved (in a way consistent with copyright law), XMAS would be much more flexible

5. **XMAS would be more useful if it could show more video clips from two or more DVDS at the same time, or close to it.** This would enable users to compare clips moment by moment. This feature too has been sought but, so far, has been technically infeasible.
6. **XMAS needs to run on machines other than Windows machines.** The advent of Intel-based Macintoshes may ease this problem in coming years, but that still doesn't help students who are familiar only with non-Windows operating systems. Faculty with significant numbers of such students are reluctant to use XMAS.
7. **XMAS-based publications:** Even today, scholars could conceivably create professional publications using XMAS; they would require users to also have XMAS. The easier it becomes for scholars (including students) to create publicly visible, long-lived projects, the more viable XMAS will be.
8. **XMAS might benefit from some competition.** Donaldson's goal, and iCampus's, has been to develop and spread this video- and Internet-based strategy for close study of video. That idea might well spread more quickly if more than one such tool existed. As Frank Davidson, a Senior Research Associate at MIT, once remarked, "It's almost impossible for a lawyer to make a living in a small town. Ah, but if there *two* lawyers..." Together complementary, competing tools might increase the general legitimacy and visibility of this effort.

References

All quotations are from interviews with the subjects, unless otherwise noted in the text.

Crane, Diana (1972) *Invisible Colleges. Dissemination of Knowledge in Scientific Communities*, University of Chicago Press, Chicago.

Hirschman, Albert O. (1967) *Development Projects Observed*, The Brookings Institution: Washington, DC.

Marcus, Leah S. (2005) "Interactive Shakespeare. Provost's Awards. Final Report" April 27. Unpublished.

Attachment 1. Chronology of SVAS/XMAS versions

Name of	Distinguishing features	When was this	Representative Instances
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version	of this version, compared to what came before and after	version first used in a course and where?	of Use
SVAS	<p>2 video windows, a scrolling text window for the Shakespeare text, linked to multiple video versions of several plays, and a bulletin board style discussion window for comments; used streaming video; no DVD capability.</p> <p>MRAS allowed users to stop a video and annotate at the stop point. Annotations to specific points in the video could be read on line throughout the company. Users also could see the PowerPoint slides relevant to those video segments if there were any.)</p>	<p>Preliminary version. No scrolling text or text to video links. Used first in the last few weeks of Fall 2000 in 21L009 (Shakespeare). MIT.</p> <p>Full Version Fall 2001 (21L009, Shakespeare) MIT</p>	<p>Used in On-line distance seminar at Shakespeare Association, 2001. Hardy Cook and Mark Lawhorn and possibly one or two others were able to use; other participants were not able to because of firewall and other issues. Extensive collaborations planned for Cal. Poly San Luis Obispo (with Prof. Steven Marx) and elsewhere foundered on difficulty of using system, especially crashes, long video buffering times and inability to connect through firewalls.</p>
XMAS 1	<p>One video window, DVD capability, Other windows can be opened to permit use of image collections and texts, discussions which can include playable video and multimedia essays. Streaming video capability present in the software but not supported in the interface in current version. Unlike SVAS, windows are floating; system supports class presentations with full screen video, the writing and editing of multimedia essays as well as discussion. Software developed by MIT project team from ground up at MIT only, not using SVAS code.</p>	<p>Spring 2003 (21L009, Shakespeare)</p>	<p>Western Michigan University, Bentley College, Mt Holyoke College, Vanderbilt University, etc.</p>
XMAS 2	<p>Improvements to user interface, administrative tools supporting discussion,</p>	<p>Spring 2006 (21L009, 21L435) MIT</p>	<p>RIT, Kapi'olani Community College, etc.</p>

Chapter 7: xTutor – Online Lectures and Interactive Homework

From the Beginning: Before iCampus Funding

The xTutor case study begins in the mid to late 1990's with the desire on the part of several MIT Electrical Engineering and Computer Science (EECS) faculty members to improve two core courses, 6.001 – Structure and Interpretation of Computer Programs, and 6.004 – Computation Structures. Each course was taught by different sets of faculty. And, each set had similar pedagogical concerns, which led them to seek solutions using online technology. Although later on these faculty members became aware of one another's efforts, initially each group devised its own strategy – they did not collaborate on making these changes except in a most informal way. It was only after each had a fairly stable technological solution for their courses, that they began collaborating on what is now called xTutor. iCampus funding was the impetus that brought them together to create this software framework.

As course enrollments had grown rapidly in the 1990's, the EECS department was faced with the challenge of making large lecture classes 'work' for both the faculty teaching their courses and the students taking the courses. MIT values maximum interaction between students and faculty and so needed solutions (such as a technology infrastructure) that would support interaction, even for large courses such as 6.001 or smaller ones, such as 6.004⁶¹. Motivating the desire for change among these faculty members (as well as others) was a growing sense of a lack of interaction students could have with faculty. They were also concerned that students could 'slide by', not really developing an ability to apply the concepts or master the skills well enough for use in other contexts. Tomás Lozano-Pérez (leader in making changes to 6.001 pedagogy) describes the problems as he saw them.

“I was frustrated by a number of things at the time, among them the amount of repeated effort into lectures that didn't seem to pay back. A lecture seemed to be a lot of work and it didn't matter who gave them. 400 people and not much interaction. Wouldn't it be great if we could stop lecturing and start interacting with students. That was part of the motivation. The other part was...the C students. 30% of the students could go through the whole term and get nothing completely correct –getting partial credit for everything....They'd hand in work, discover it was partially right and never finish it.”

Chris Terman (leader in making changes to 6.004 pedagogy) said much the same in an interview with us when he commented about the problems in 6.004, a much more hands-on course:

“We had courses with hundreds and hundreds of students, and staff couldn't keep up with contact hours,Some of us felt that we weren't giving the students the response we wanted to.... It was quite a task to grade problem sets. We had to hire undergraduate graders and as a result had problems with consistency. The students would do the problem sets and it would be weeks before they got feedback and they'd be less than interested. So there were timeliness, labor and quality control issues.” (Terman, February 2006)

⁶¹ It is important to note here that these two courses make up the computer science track of required courses for all EECS undergraduate majors, so changes made in these two courses alone would have a significant impact on the curriculum.

Part I of this story described in the next sections, covers the span prior to iCampus funding when Terman and Lozano-Pérez worked independently from one another. During this period, each team created software to support his particular course. Towards the end of this period, Lozano-Pérez applied for and received iCampus funding to stabilize and assess his solution, and at the same time explore how it might be used in other courses. This is the bridge between Part I and Part II of the story. Part II of the story focuses on the development and dissemination of xTutor, which was the result of the iCampus proposal that allowed Terman and Lozano-Pérez to collaborate to transform their individual course solutions into a software framework that would support faculty members in making similar course transformations, regardless of the course content.

Part I: Early Efforts

At the end of the fall 1999 semester, Lozano-Pérez, who taught one of the 6.001 recitations, approached Eric Grimson (at that time the faculty member in charge of the course⁶²) and Leslie Kaebbling (also teaching a recitation section) and suggested creating an online version of the course. Lozano-Pérez suggested building software that would link online lectures to power point slides and the opportunity to complete short programming problems in Scheme, the programming language taught in the course. Students could complete the problems online and receive immediate feedback through a series of hints to help them complete the problems correctly. By employing this software, he hoped, there would be less emphasis on the lectures and the students (and faculty) would spend more time in the learning activities that mattered, i.e., interaction with the content and one another. Grimson and Kaebbling agreed to experiment with this approach to teaching 6.001.

During the winter break between 1999 and 2000 Lozano-Pérez wrote the code for the system (called Tutor), Grimson recorded the lectures, and Kaebbling wrote most of the problems. They pilot tested the idea with 25 students in Kaebbling's recitation section in the spring 2000 semester. At the end of the semester they compared test scores and found they were about the same for this group of students as for students in other sections of the traditional 6.001 course. Students reported that they liked the flexibility of being able to arrange for the lectures in their own schedules as well as the idea of checking work before submitting it. More importantly however, they were excited to find that the students echoed back to them one of their main goals: that they looked at the homework as a learning opportunity, not a burden. Based on the results from this experiment, they decided to implement the changes full-scale in 6.001 the following semester.

The first version of Tutor was developed on a shoestring. Over time however, there was a small but growing need for resources to support further development. Fortunately major new sources of funding became available. The team first received d'Arbelloff funding and then applied for iCampus support as well. iCampus funds were used to develop the software further, to assess the impact of the changes on student learning, and to encourage others in the department to try out the methods Lozano-Pérez and his colleagues had introduced in 6.001. Assessment of the project was necessary because, according to Lozano-Pérez, there was

a lot of discussion on campus whether we were hurting the students by making this change.... There's only one group of people more conservative than our students and that's the faculty. Are you guys screwing up? [They asked us.] Assessment showed that if anything, it was more effective, not less.

⁶² It is typical in the EECS department for one faculty member to "be in charge" of a course, even if they are not teaching it. "Being in charge" means that this person is responsible for the course design and content and works very closely with the faculty members (not graduate students) who lecture and run the recitation sections.

Once fully implemented in the fall of 2000, the team regularly evaluated student reaction to the course. It became apparent that students thought live lectures were more important than just the recorded lectures, so in the spring of 2001, five live lectures were added back into the curriculum. In 2002, a study (funded by iCampus) was completed assessing the impact of the online curriculum on learning broad programming concepts as well as more detailed materials. The study's objective was to assess specifically how well the on-line lectures taught both broad programming concepts and detailed material in comparison to the live lectures. The most striking and important finding of this study was simple: student learning of the material, as measured by quizzes and the final exam, was significantly better in the online version than in the live lecture mode (Newman, 2003)

Chris Terman's story is similar to Lozano-Pérez's. In charge of 6.004, Digital Systems Design and Computer Architecture, he and Steve Ward, who co-taught the course, had become frustrated by the students' inability to get timely, high quality feedback from TAs and instructors as they worked on design problems. The solution they developed was a web interface that allowed students access to client-side computer-aided design and simulation applications written in Java (which can run as a standalone or as applets) that interact with service-side code to retrieve student input and record their interactions. The online materials covered only the lab component for the course – the rest of the course was done as before, although there were online archives of all of the relevant documents. This design allowed Terman and Ward to implement software that would allow the students to 'get their hands dirty' doing a real programming project. Terman's focus was to create software that allowed the assignment of, and automatic feedback and grading for, fairly sophisticated design problems. Terman planned for software that, in combination with the work of faculty and TAs, could help students "coping with design issues at each level of abstraction."

Like the Lozano-Pérez solution, the 6.004 courseware was developed on a shoestring budget and easily implemented because it did not require other department or campus resources.

Part II: Changing the Focus from Course Solutions to a Generalizable Software Framework

In 1999 Tomás Lozano-Pérez submitted a proposal for iCampus funding called, 'Beyond the Firehose: Learning by Doing', to exploit the Tutor technology to "combine the lecture, the recitation, the tutorial, the laboratory, the problem set, the team project, and the discussion group into a seamless whole that is more effective than the separate activities." (Lozano-Pérez, 1999).

About 18 months after receiving funding for the project, and prior to the second iCampus proposal (submitted in 2002) Lozano-Pérez successfully re-implemented Tutor in 6.034, the artificial intelligence course. Again, Kaebbling partnered with him to conduct the course, creating lectures and more elaborate problems than were used in 6.001. They added an online proof checker to the online system to try out more complex feedback systems. By this time, neither Lozano-Pérez nor Kaebbling was teaching 6.001, but Grimson and the next set of faculty teaching the course (Duane Boning) continued to use Tutor.

During this time frame, several other MIT faculty members also tried out Tutor in other classes. For example Albert Meyer, who had taught a recitation for 6.001 tried it out in his course, 6.042, Mathematics for Computer Science. Hal Abelson and Gerard Sussman used Tutor for one semester in 6.002, Circuits and Electronics, another core course for entering EECS students. These efforts illustrated the willingness of several of the EECS faculty to try out and test the new software, allowing them to experiment with different ways of delivering their courses. While they may not have adopted the courseware fully, for example Abelson and Sussman abandoned it all-together and created their own system, the sense of our interviewees is that others have continued

to use it in ways that meet their particular pedagogical needs, e.g., for one or two modules, or set of problems.

The experiment in 6.002 did have an important and unintended, but positive consequence. Harriet Fell, a visiting Computer Science faculty member from Northeastern University took the course and thoroughly enjoyed doing the problems online. Through her connection with Hal Abelson, she contacted Lozano-Pérez and worked with him to transport the use of Tutor into her Discrete Structures math class the following year.

The Lozano-Pérez and Terman Collaboration

Although Terman and Lozano-Pérez knew they were working on similar problems, using similar solutions, prior to 2000 they were not collaborating in any formal way. They did, however, share some of the same conclusions about their work informally. As they began to work with other faculty members who wished to find and use online technologies similar to theirs, it became clear to them that a more extensible technical solution than either of their own individual products was necessary. Terman and Lozano-Pérez decided to collaborate in a second proposal to iCampus, one authored by Grimson.

This proposal brought together the two groups of software developers and the growing cadre of users surrounding their projects. The intent of this proposal was to extend previous versions of the course software to become a ‘novel framework for presenting course material and providing feedback to students’ (Grimson, 2002). The new product, called xTutor, would combine the components of Tutor with Terman’s Python based software to create a maintainable software framework for other faculty to use. This new software would not be tied to a single course. From the standpoint of an instructor xTutor would be “an interactive suite of materials, based on platform-independent input from the instructor” (Grimson, 2002). xTutor would allow an instructor with little or no programming experience to create a course using his or her own textual materials, simulations, visualizations and narrative presentations. Table 1. lists the features of the course level software solutions as compared to the architected solution suitable for use by diverse faculty in diverse courses.

Table 1. Software requirements for Tutor, Terman’s Software and xTutor

Tutor (Lozano-Pérez)	6.004 Courseware (Terman)	Current Version of xTutor
Course dependent: 6.001	Course dependent: 6.004	Course independent
Coded in Scheme	Coded in Python	Coded in Python
		Open source project
		Student administration: authentication, grading, etc.
		Database of reusable assignments
Linked course content via:	Linked course content via:	Linked course content via:
<ul style="list-style-type: none"> • audio recordings of lectures • power point slides used in lecture • exams • short programming problems that can be done until completed correctly • fill-in the blank and multiple 	<ul style="list-style-type: none"> • aplets • complex programming design problems • provides immediate feedback 	<ul style="list-style-type: none"> • audio recordings of lectures • automated tutoring • supports range of types of assignments, from: short answer, multiple choice problems to more complex design problems, writing programs and proving

- | | |
|------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>choice problems</p> <ul style="list-style-type: none">• provides immediate feedback | <p>theorems.</p> <ul style="list-style-type: none">• provides immediate feedback• power point slides used in lecture• exams• short programming problems that can be done until completed correctly; hints provided |
|------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

The focus of xTutor remained on providing students with immediate feedback, non-linear connections to content and concepts and learning materials, and wider exploration of course materials. As part of this framework, the developers envisioned a repository of materials where instructors could store and share subsets of content and materials, adopt or revise them to meet their needs and create ‘new’ courses or classes by building on others’ work. They also wished to create a tool that supported a wide range of teaching styles. Ambitious in vision, this proposal expanded the informal cadre of EECS faculty members to include others with similar goals such as Julie Greenberg, a faculty member from bioengineering who had implemented Tutor in her course, HST582.

Their focus was initially on meeting the needs of the EECS faculty teaching the core curriculum, i.e., the desire to improve the core courses continually, in this case implementing 6.001, 6.004, and 6.034 with the new framework. At the same time, they sought to share these materials with others, hoping eventually to extend the use of xTutor software to encompass a goodly proportion of the EECS curriculum. This would allow them to demonstrate the concept and encourage other EECS faculty members to undertake similar course transformations. This was an ambitious proposal focused on laying the groundwork for dissemination of a product, one whose components had been tested independently from one another, but that had not been combined or implemented as a whole.

Dissemination of the Innovation

The Role of Cadres in Informal Dissemination

Within MIT, dissemination efforts during the first part of this case did not extend much beyond the initial informally organized cadres of faculty interested in the various course reform efforts occurring around 6.001 and 6.004. Perhaps more than other iCampus project, these efforts were very closely tied to the courses for which they were designed. Most of the people who experimented with using these innovations were faculty who had been involved in teaching 6.001 and had become intrigued with the idea of using Tutor in other courses. These early potential adopters highlight a major hurdle to adoption (and probably inspired the idea to develop a more universal software solution.). Lozano-Pérez describes the main problem with adoption being that of lack of time:

“The real problem was that it requires substantial investment of time, you really have to be motivated to do it – for most faculty, they are “overwhelmed with opportunity” to try new and interesting things. So convincing someone to use technology is hard...”

Some faculty, like Harriet Fell, user of the original Tutor system at Northeastern, echoed how time intensive it was to implement her course using the system. She also noted that once she had implemented it, she was committed to using it.⁶³ She integrated the problem set aspect of the software into her course and has used it for four years. Fell noted that she spent most of her weekends, while teaching the course, developing problems and inputting them into the system. She made this commitment for a simple reason: the students loved it as much as she had. And, once she had made the changes, there was no way to turn back; it had motivated students to learn in a class that they do not like. Her use of it turned around their attitudes and she believes was instrumental in her winning a prestigious campus teaching award.

Within MIT, the interest in using the software has spread slowly, in part because it requires faculty to re-design all or parts of their courses. To date, only 6.001, 6.004 and 6.034 have transitioned to the first version of xTutor (only now are they transitioning into being supported by the newest version.) Others who have used xTutor (or Tutor) have focused on the use of the problem set functionality only, because of its flexibility. Julie Greenberg appears to be the only faculty member who has persisted in using it on a regular basis, and she continues to use the Tutor version of the software (as far as she knows.) Both Fell and Greenberg received a significant amount of help by Lozano-Pérez in setting up the first instance of the software for their courses. While Fell, a computer scientist has adopted and developed new problem sets, learning the programming languages necessary to do so, Greenberg relied upon a graduate assistant to set up the problem sets.

Even in instances where interest in the framework is high, there is reluctance to make these changes without financial support to provide faculty with release time or staff. Terman described working with John Belcher, an MIT Physics professor and Haynes Miller, MIT Math professor, both having expressed interest in using xTutor.

“I thought that showing them how my infrastructure worked would make it easier for them...It was, but everything is money driven – if there was money to support [making the change] they’d be more interested...[you] need staff time to put content up online – they have invested hugely in what they’ve already done, the stuff they show you has been supported by various grants. It’s very time consuming thing to invent and deploy – most faculty have a huge number of obligations....In terms of implementing [the kind of change required by xTutor or Tutor], even at MIT, they’d need support. It takes time.

Subsequent interviews with Belcher and Miller supported the notion that time was the major factor in their decisions not to pursue the use of xTutor in their courses. Miller, who is very interested in using the new version of xTutor commented that he has put implementation of xTutor off as he awaits a funding decision about a proposal to the Singapore Alliance, an MIT funded program. Should he receive this funding he plans to implement his course in xTutor. It’s not so much the more mechanical aspects of making the transition he said, but the thinking about, rethinking and redesigning the course that is so time intensive.

Formal Dissemination Efforts

Formal dissemination and outreach efforts were added to the iCampus mission in 2004. Prior to this new focus dissemination efforts had been limited to adoptions or trial runs resulting from interpersonal connections among the small cadre of EECS faculty (i.e., the project PIs, Ward,

⁶³ Haynes Miller echoed this idea when he noted that when a faculty member adopts a technology solution, it has the effect of making the course structure less flexible. By this he meant that after taking the time to make the first change, faculty members are reluctant to make continuous changes because it is so time consuming.

Ableson, Kaebbling, etc.) who were involved in teaching 6.001 or 6.004. So it should surprise no one that none of the cadre members felt that dissemination of Tutor, the 6.004 Courseware or xTutor was a priority for them. Perhaps this is a reflection on their efforts to complete the next version of the software or perhaps it was because they had not experienced a high enough demand by other faculty to use it. Both Terman and Lozano-Pérez have worked extremely closely with those faculty members (both within MIT and outside of MIT) who have actually used the software. These efforts have been very collegial in nature – they are more than happy to help their colleagues use the framework, but have had little time to disseminate it in more than a one to one or face to face manner.

While not originally a priority, both Lozano-Pérez and Terman did encourage others to learn about Tutor and xTutor; for example, Lozano-Pérez described a session he ran at a Microsoft ed-tech summit for faculty and Terman described talking with colleagues about the project. These efforts however, did not connect them to other larger coalitions of like-minded faculty, nor did they seek out these coalitions as being essential to their project as being potential allies in implementing educational innovation or reform, or for providing feedback on the technology involved. Instead, the more local MIT cadre of involved faculty members seemed to fulfill those needs. Recently, with the EECS curriculum revision project, both view this as an opportunity to revise courses to take advantage of xTutor, though no formal efforts have been made to work with faculty to do so.

With the shift towards more formal dissemination efforts, most especially the hiring of Phil Long to coordinate efforts and the development of the hubs⁶⁴, dissemination efforts have shifted away from the informal methods used by this cadre of faculty members. This shift may have interesting implications, since most of the successful adoption (and maintenance) of xTutor to date has occurred because of strong interpersonal connections with the project PIs to begin with (as exemplified by Fell's case) or through the development of these connections through subsequent work (as described in the case study regarding faculty from the University of Queensland.)

The hub strategy may also involve moving away from the more course-centric model that has been successfully employed so far⁶⁵ to one centered on dissemination of software. This will require new ways of 'selling' the product to faculty, since the commonly understood values and practices of computer science faculty as expressed by course content will no longer be the case.

Also important to the dissemination of xTutor will be the MIT Open Courseware (OCW) initiative, which has played an important role in disseminating the courses supported by xTutor. Though its goal is to provide access to course content, by doing so, it requires support for the software behind the course – xTutor. Already it has given thousands⁶⁶ of people access to 6.001 and 6.034. (Terman describes 6.004 as being very idiosyncratic and as far as he knows is only taught at MIT.) Though the OCW may help disseminate the courses to a larger audience

⁶⁴ Hub institutions that have explored the use of xTutor or adopted it in some way include: Mariposa Community college, University of Rhode Island, Cambridge in the UK and the University of Queensland in Australia.

⁶⁵ 6.001 is a course of particular interest to computer science faculty. It was what originally piqued the interest of the UQ faculty, who are from a hub institution. It also has piqued the interest of faculty from China, where it was demonstrated as a part of the MISTI program. Interest in this class was reportedly high as reported by Sean Gilbert when discussing efforts to disseminate the iLab project. 6.034, though more specific, also generates a great deal of interest. Both of these courses are the only courses to employ fully all aspects of xTutor, that is they include the online lectures as well as online problem sets.

⁶⁶ As of August 17, 2006 approximately 1,900 users had used 6.001 and 1,100 users have used 6.034.

(primarily self learners) we know little about this group of adopters since the current OCW system does not track this type of information.

To date then, the impact of this innovation has been mainly felt within two originating courses at MIT: 6.001 and 6.004, and more recently in 6.034. Given their place in the major, this means that a significant number of students, upwards of 2,000, have taken a course supported by this software framework. And, given the positive assessment of changes in students' learning as measured by Newman (2002) this has been a successful pedagogical innovation.

It is important to note that at the time of these interviews (February 2006 – October 2006) the new version of xTutor has not yet been released. Therefore, discussion of dissemination focused on the online versions of the courses themselves, 6.001 and 6.034, which were supported by the earlier versions of Tutor and xTutor or the 6.004 Courseware. The following adoption case studies were selected for more in-depth examination because they focus on the hub model and highlight some of the challenges associated with this approach.

Selected Adoption Case Studies

Adopting xTutor – Starting with a Course – University of Queensland (UQ)

Peter Robinson and Roger Duke are the two faculty members who are primarily responsible for adopting the 6.001 Scheme course for use in the Information Technology and Electrical Engineering (ITEE) program at the University of Queensland. In 2004, the curriculum in ITEE had been altered; the introductory Computer Science course shifting from teaching Java to teaching Scheme. Scheme's syntax is easy and students can write a working program quite quickly. ITEE faculty members (like those at MIT) saw the use of Scheme as a strategy to help introductory students get into learning how computer programmers think without needing to wait until after students had mastered arcane syntax.

To teach the new course in Scheme, Duke worked with another colleague to develop some standard, tutorial kinds of exercises for students and they started teaching it using Scheme as a pilot in 2004. In January of 2005, Duke walked by Mark Schultz's office.⁶⁷ As Duke walked by Schulz's door, Mark called out, "Have a look at this, you'll think it's really good!" What Mark was referring to was the MIT online course, 6.001.

With this brief introduction, Duke and Robinson were hooked on using the MIT course and Duke recalls that it was an easy decision to adopt it.

"The first thing that struck me was the quality of the online lectures and the tutorial problems. Also it had to be something that could be relatively easy to use and not make things too complicated for us or for the students. It didn't take that long. Only a week to decide this was the right 'go'."

Robinson added that the one thing that almost stopped them from adopting 6.001 was convincing Duke that it really was free – he thought there might be a 'catch' to it somewhere down the line.⁶⁸

⁶⁷ UQ is a hub for iCampus dissemination, and Schulz, another ITEE faculty member, leads that dissemination effort.

⁶⁸ They were not the only ones to hit this temporary roadblock. The faculty member at Notre Dame who wanted to adopt XMAS was stalled for months by attorneys at the University because they were required to review the software license, and there was no license, not even one that said "This is a license that requires nothing, not even a signature. Do whatever you like, without obligation." The borderlands between freeware and intellectual property can readily create confusion, and worse, unless carefully managed.

To learn how to adopt it, they simply registered for the online version and ran through the course materials as though they were students.

At some point in their explorations they came into contact with Hal Abelson, and he assisted them in offering the course. The first semester they offered the course they ran it using the MIT server, with “Hal and company” making the necessary UQ modifications. At that time, Robinson and Duke didn’t consider downloading the software, adapting it and running it from their own servers. In fact they reported that they didn’t know about xTutor; their focus was only on the MIT course materials for teaching Scheme online. Duke noted this about the MIT team helping them on the implementation:

“They were fantastically helpful to us. They bent over backward. Hal would be up in the middle of their night replying to our email, sent in the middle of our day. In a parallel universe, if MIT hadn’t been so helpful, perhaps it wouldn’t have caught on here. They gave us way more help than we had any right to expect.”

Throughout the interview with Duke and Robinson, neither mentioned that they knew that UQ was a part of the Hub dissemination effort or that xTutor was a part of iCampus. Perhaps this lack of communication was because Mark Schulz ‘brokered’ the relationship in the beginning, or perhaps they were so focused on the fact that the course existed and that they could use it that the underlying architecture was not important.

After working out the bugs of running the course for students at UQ using a server located at MIT, they worked with MIT to run a version of the course locally. It was at this point that they became aware of the software that ran the course, the early version of xTutor. They experienced very few problems transporting the course to their own servers for it took only a few days for the ITEE department staff to get it up and running. At this time, they did not personally make any changes to the course, except in terms of the syllabus due dates, and so forth. So there was a type of wall, the ITEE department staff, who shielded them from the software. This shift to a non-MIT server, a first for xTutor, also allowed MIT to test the transfer of the software and Duke and Robinson were happy to serve as MIT’s test bed. The UQ faculty members commented that they felt this was “one way for us to pay them back for all this wonderful stuff.”

As they explored the course more, and found they wanted to change the content, e.g., use mathematical problems more aligned to the skill levels of their students, they realized that it would be quite difficult to develop new courses for xTutor. Robinson and Duke noted that customization of the software wasn’t easy. They hoped that the new version would be easier to adapt. Duke noted:

I think it’s quite hard to develop them [referring to course materials] for xTutor, just to have lectures good enough to record. You can’t just record your ordinary lectures. Obviously you need to be funded. It’s a big effort.

Robinson added:

There’s the work of modifying Python code, adding exercises, getting automatic marking for, say, Java programs...xTutor should be more customizable, the materials and idea are really, really good. We’d like to customize and extend it more easily. Maybe produce one lecture of our own and integrate it – that’s not clear now.

For Robinson and Duke, the model of adopting xTutor through use of the actual course was successful. Neither of them indicated that they will use the software to teach other courses. This however, might change should the next version be easier to work with than the current version. Right now, they are content to work with their Scheme course, tweaking the content within the software as necessary.

Adopting xTutor: Starting with the Software (Maricopa County Community College District - MCCCCD)

The goals and results of an adoption attempt at MCCCCD had quite different outcomes from those at UQ. MCCCCD, like UQ, had been designated as a Hub for iCampus dissemination.

Alan Levine was contacted by Phil Long, a long-time friend and Outreach Coordinator for iCampus about becoming a hub campus for iCampus products. In due course, MCCCCD agreed to participate. In exchange for enhanced support from iCampus at MIT, MCCCCD (principally Levine) would work to spread the word about iCampus innovations. In 2003, Levine and another faculty member demonstrated some of the iCampus tools at an Ocotillo⁶⁹ Retreat, but this did not generate much interest among the faculty members who attended. Gary Marrer attended that retreat and like other faculty members, he recalls passing by the iCampus materials because it was so difficult to tell whether he personally could use it.

Why Marrer got involved when it didn't seem to interest him is no mystery. Levine invited him to lead the iCampus review and Marrer, as the Faculty Chair of the Committee on Emerging Learning Technologies for MCCCCD became intrigued with the idea and agreed to take this on. As the Chair, Marrer gets release time to do research on innovative technologies having to do with teaching; evaluating iCampus products was a natural thing to do in that role. Most of his release time has been spent looking at the iCampus products and recounting what he's been doing via his blog (<http://zircon/mcli.dist.maricopa.edu/emerging/>). Taking on the role of faculty member at MCCCCD when examining these products, he noted that:

“There's something mystical about MIT [to other faculty], the products [iCampus] all looked like rocket science.... the tools are specific for certain areas of expertise, e.g., Xmas focuses on creative arts, so it is hard to determine who the right faculty would be to try the product out, another example would be iLabs. It is for an engineering environment – not something I am doing – so it is hard to find the group to adopt it.”

As a computer science faculty member, he was more personally drawn to xTutor so he began to explore it in more depth. However, he wasn't happy when he found that the documentation that came with xTutor (available for downloading at the iCampus xTutor site) seemed to him more a part of a research project than a document designed for people who wanted to adopt it 'out of the box.' The documentation, he thought, was written from a coding standpoint, not a teaching standpoint. For example, there was no stepwise tutorial. This meant that xTutor was very painful to learn. He spent a great deal of time reverse engineering the product. If he had not had experience with Python, SQL, or other programs, he would have given up.

To examine the course, the first thing he did was sign up for the MIT class through the iCampus website. At the same time, he downloaded the code in order to experiment on his own server. He tracked his experiences on his blog. It is here that he logs excitement about the potential for the product. But, even in his excitement, it is clear that his opinion is mediated by his standpoint as a gatekeeper to such products for his campus. That is that the typical faculty member on his campus would not be able to use xTutor to create a course or adopt an existing course.

Even though he has become very familiar with xTutor, Marrer has not yet used it in his own teaching. He finds xTutor 'too time intensive.' At MCCCCD, they have a class in xml that he

⁶⁹ MCCCCD is made up of 10 campuses and serves about 150,000 students. Since Maricopa is so large, they support a program called Ocotillo to help faculty innovators work on projects dealing with innovation and teaching. Selected faculty members receive release time to try out innovations, conduct research on them, and decide if they will work in the MCCCCD environment.

thinks would be good to change into a self-paced course. xTutor would be just the thing to do that but he says it would take too much time to develop it in xTutor. It would be great, but it might take 5 – 10 times longer to develop in xTutor than in other environments.

He adds that he has given this feedback to the iCampus staff, explaining that xTutor is practical (for the faculty Marrer represents) only if it requires the same level of expertise as Blackboard. To be adoptable by others, the software has to be very easy for people to use. When asked whether and how xTutor might be used at MCCC in the future, Marrer replied that if given time and if there were authoring tools developed for it, people would be more willing to adopt it. He feels that the thing holding it back is the lack of a community building mechanism that could help people share the materials. He suggested that the developers take on an open source model to engage users. In his opinion, an open source development model would give others a chance to develop the middle ware necessary to make it easier for faculty to use and adopt.

Marrer's impressions about the need for open source community to help share information might in part be driven by the lack of access to and communication with xTutor developers. (Communication gaps may be in part because Alan Levine has since left MCCC.) Marrer did have an opportunity to meet with Phil Long when he attended the Campus Magazine Technology Conference held at MIT in August 2006. In this informal meeting Long connected him with Mark Schulz at UQ, so they could begin communicating. Marrer also noted that it was very difficult to meet with or talk with the faculty developing xTutor – so unlike the experience of UQ developers (perhaps because he was not implementing the course, but was in fact interested in the software) reinforcing his impression that xTutor was a project built on a research model. This suggests to him that the original faculty involved had moved on to new questions, new issues and that xTutor was now 'old hat' for them. In a sense, both Terman and Lozano-Pérez confirm this view when they talked about how they could not provide the necessary day-to-day support to those off campus who wish to use xTutor.

Marrer's gatekeeping role is critical when examining adoption of xTutor outside of the computer science context. Marrer as the gatekeeper for his campus feels that xTutor is simply not ready for his faculty who know little about programming. He feels that the user and developer community have to be able to come together easily and share it's learning with one another. That such a community could then extend into the next phase, building xTutor in such a way that you can reuse courses and courses materials that have been developed in xTutor by other faculty. He feels that by attaching it to a repository of some sort it would reduce the amount of time it takes to develop new courses, a development that would make it much more attractive to faculty.

Analysis

xTutor is an example of an iCampus project that evolved out of efforts to find course-centric solutions to a pressing need to manage students' own learning more interactively in large classes. What was originally a 'local' solution for a single course evolved into a more 'global' solution, that of creating a software framework to support faculty members who want to move away from dependence on lecture only teaching formats to interactive learning, regardless of the course content.

Within 6.001, 6.004 and 6.034, adoption and institutionalization seems to have depended upon:

- Cadres of faculty who worked together to develop and implement the innovation. Lozano-Pérez and Terman did not work alone. They had their own group of friends and colleagues who sustained them in this effort, both personally and professionally.
- Strong ties to the department administration, which allowed them the freedom to experiment and supported their efforts to make the changes.

- Inside tracks to funding opportunities that served to ‘reward’ them for their efforts in innovation (iCampus funding was described as a reward as much as it was necessary to further the project.)

In order to spread into new courses in MIT’s EECS department, a different set of factors also came into play:

- Several faculty members who were a part of the cadre who taught the changed core courses chose to experiment with Tutor (or xTutor) in other courses for which they are responsible. In some of these cases, Terman and Lozano-Pérez set up example instances of the software so it could be tested in a particular course.
- Financial help through continued iCampus funding for making required course change.

One untested adoption strategy focuses on the hope of the cadre of faculty involved in xTutor that the recently undertaken EECS curriculum revision project will encourage EECS faculty members to use xTutor when making course revisions. While there are no formal plans for helping faculty do this, this cadre has been promoting its use during planning meetings and more informally.

Adoption of xTutor outside MIT also seems most successful when adopters come to the innovation through adoption of the online versions of the 6.001 and 6.034. This points to the importance of course content in the process of adoption as well as the importance of adoption channels linking the innovating institution to others that teach roughly the same content in roughly the same way.⁷⁰ Faculty who have successfully adopted Tutor or xTutor were first drawn to the fact that an online course existed that they could use with minimal ‘tweaking’. Again, MIT support for making changes, hosting initial offerings and so forth were essential in the successful adoption and subsequent importation of the software to the new campus.

The importance of the cadre of faculty involved seemed to have a positive impact on adoption within EECS, and possibly other science, math and engineering courses in MIT. In contrast, this type of cadre, seemed less important with regards to dissemination to other campuses. Here, after learning that these courses existed and were available for use, adoption was based on interest in the online courses. This type of adoption is an example how innovation might be more easily transferred from one set of innovators to another. In other words, the online courses moved easily from the MIT innovators to innovators at other campuses. At the campuses who have adopted these courses there is no evidence that adoption of xTutor will spread beyond the original innovators to faculty members who might be considered ‘early adopters’ as defined by Rogers. (2005).

In contrast the MCCCDC case (where the main interest was in xTutor as software not the course) illustrates how the lack of ease of use can negatively impact adoption. At MCCCDC, xTutor was compared with other instructional software tools faculty might use when teaching a course, e.g., Blackboard or Turnitin. Since focus was on the ability of xTutor to support the development of new courses or refinement of existing, Marrer’s evaluation of the software was that it was not at a state where a faculty member who has little or no programming skills could use it. Even though Marrer has described it enthusiastically in his blog, no one has adopted it to date. Marrer himself has not been motivated to use it even though he knows of one course that would benefit from it. It is important to note here, that Marrer has been working with the currently available version of xTutor. This version is not the version its developers envision releasing to the public. The version scheduled to be released later in 2006 may resolve a number of the usability issues described by Marrer and others.

⁷⁰ The importance of this peer-to-peer relationship around course content comes out in our studies of other iCampus projects, too (e.g., TEAL, XMAS)

A primary factor in both of these two cases is the role of the gatekeepers. Marrer was investigating xTutor on behalf of the faculty members at the 10 colleges of the District (and any other colleges with which MCCCDC might interact in its role as an iCampus hub). Even if Marrer had found xTutor attractive for others, he would have been presenting it to them as a tool without content. It seems possible that encouraging adoption of a tool may be more difficult to ‘sell’ than adoption of an entire course or set of content. The experience of Robinson and Duke at UQ illustrates how the gatekeeper there, Mark Schulz easily captured their interest by finding a solution to their problem by first finding a course that met their needs. In this solution, experiencing the innovation first through a ‘package deal’ i.e., they used the entire course with help from MIT led to their interest to try xTutor.

Recommendations

This case study describes the process of development of a product that has not yet been released in its ‘final’ form, nor has it been fully tested with faculty users. It is a story then that cannot truly focus on dissemination, be it successful or not. It can illustrate however, a number of the challenges associated with the evolution of a software solution that meets the needs of a small set of faculty (mainly the developers and several of their colleagues), and does so quite well, into a product that is meant to meet the needs of a set of ill-defined, diverse and multidisciplinary faculty members.

The two cases described above illustrate how interest in a particular course or course content can drive the successful adoption of a software solution, with little knowledge of that solution by the adopters themselves. Robinson and Duke thought first about the content, and only recently have begun to actually explore how they adapt the technology framework to meet their unique needs. In contrast, Marrer, has explored the technology framework, drawn to it only initially by his interest in the content. His exploration illustrates how the transition from a single course solution to a ‘generic’ framework may require a different approach to dissemination, one more akin to the types of dissemination undertaken by commercial or open source software products.

Perhaps the most critical recommendation to be drawn from these disparate cases is the need for the developers of xTutor to undertake significant user testing as well as to conduct a market analysis of the need for this product and explore potential competing products⁷¹. As they have learned from the few faculty members who have adopted the Tutor and earlier versions of xTutor, there is high interest in the support for the problem set functionality. There is less interest in terms of the lectures and support for course content. The levels of interest may reflect two distinct markets: the first being for a course focused on this content, the second being in the architecture. Regardless, the development team should conduct user testing of the software to learn what it takes for faculty members (particularly those who are not adept at computer programming) to learn how to use the software.

Usability testing should also address the question of why faculty members might choose this product over others, as well as how to ‘catch their attention’ and interest them in this solution. Our interviewees (adopters, non-adopters and developers) all focused a great deal on the lack of time that faculty members have to learn this kind of thing. If xTutor requires faculty members to spend more time, because of bad user design, then it will fail. Those faculty members who do use it do so because it has solved a problem for them and others have done the technical support

⁷¹ For example, the 2006 Premier Award for Excellence in Engineering Education will be awarded to software developed to help computer science faculty design interactive, complex problem sets for their students. At the time of this writing, the actual name of the award has not been announced. See www.needs.org for more information.

necessary to implement xTutor, or it has solved a problem and they have had the programming expertise and desire to tinker with the software themselves. Both of these models are not sustainable models for future adoption of xTutor.

The project at this point in time is at an important juncture for its developers must decide if it is a project that is worthy of the considerable effort that may be needed to disseminate it successfully. The results from the testing and the market analysis described above should determine whether further work on dissemination of the final product should be pursued.

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Chapter 8: Exploring the Hub Strategy for Adoption - Lessons from the University of Queensland

“I think this university is looking for something out of the ordinary...I really like the people I work with here. There’s a core bunch of people who just like doing good stuff and who are always in corridor conversations with each other even though we’re really busy.”

- UQ Faculty Member

The iCampus program has tried at least four strategies to foster long term, widespread adoption of iCampus projects inside and outside the Institute:

- 1) **Laissez faire** – responsibility for adoption rests by default with the principle investigator and others associated with the project. This is the iCampus management’s strategy for most of the 70 or so iCampus-funded projects. It has been the dominant strategy for XMAS until recently, for example.
- 2) **Individualized outreach for designated projects** – Phil Long, in charge of outreach, and, occasionally, other iCampus staff, attends conferences and visits campuses, talking about projects.
- 3) **Hub universities work with institutions in their area** - iCampus recruits institutions to try iCampus projects, especially looking for institutions willing to be regional hubs that will implement a number of iCampus projects themselves and then play a prominent role regionally in informing and supporting neighbor institutions. The effort by MIT per hub has varied quite a lot, depending in part on MIT’s perception of the hub’s own investment of effort.
- 4) **Consortia** – Like the ‘hub’ strategy, this approach offloads the burden for promoting long-term adoption on entities that are each organized around one specific iCampus project. iMOAT began as such a consortium almost from the first day. Consortia are in planning stages for iLab and xTutor.

This chapter focuses on the “hub” strategy and, in particular, on its implementation at the University of Queensland (UQ) in Australia. As of late summer 2006, iCampus has formal agreements with nine hub institutions around the world. At this time, Queensland appears to do more as a hub internally and externally than most or all other hubs. **Is this exceptional performance a hint that the hub strategy will usually fail unless the stars are in unusual configurations in the local heavens? Or is Queensland just a little bit ahead for reasons that signal that at least some other hubs will soon follow? The course of events at the University provides some clues.**

History of Engagement

At first the UQ success seems to be the fruit of unlikely coincidences, most of them lucky. Margaret Gardner, Deputy Vice-Chancellor [Academic] of the University of Queensland (UQ) was at an EDUCAUSE conference in November 2004 where she met Phil Long. She invited Long to come to the University of Queensland. Happily, he was able to do so.

When Long visited UQ, as it happened, Mark Schulz and Brian Lovell of Information Technology and Electrical Engineering (ITEE) were in the audience. Long's discussion of iLabs was what grabbed their attention.

Like many universities, UQ was short of funds for laboratories. The ability to have more labs, and more kinds of labs, with lower up front costs was appealing. (The last upgrade of ITEE labs had cost half a million Australian dollars.) xTutor was also interesting to them.

The notion of collaborating with MIT was not strange. UQ had plenty of experience with international collaboration, in Asia. By working with polytechnics in Singapore, creating organized programs for their diploma graduates to come to UQ and complete a university degree, UQ had gained students and revenue, while also providing the Singapore institutions with a prestigious relationship that helped them attract students. Even more to the point, UQ had been trying to work with MIT to set up an Asian site for MIT's Media Lab. Although that effort would soon peter out, Schulz and other UQ advocates didn't blame MIT for the problems. In fact the effort had whetted their appetites for working with MIT. So when Long described the idea of having hubs in different regions of the world that could then serve as local sources of iCampus software and support, he found a prepared and eager audience.

Schulz, a Senior Lecturer in ITEE, immediately sent a memo to Margaret Gardner suggesting that UQ be the Australian hub. Schulz had canvassed academic staff and found many people interested in working with xTutor and iLabs, he said. He pointed to the appeal of the labs for attracting Asian students to UQ, and mentioned that some faculty thought that working with the labs could advance their research. By sharing UQ-developed iLabs with other universities and high schools, more of the best students could be attracted to UQ, Schulz suggested. And, most importantly, UQ would benefit from the "linkage we create between the UQ brand and the MIT brand." Gardner was easily persuaded.

But then came the first unlucky coincidence. Margaret Gardner left the University almost immediately, becoming Vice Chancellor (president) of RMIT University. And so it was that the fledgling iCampus plan, along with all Gardner's other activities, fell into the lap of Paul Greenfield, Executive Pro Vice Chancellor of the University. Greenfield had his own activities to keep him busy, and the proposal that UQ volunteer to be a hub languished. Schulz repeatedly sent messages up the hierarchy but nothing came back.

After some months of inaction, another coincidence got things moving again. Brian Lovell, who had attended the Long presentation with Schulz, heard that a Brisbane City official was heading for Boston. Lovell asked if the official would contact Phil Long, and suggest that Long contact Greenfield. Lovell's strategy worked. Long wrote back and UQ responded swiftly. In fact, a delegation was dispatched to the United States to deliver UQ's signed hub agreement in person.

Schulz, who went to MIT to carry the agreement, was delighted when Long unexpectedly spent an entire day with him, briefing him, introducing him to iCampus project leaders, and demonstrating iCampus projects. This quick response and generosity with time and resources seems to have marked MIT's support for Queensland since then. In fact, both institutions have been unusually generous with time and effort, and have pointed to the other institution's investments as a reason for their responsiveness.

When Schulz returned, Michael Keniger, newly appointed to replace Margaret Gardner, asked Schultz to take the lead in organizing UQ's hub activities. Keniger had been pleased with the breadth of interest in iCampus. Not only was ITEE actively working on an iLab and on its first use of xTutor, but the School of English, Media Studies and Art History was also interested in XMAS and soon would invite Pete Donaldson of MIT to become the inaugural Lloyd Davis Memorial Visiting Professor in Shakespeare Studies.

To Schulz's surprise and pleasure, Keniger suggested a figure of AU\$100,000 as a budget and to be thinking in terms of three years of activity. Schulz responded with a three year budget, with a first year request of AUD\$118,000, which was granted.

This budget was just one indication of the deep and continuing interest that Keniger, Greenfield and the UQ leadership have taken in iCampus. Keniger also asked Paul Bailes, head of Information Technology and Electrical Engineering, to support Schulz's effort. And, both in public addresses and private interviews, Keniger has shown a deep understanding of, and enthusiasm for, the iCampus work.

Nonetheless work slowed for a time when Schulz was named Director of Studies for the Faculty. Nonetheless he began a series of visits to other Australian institutions, talking about the possibilities of iCampus.

Meanwhile Schulz assigned an ITEE undergraduate, Joel Carpenter, the task of creating an iLab. Several months went by and the expected equipment had not arrived, so Carpenter got a new iLab assignment: to create a remote lab to work within the MIT iLab architecture, so that undergraduates could operate a pole balancing experiment created the year before. This experiment (also referred to as an inverted pendulum) had, coincidentally, an important feature unusual among iLabs: it was interesting for laymen to watch in operation. The students in the lab had to write a computer program that would use sensor inputs to flip a pole, initially hanging straight down, and then balance it (similar to the action needed to balance a pool cue with one hand).

Carpenter worked with little UQ supervision. MIT didn't become aware of his work until late in the game, because Carpenter was working with publicly visible files and downloads. His experiment was completed in the nick of time, not only for the course in question. Long had been invited back to UQ to keynote Teaching and Learning Week, and the pole balancing experiment was made a key element of the publicity campaign for the week, featuring in advertising as well as in the program itself. iCampus was on its way at UQ.

MIT continued to provide vigorous support. Peter Robinson and Roger Duke, who use xTutor to support a required introductory course in computer science, remarked with amazement on how quickly and completely MIT responded to e-mailed requests for help. They expected answers in a week, but were amazed when someone at MIT would respond in the middle of the night (in the US) to questions e-mailed from the daytime side of the globe.

If a June 2006 iCampus workshop hosted by UQ is any gauge, the effort is off to a good start. Schulz' extensive travels helped attract one or more participants each from education.au (a government-funded agency with responsibility for promoting networking), the University of Melbourne, the Royal Melbourne Institute of Technology, and University of Technology Sydney. Although many more institutions were invited and did not come, the two days of sessions were lively, and resulted in a number of plans for future work, especially for iLabs, where several institutions said they would create labs, and XMAS, where a brainstorming session produced some exciting new thoughts about system use, including for helping academics discuss and learn from video of their own teaching. The week of activity also was exciting for visitors from MIT for other reasons. Jane Hunter, leader of the eResearch Group in Information Technology and Electrical Engineering, was already doing work on video annotation that complemented and compared favorably with XMAS. Collaboration with XMAS developers may result.

As of November 2006, there are:

- seven iLabs experiments in use or in development at UQ

- continuing use of xTutor and interest from other institutions (especially when the anticipated new version of xTutor allows more tailoring, such as the addition of new problems or lecture elements),
- an XMAS server and XMAS client software on at least 10 machines

In almost a dozen interviews conducted during June, as well as via informal observation during the week-long visit, the author saw many evidences of interest and commitment at UQ.⁷² It's true that, as at MIT, the majority of people are undoubtedly completely unaware of iCampus (for example the physicists teaching introductory physics may not have heard of TEAL or be aware of iCampus, according to another physicist at UQ who hadn't yet told them about iCampus). But for an effort that has been seriously underway for only about a year, the progress has been impressive. No other hub can yet match it.

It's time to return to the question with which we began: is this the fruit of many happy accidents? Or are there clues from the UQ experience that indicate conditions under which the hub strategy is most likely to work?

Analysis of the Hub Strategy for Fostering Adoption

The hub strategy has most often worked in the past when some or all of the following factors worked in its favor:

1. When the center is able to spend money each year to support the hubs (e.g., US government supporting agricultural extension centers around universities); or
2. When maintaining the hub involves little real cost to the institution involved (e.g., mirror sites for software downloads)
3. When the material being disseminated by the hub has its own attractive power so that the hub needn't do all the work in finding beneficiaries.

Almost none of these factors were working in iCampus' favor.

The hub relationship required significant investment by MIT and by the hub to work: a) MIT offering support in a variety of forms including financial if necessary up until Dec. 2006, and b) the hub institution fostering internal and external adoption, until and perhaps after Dec. 2006. But MIT began looking for hubs only about two years before the project was due to end. In the time scale of academic change, this wasn't much time. And other factors were against the success of the strategy.

The 'attractive power' was lacking, too. "MIT" is a well-known brand, but "iCampus" and no one, even MIT and Microsoft, had any interest in establishing it. "iCampus" in fact is simply the label for a rather diverse set of educational technology projects with little in common except a source of funding: they don't appeal to the same audiences, for example, so disseminating each one can be a separate chore, with burdens on different faculty at the hub to serve as evangelists and support for potential adopters in their regions.

With these factors working against the hub strategy generally, why was UQ relatively successful in implementing it. To summarize factors mentioned earlier in the case,

- A UQ culture which is aggressive, confident, decentralized, and "can-do";

⁷² For more information about the University of Queensland effort, see their iCampus web site at <http://icampus.uq.edu.au/>. As of November 2006, the site includes a video welcome address from the Pro Vice Chancellor and information about iCampus related projects at UQ.

- iLabs had a powerful appeal for UQ because of its need for more laboratory facilities and the idea that MIT-UQ iLabs, deployed in regional high schools, could help UQ attract more students. It seems doubtful to us if UQ would have agreed to act as a hub for all of iCampus without iLabs.
- UQ staff had a history of successful collaborations with other institutions in the region
- On this side of the world, “MIT” was a name that had mainly positive connotations that could help UQ attract resources, especially if, as UQ hopes, this collaboration leads to a wider set of working relationships with MIT. iCampus was not the first attempt by UQ and MIT staff to collaborate, but it is the most successful to date. And, this far from MIT, UQ did not need to worry about publicizing a competitor.
- Australian institutions compete for prestige and resources. The University of Melbourne had expressed interest in being the iCampus hub, which intensified the desire of UQ to get that relationship.
- MIT made a substantial investment in the relationship, with several visits by the Outreach Coordinator and other iCampus staff. Once momentum began to build, the iCampus Outreach Coordinator began bringing the UQ coordinator, Mark Schulz, to other countries to help represent the program.
- UQ has talented, well-educated undergraduates who could develop iLabs with relatively little supervision.

For future initiatives such as iCampus, outreach networks with hubs continue to be a good idea but we suggest that:

- The networks each be organized around a clear educational goal, a clear educational strategy, and a strategy for encouraging and supporting adoption of its ideas and materials.
- The networks be organized in a way that assures long term funding for the hubs’ work.
- The networks not usually be centered on one institution (such as this network was around MIT).

We return to these suggestions, in a broader context, in Chapter 10.

Chapter 9: Findings: How Were the Five Projects Valuable? What Factors Affected Their Adoption?

To summarize our findings from over 150 interviews and the study of many documents in a nutshell, these projects have developed ideas, materials and services that promote learning that is authentic, active, collaborative, and feedback-rich. They deserve wide adoption. And widespread adoption is an important way to amortize the substantial sums spent on these projects.

But despite the quality of the work, despite the fact that the materials are free, and despite the fact that iCampus has allocated about \$2.5 million for outreach (about 10% of its total budget), adoption of these innovations has so far been limited to a handful of faculty and institutions for each project. That level of adoption is all too typical for faculty-developed, content-specific academic software projects. In fact, as these case studies have shown, the barriers to adoption are so daunting that it's a tribute to hard work by the projects and iCampus staff that there has been any adoption at all.

This chapter spells out our findings in more detail, and chapter 10 describes our recommendations for action by universities, foundations and government funding programs, and corporations in order to assure that much wider levels of adoption and use can be achieved to help higher education adapt to changing needs and constraints.

Finding A: These iCampus projects have improved education at MIT and at some other institutions, making learning more authentic, active, collaborative, and feedback-rich.

There is, and has long been, widespread agreement that education can and should be:

- more authentic (bearing a closer resemblance to the tasks and problems of work and life after college),
- more active (engage students' attention, energy, and creativity),
- more collaborative (students thinking and learning together), and
- more feedback-rich (students learning by getting rapid results from and/or assessment of work they have done).

Many projects before iCampus have demonstrated that technology can play a role in enriching all four of these goals, often simultaneously. iCampus projects have contributed to what we know, and to what we can do, in all four areas. And the impact of these five projects has gone beyond proof-of-concept. For example, the ideas have been institutionalized in a two-term physics sequence required of most MIT students, in three of the four core courses required by MIT's largest undergraduate major, and in the writing assessment used for incoming MIT students. For all five projects, ideas and materials advancing these values have been adopted not just by the faculty who were directly involved with the projects, but also by additional faculty at MIT and by faculty at other institutions. These adoptions, along with evaluative evidence, clearly demonstrate the value of these materials and ideas.

	iLabs	iMOAT	TEAL	XMAS	xTutor
More authentic	Laboratory work in lecture courses, sometimes using professional-grade equipment	Writing assignments more closely resemble actual academic assignments than previously possible	Laboratory work incorporated in what previously had been a lecture course	In Shakespeare, enables studies of the performance, not just the 'script'	Student in computer science gets feedback on how to improve computer programs
More active	Student does experiments	Student writes more extensively than in previous assessment procedure	Personal response systems; extensive discussion; laboratory experiments	Students use video clips in online discussions, projects, presentations instead of just watching it	Student in computer science writes more complex programs while still getting online feedback
More collaborative	Students often work in teams on labs, rather than alone on traditional homework	--	The majority of TEAL classwork requires students to work in groups	Student presentations followed by discussion	Class time freed up for more discussion and group problem solving
More Feedback-rich	Results from real experiments, quickly achieved, with time to do them again	iMOAT can be used to provide students with more feedback on writing than is traditionally available through placement exams	Lab experiment results; personal response systems feedback from other students; feedback from instructor and TAs	Reactions to student presentations and through online discussions	Automatic grading of homework; feedback in class (using time that would otherwise have been spent taking lecture notes)

Evaluation findings and the experiences of adopters for each of the five projects have been summarized in previous chapters.

Finding B: Achieving adoption of these projects is very important, and extremely difficult

Widespread, long-term adoption of iCampus ideas and materials was considered important by project and iCampus staff. In interviews, we heard a variety of reasons for considering adoption a priority:

- It was often important to principal investigators to achieve wider and long term adoption by others in order to sustain their own work – because of financial contributions from others (iMOAT), institutionalization at MIT (all five), and the credibility for internal purposes gained by external use (all five)
- Microsoft wanted to justify its investment in iCampus by its benefits to other institutions as well as by longer term influence at MIT.

- Promoting adoption outside MIT was seen as a way of getting ideas for making software better for use inside MIT (iMOAT)
- Wider and long term use, benefiting large numbers of students, helped justify the money spent on the projects' development.

For all their value and despite the fact that the materials are available at no charge, levels of project adoption have been modest. Of the tens of thousands of universities and colleges in the world, less than 1/10 of 1% are using the materials, and the rate of increase in adoption is slow, despite iCampus's aggressive and well-funded outreach effort. The difficulty in achieving adoption of materials 'not invented here' is well-known and almost universal in the arena of faculty-developed materials of this type

Our study revealed many barriers impeding the wide adoption of iCampus projects, inside and outside MIT:

- For any content-specific innovation, only a few faculty members at any given university or school teach courses in which the innovation (e.g., the Microelectronics Device Characterization Laboratory) might conceivably be used. Of course, researchers in engineering or science face a similar challenge in disseminating their findings: at any one institution only a few faculty members would be interested. But the resemblance between the dissemination of most scientific research and the dissemination of most subject-specific educational improvements ends there.
- Few potential users search the world for innovations to adopt. In the world of basic scientific research, in contrast, faculty members who do the same research usually attend the same meetings and read the same authoritative journals; they are trained and rewarded to attend to advances in their fields. But for typical teaching improvements in the disciplines, many innovators and potential adopters don't have a professional association where they could easily learn about innovations for the courses they teach. Or, if there is such an association, they don't have the time, money or incentive to participate in the content-specific, teaching-related activities. So, if widespread adoption of content-specific teaching innovations occurs, it is not usually because hundreds of thousands of pro-active potential adopters were scouring the landscape for new teaching ideas. Instead the new ideas have to be disseminated by the innovators who must successfully attract the attention of adopters who usually don't have the time or rewards to pay attention.
- Principal investigators (PIs) are essential to dissemination for content-specific innovations but PIs are not trained, rewarded or supported to engage in dissemination. (iLabs, xTutor; TEAL, iMOAT and XMAS). They may not be familiar with the relevant professional associations and may not have much visibility or credibility as educational innovators. That makes it difficult for them to catch the attention of potential adopters.

Their departments and institutions are not rewarded, either, for dissemination of innovations. At MIT-type institutions, such rewards accrue to faculty only when instructional innovation is integral to faculty research and (better yet) leads to a continuing stream of grants.
- So potential adopters aren't looking for innovations, and the innovators aren't trained, rewarded or supported to seek out potential adopters from among their peers. What about using intermediaries? In employing a hub strategy, iCampus sought to work from its PIs through its Outreach Coordinator to teaching centers, chief academic officers, IT leaders, or other central points of content. The plan was for these hub leaders to seek out and perhaps persuade faculty teaching courses comparable to those of the iCampus PI to try

the iCampus project. But for content-specific innovations such as the Microelectronics Device Characterization Laboratory, it's usually inefficient and even ineffective to rely on a chain of intermediaries. The staff members at the potential adopting institution usually don't have the time or expertise to make the match between instructors and such content-specific innovations. In fact they may well squander political capital by giving the appearance of telling respected faculty members how to teach.

- Time scales clash in any kind of educational technology initiative. Technology changes quickly, so quickly, in fact, that in a couple of years software may cease to operate if it isn't updated to keep pace with changes in operating systems, networking, and other software with which it inter-operates. But education changes slowly. So, when it comes time to decide whether or not to invest lots more time and money in updating the academic software, there may not yet be much use of it, or much visible benefit from the uses that have occurred thus far. This clash of time scales has been responsible for the disappearance of many millions of dollars of academic software.

Another potential clash of time scales: Corporate budget years may clash with university calendars, making it hard to fund faculty in university-corporation alliances because the time of year when faculty have time to plan innovations may not be the time of year when the corporation can build such requests into budgets.

A third clash: if software is being designed for use in a single course that is taught once a year, or once every two years, a small delay in process or development may lead to a huge delay in use. The use of XMAS at one university was delayed a year because the university's lawyers, who were required to approve all software licenses, took several months to figure out how to deal with the open source nature of XMAS. And the course for which XMAS was to be used is only taught once a year.

- "Rapture of the Technology": Technology, when used for education, can easily draw a self-defeating amount of attention to itself: attracting a damaging fraction of available funds to development. (Ehrmann, 2002) For these projects one sign of rapture of the technology was adoption materials that focused more on technological innovation than on educating potential adopters about the circumstances under which they might need to use the innovation, curricular materials for taking advantage of the innovation, costs of the innovation, risks of the innovation, and the like. iMOAT was relatively good at avoiding rapture of the technology, but the other projects all succumbed to it in varying degrees.

So we have a rock (adoptions that require wider adoption in order to justify the investment in their R&D) and a hard place (potential adopters who aren't out looking for ideas, weak communications channels, and innovators who usually aren't rewarded, trained or supported to disseminate their work in education). And yet dissemination and adoption of these ideas did happen to some degree. Our inquiry has focused on explaining why it sometimes succeeded.

Sustainable, spreading use of these five projects has been a function of the innovation's features (summarized below), the strategies used to promote the project's adoption (Finding D), and motivations of the adopting institution (summarized in Finding E)

Finding C: Certain project features make adoption a bit more likely.

We begin with the features we saw in iCampus projects that affected their chances for wider adoption.

- Value, or at least legitimacy, sufficient for all the stakeholders needed to implement the innovation and sustain it, e.g., faculty, IT support staff, institutional leaders in some cases, faculty development program. For example, XMAS seems to have attracted some librarians' interest, who saw the development of library facilities with computers and reserved DVDs as an asset whose value could go beyond supporting the faculty member who was using XMAS. It's important to note that the value lies in the pedagogical features of the project, not just the technology. For example, the University of Queensland inverted pendulum iLab has attracted attention in part because its elegant interface makes it much easier for the undergraduate to analyze how programs are performing, much easier than was the case for the original lab used before iLabs.
- Recognizability: Good fit with current ideas about how to improve education using new technology so that potential adopters easily recognize the specific innovation. All five projects were easier to explain because of wider changes in the world (e.g., uses of the Web for buying products, doing research in class).
- Incremental adoption possible: Projects that can be adopted in ways that initially affect only a small part of a course or process so that it be used with rewarding results but manageable investment and risk by someone not yet convinced of the value of the innovation. This factor favored adopting TEAL simulations and/or TEAL problems, for example. Adopting the whole TEAL model (classroom designs, texts, simulations, and more) was considerably more difficult and expensive but might be delayed until after the course content had demonstrated its value.
- Flexibility and multiple uses so that more innovators are likely to find (or even invent) a use that then deeply engages them. LSU's adoption of iMOAT to do mass assessment of writing at the end of the freshman year exemplifies this kind of innovation.
- Affordability; Time-saving for faculty, or at least not too time-consuming. The xTutor Scheme course frees faculty from time that might have been spent lecturing and grading homework in order to spend more time helping students learn through problem-solving.
- Ease of use for faculty, students, and support staff. XMAS, for example, was easy enough to use that at least one adopter needed no help from the technical staff at her institution.
- Few collaborators required. The xTutor Scheme course requires fewer collaborators than, say, developing a TEAL classroom.
- Project as service: Conceiving of the innovation as a service for adoption and use, not just as a product for dissemination. When CalTech saw iMOAT as a product, they decided they could do better by designing their own version. When they realized later that iMOAT was a 24x7 service with high reliability and tech support, they rejoined the Consortium. The Consortium's member fees pay for iMOAT maintenance and continued operation.

- The ability of undergraduates to play a role in developing or adopting the innovation, both to help faculty and to demonstrate that implementation is feasible. The University of Queensland's engagement in the use and promotion of iLabs was triggered when an undergraduate with little supervision downloaded the Shared Architecture and then developed an iLab for a local experiment.
- Content-rich innovations versus multi-use tools. Content-rich (e.g., the xTutor Scheme course) can be easier for the few potential faculty users in any one institution to grasp than tools (e.g., xTutor as an authoring system). Tools have more potential users per institution, but reaching those faculty users can be quite difficult unless the adopting institution makes a serious investment.

Finding D: Some Strategies Helped Promote Adoption Despite These Difficulties. Pre-existing Coalitions for instructional Improvement were Especially Important.

Several strategies were employed by iCampus principal investigators and staff in order to attract the attention of and support potential adopters: communicating through coalitions for instructional improvement (especially pre-existing coalitions); involving potential adopters in setting specifications for the project; and making web-based materials and services freely available for download and/or use online.

Coalitions for Instructional Improvement: Some of our five projects had unusual success in promoting adoption, even before getting help from iCampus's half-time outreach coordinator. We found that those Principal Investigators had already been in relationships with other faculty members where talking about teaching, and innovation, in their shared courses was customary. The contexts were different – professional associations, informal networks, a style that EECS has for teaching large courses, educational relationships that MIT had established with Cambridge and the National University of Singapore, MIT's program of sending undergraduates to China⁷³ – but they all made it more comfortable for innovators and potential adopters to compare notes and try ideas. So we have termed all of these *coalitions for instructional improvement*.

The easiest adoption successes came from coalitions in which the PI had been active before the iCampus project, especially if the PI had a history of making contributions of this sort in the past (e.g., Pete Donaldson's prominence in using video clips for studying performance in the Shakespeare Association of America). Such a track record also makes it easier for the PI to use communications channels (e.g., Donaldson using mailing lists of participants in his prior workshops to tell them of the availability of his new project, XMAS). When such a PI announces that he has made another step forward and people can freely use it, many peers pay attention.

These pre-existing engagements had another profound impact: the PI was often thinking quite concretely about how to influence others in the coalition right from the beginning of the project and could then easily use the communications channels of the coalition to spread the message to peers.

Where appropriate coalitions did not exist, iCampus attempted to create them, e.g., the iMOAT consortium which built on an existing coalition; groups of institutions focused on 'regional hub' institutions disseminating many iCampus projects. Creating coalitions from scratch was quite difficult, and there was a high failure rate.

⁷³ The collaboration with the National University of Singapore and the role of undergraduates sent to China were each described in chapter 3, iLabs.

Other Promising Strategies used by iCampus for Promoting Adoption

In addition to its use of pre-existing and new coalitions of various sorts, we note two other promising strategies employed by iCampus.

1. iMOAT engaged potential adopters in creating the specifications for the innovation: A design process involved potential users in the creation of specification, design conferences and software testing in order to make the innovation both more valuable and also more visible to its potential users. Project funds were used to bring participants to annual meetings at MIT; they also met at professional conferences and by conference call on a regular basis. iMOAT did not require them to promise to use the software. The practice resulted in more robust, flexible software, and laid the groundwork for most of the participating institutions to help found the iMOAT consortium, paying dues for its service and to help maintain the software.
2. Use of the Internet to enable casual users to try out and use the innovation freely and, in some instances, anonymously. This practice worked well for all the projects we studied. For example, students or faculty could use the two xTutor-based courses over the Internet.

Finding E: Some Institutions are More Likely to Support Adoption of Innovations Like These

Occasionally institutions *are* on the prowl for ideas and that makes a big difference in the adoption process. The Windward School in California, for example, was seeking examples of how science programs were using new kinds of learning space in order to support active learning. They were going to design two new buildings and wanted a notion of how the best science programs in colleges, colleges their graduates might attend, were doing things. Their search led them to TEAL and they bought plane tickets to come to MIT and have a look. But the stories we've uncovered in this study strengthened our prior belief that this kind of institutional search for ideas is rare.

To get the collaboration of other institutions in spreading MIT/iCampus ideas, it helped if the institutions were far away. The Outreach Coordinator of iCampus joked that interest in iCampus innovations varied by the cube root of the distance from Cambridge. Institutions like the University of Queensland saw local advantages to associating themselves with the MIT 'brand' and little competitive threat from an institution so far away.

Chapter 10: Recommendations for Fostering Future Improvements in Education with Technology

The TLT Group has been asked, “In light of the experience of iCampus, especially projects selected by MIT and Microsoft for close study, what can be learned about priorities for educational technology initiatives in the future and about how the spread of such innovations can be more effectively supported?”

Drawing on our study of these five projects and on experience, we make five recommendations. The first deals with the kind of educational change whose feasibility has been illustrated by these five projects. The remaining four are strategies to overcome the enormous difficulties of disseminating and adopting such improvements. Stated briefly, the five recommendations are:

1. Improve education by making it more authentic, active, collaborative, and feedback rich. iCampus software and ideas can provide useful elements for such a campaign.
2. Create demand to adopt ideas and materials from other sources by encouraging all faculty members to improve and document learning in their programs.
3. Nurture coalitions for instructional improvement, within and across institutions, in order to create better channels for sharing and improving innovations.
4. Create more higher education-corporate alliances in order to support the development and dissemination of new educational technology materials and practices.
5. Supply faculty innovators with help in educational design, software development, assessment methods, formative evaluation, and/or in sharing ideas with others in their disciplines who teach comparable courses.

We believe that these recommendations will be more feasible if there is substantial collaboration among universities and colleges, foundations and government agencies, and corporations. Therefore discussion of each of these five recommendations begins with a general description, followed by actionable recommendations for universities, for foundations and government agencies that support innovative work in education, for corporations and, finally, for MIT. The MIT recommendations supplement the university recommendations, with suggestions specific to the Institute.

Recommendation 1. Improve education by making it more authentic, active, collaborative, and feedback-rich. iCampus software and ideas can provide useful elements for such a campaign.

There is, and has long been, widespread agreement that many elements of higher education should be:

- more *authentic* (in some ways bear a closer resemblance to the tasks and problems of life after college),
- more *active* (engage students’ attention, energy, and creativity),
- more *collaborative* (students thinking and learning together), and
- more *feedback-rich* (students learning by getting rapid results from and/or assessment of work they have done).

iCampus explored these themes, demonstrating some new possibilities, techniques, and materials. We recommend that universities and colleges, in collaboration with foundations, government agencies, and corporations, campaign to make such improvements, gradually and cumulatively. If these improvements can be institutionalized, substantial improvements in outcomes ought to be possible, e.g., improving the ability of graduating students to apply concepts to unfamiliar problems.

Recommendations such as this can sound trite, because so many people and reports have made them already and because so little has apparently happened. The bulk of the following recommendations describe recommendations for how to implement improvements such as these.

1.1 Colleges and Universities – Implementing Recommendation 1

1.1.1 Decide, at the institutional and programmatic level, whether and how to implement this recommendation; include other stakeholders in the discussion.

Changes of this magnitude are the responsibility of the faculty at most universities, and little is likely to happen at most universities and colleges without their commitment and enthusiasm. But, while faculty leadership is essential, faculty members are not by themselves able to implement such changes. Planning efforts must also include the many other stakeholders whose active participation is essential (e.g., chief academic officer, library, teaching & learning center, academic computing, facilities and space planning, representatives from employers and graduate schools to which graduates often go next, development office, legislative affairs, alumni, and others.)

1.1.2 Give preference in hiring to faculty candidates with a demonstrated preference for, and skill in, these types of teaching.

The emphasis here is on authentic, active, collaborative and feedback-rich, not on technology per se. It's easier to train a faculty member committed to active learning how to use technology to move further in that direction than it is to persuade a faculty member who is adept with a technology (e.g., giving PowerPoint lectures to large numbers of silent, note-taking students) to change his or her pedagogical aims to emphasize discussion and problem-solving.

1.1.3 Grant release time for major course improvements, with preference to faculty who work together on the same course, or sequences of courses.

While most improvements must be done without release time, which is to say that they will involve relatively small, low-risk, low cost improvements (see Recommendation 5.1.1 on 'low threshold improvements'⁷⁴), changes of this sort also require rethinking course designs. And that will often require periodic release time or comparable forms of special support.

1.1.4 Use these goals as criteria for investing discretionary funds in curricular development, new technology, space renovation, and other purposes, and as themes for soliciting funds from alumni, legislatures, foundations, and other sources.

1.1.5 Academic computing, the teaching & learning center, distance learning, the library and any other units responsible for professional development and course improvement should coordinate and organize their collective efforts around these goals.

These will not be the only organizing goals for these units, of course, but it's important that these units work in a coordinated way to promote this kind of progress.

⁷⁴ For more on 'low threshold' improvements, see Recommendation 5.1.1.

1.1.6 Develop and maintain assessment procedures to guide progress on these goals within academic programs.

Regular surveys of how students learn and how faculty teach can provide useful guidance about where progress is occurring. Such evidence can also be used to decide where additional resources are needed and to help justify appeals for more resources from benefactors and from government. In the United States, the National Survey of Student Engagement (NSSE) and the Community College Survey of Student Engagement (CCSSE) provide useful contributions to this evidence.⁷⁵

Such surveys should be complemented with other kinds of evidence, including student work, criteria used in grading student assignments, videos of classroom work, interviews, focus groups, and data drawn from learning management systems.

When archiving data on teaching/learning activities in academic programs, use these four themes (authentic, active, collaborative, and feedback-rich) as indexing terms to make it easier for faculty and staff to find examples of current progress.

1.2 Government Agencies and Foundations – Implementing Recommendation 1

1.2.1 Support model campaigns for curricular improvement within institutions.

A campaign to create education that is more authentic, active, collaborative and feedback-rich using technology needs to succeed first in a constellation of model programs and universities. These lighthouse programs can demonstrate strategies for supporting and documenting such improvements. Note: the temptation might be to wait until some new technology has appeared, or is in wide use. That would be a mistake. Technologies never stop changing. The right time to start an education/technology campaign is always ‘now.’

1.2.2 Support development of appropriate methods for assessing these teaching/learning activities and outcomes in the disciplines.

As the TEAL case study has described, Hestenes and Halloun’s development of the Force Concept Inventory (FCI) helped trigger and guide an extensive program of improvement in physics education. That’s because the FCI combines several distinctive features:

1. Mainstream physicists quickly understand that this is a good way to measure conceptual learning by their students, but
2. They are then usually surprised by how poorly their students, even their good students to. The assessment has revealed that student scores on traditional tests and homework were more tests of memorization and mathematical routine than of physics understanding.
3. The FCI is also capable of measuring improvements that innovations have caused. This is because of two complementary facts:
 - Pioneering faculty members have indeed developed ways of improving students’ understanding of concepts, and
 - The FCI is sensitive enough to detect those gains.

⁷⁵ For more on the National Survey of Student Engagement (NSSE), see <http://nsse.iub.edu/index.cfm>. For more on the Community College Survey of Student Engagement, see <http://www.ccsse.org/>.

Put those features together and you have a tool that can provide impetus for local initiatives and guidance for improving those efforts, based both on local data and on data collected by others using the same assessment tool.

It's not news that we need more tools like the FCI. These tools will likely be discipline specific and may often focus on the kinds of learning that can be most enhanced by appropriate kinds of authentic, active, collaborative and feedback-rich learning.

1.2.3 Continue to support exploratory R&D.

Many of these recommendations deal with implementation of reforms such as those pioneered by iCampus. But it is also important to continue to support a range of more exploratory projects that are designed as proofs of concept, to expand our imagination of what is possible. In funding such projects, several criteria should be kept in mind:

- We have some ability to predict the availability and costs of hardware and software in the future, if only by looking at comparable technology in the past. Exploratory projects that use projects relying on affordable reliable technology are less risky than projects that simultaneously explore cutting edge technology and cutting edge education. It only rarely makes sense to fund educational experiments that are based on technology that, three years after funding, will still be too expensive or unreliable for wide deployment.
- As this report has detailed, there is little reason to think that ideas pioneered by projects such as these will spread on their own. Only a limited audience will notice or remember what these projects accomplish unless substantial support for widespread adoption is also supported.

1.2.4 When considering new proposals for funding, recognize that, even at the proposal stage, it is possible to assess how adoptable the ultimate product or idea might be.

The Findings section of this report lists characteristics that could be used as partial criteria for funding when wide adoption is a program goal. To summarize them:

- Value, or at least legitimacy, sufficient for all the stakeholders needed to implement the innovation and sustain it, e.g., faculty, IT support staff, institutional leaders in some cases, faculty development program.
- Recognizability: Idea is already in wide discussion so potential adopters can easily recognize the specific innovation.
- Incremental adoption possible: Can be adopted in ways that initially affect only a small part of a course or process so that it be used with rewarding results but manageable investment and risk by someone not yet convinced of the value of the innovation.
- Flexibility and multiple uses so that more innovators are likely to find (or even invent) a use that then deeply engages them.
- Affordability; Time-saving for faculty, or at least not too time-consuming.
- Ease of use for faculty, students, and support staff.
- Few collaborators required.
- The ability of undergraduates to play a role in developing or adopting the innovation, both to help faculty and to demonstrate that implementation is feasible.

1.3 Corporations – Implementing Recommendation 1

1.3.1 **Support education/technology campaigns** with money, corporate staff collaborating with university staff, dissemination support through marketing.

Corporations have much at stake here: the abilities of the people corporations hire from college depends to a significant degree on whether their education is authentic (e.g., dealing directly with the kinds of issues that graduates will face later on), active, collaborative and feedback rich. The better job colleges do, the better off are the corporations who hire their graduates.

Other recommendations below contain more specific suggestions for roles corporations can play in contributing to the success of campaigns to use technology to foster learning that is more authentic, active, collaborative and feedback-rich.

1.4 Additional Implementation Recommendations Specifically for MIT

As we mentioned above, these recommendations are meant as additional, more specific notes to complement the section above which is addressed to universities and colleges.

1.4.1 **Move forward with these five projects.**

By “moving forward,” we mean two things. **First, continue to apply innovative and inquiring thinking to their further development. Second, consider each of them as part of wider patterns of improvement at the Institute.** For example, TEAL and iLabs should be seen as parts of a larger pattern of improvement in how experimentation figures in science learning at the Institute. XMAS should be seen one of many tools for enabling more active and collaborative use of visual resources. xTutor should be seen as a mechanism for increasing feedback among faculty and students. Many of the remaining recommendations deal with how to design such campaigns to improve education at MIT.

1.4.2 **MIT should systematically review all educational innovations supported with major grants from sources such as iCampus in order to determine which deserve internal support for wider deployment or further development.**

We have not studied the other iCampus projects, or other projects of this type done with other sources of funds. But we have seen enough to believe there is a risk that some projects of great potential value to the Institute and the wider educational community may simply wither due to lack of internal attention and support. This kind of review will require significant staff time and some use of external review to make sure that the evaluation of each project includes attention to good practices elsewhere.

Recommendation 2. Create demand to adopt ideas and materials from other sources by encouraging all faculty members to improve and document learning in their programs,⁷⁶ year after year.

To survive, and to fulfill their missions, universities need to adapt far more rapidly to changes in social needs, student demands, disciplinary progress, and a variety of other pressures and opportunities. As we have seen, a variety of internal factors make that kind of rapid adaptation extremely difficult.

This recommendation focuses on one fact: the academic program cannot adapt rapidly unless academic staff import and adapt ideas, materials and insights: no institution can develop everything it needs internally, and no institution is so unique that it must do so.

Today, however, “not invented here” remains the norm. In 1990, one of the authors oversaw a grant competition at The Annenberg/CPB Projects. Over 10% of all institutions in the United States submitted proposals to create online degree programs and, in citing their track records, most of them asserted that ‘so far as we know, we are the only ones doing this.’ Isolation and inventing one’s own wheel allows the illusion of being first. But it is a slow and wasteful way to adapt.

In research, the best researchers are those most aware of advances all over the world in their fields. They draw on the tools, insights, and failures of their colleagues because they know that importing is essential to success. **The same mentality is needed in education: the best teachers should continually search new educational insights, tools and materials in their disciplines, and selectively adapt them in order to improve their own academic programs.**

This increased pace of improvement in academic programs is necessary not just to attract students and educate all of them in an effective and up-to-date way in their fields, but also educate enough people to help us meet a staggering array of changing needs – economic development, rapid changes in digital technology, terrorism, global warming...

Yet few institutions provide much help for typical faculty members to learn about new findings in educational research, new developments in teaching their disciplines, and new developments in educational technology within their disciplines. Nor do many institutions reward, support, or press faculty members to continually update and improve their academic programs.

The Findings section discussed how this lack of ‘pull’ for new ideas shifts all the responsibility for dissemination onto innovators who must push their ideas outward, finding and persuading pre-occupied colleagues.

Widespread dissemination and adoption of new teaching ideas is nearly impossible unless there is widespread demand: potential adopters who are in ‘search mode,’ continually seeking new ideas and materials. Therefore we recommend that colleges and universities find ways to reward and support faculty who persistently update, improve and document learning in their programs.

Barriers to implementation: There are many reasons why few institutions currently reward faculty who make continual, documented improvements in learning in their programs. Only a relatively

⁷⁶ “Programs”: we chose this word to emphasize the importance of collaboration among instructors to improve degree programs (courses of study) and to evaluate those improvements. The goal ultimately is to enhance the education that graduates receive and the course of study can be the best level on which to act. Innovations that may seem promising at the assignment level may produce no perceptible impact on the typical graduate. And significant improvements in the skills of graduates may stem from pervasive, cumulative changes that, at the level of individual assignments, may seem quite modest.

few faculty members in the United States have received even a brief education in thinking about teaching and assessment. As a faculty member remarked to one of the authors of this report some years ago, 'I'd like to keep a journal about my teaching so I can see, over the years, whether I'm changing what I do. But I don't have the language to describe what I'm doing as a teacher.' Another interviewee pointed out that, of all the professions, only university faculty members are under no pressure or requirement to engage in professional development in order to maintain their status.⁷⁷

Despite the difficulties, several factors make this recommendation imperative. Pressures on universities and colleges are mounting, and with them insistence from stakeholders that institutions and their faculty be able to describe how their students are learning. And changes in technology, the disciplines and society are turbulent and rapid: in many fields, approaches to teaching that worked well a decade ago are no longer adequate. The half life of teaching materials and approaches is shrinking. It is impossible that individual faculty will each invent all the new ideas and materials they need. So the reward and support system must help them reallocate time so that faculty members spend more time searching for, adapting and assessing new ideas and materials.

2.1 Universities – Implementing Recommendation 2

2.1.1 Assist and reward *all* faculty members who discover, adapt and share practices and findings from other institutions as part of the process of improving their academic programs.

The goals of this report are most likely to be implemented if all instructional staff at all institutions are challenged and supported to improve their teaching continually, in part by importing and adapting the best ideas and materials from around the world. To accomplish this, the institution needs to demonstrate the feasibility of continual improvement. The kind of improvement needed must be both a) cumulative and meaningful over a period of years, b) possible within the normal life of mainstream faculty members. The former means focusing in large part on improvements that are, individually, low threshold but that, over time, add up to major change. The latter means that institutions need to provide much more support for teaching improvement. Recommendation 5 in this report returns to this issue in more detail.

2.1.2 Alter procedures and criteria for hiring, promotion and tenure in order to find and support faculty members who will continually import ideas as part of their effort to improve and evaluate their teaching.

When hiring new faculty, examine whether the candidates have continually documented and improved their teaching, and whether they are knowledgeable about good practices and relevant research from other institutions.

⁷⁷ In the United Kingdom (and perhaps elsewhere), this is beginning to change. See the next footnote on the Higher Education Academy. In the United States, there seems to be some movement toward increased assessment of the quality of university education via surveys, tests, portfolios and other means. This could, in the long run, increase the pressure on institutions to support and reward departments and faculty who continually improve their programs.

2.1.3 Discretionary funding programs should challenge and support faculty to adopt best practices from around the world.

Instead of making discretionary grants for course improvements to faculty members that are based on solely on personal enthusiasm and creativity, the institution ought to also require and assist faculty to discover what others have already done. Their course improvements ought to be based on that prior work.

This is especially important, and especially difficult, in educational technology in the disciplines. Educational technology applications are fed by three fields: education (including learning theories instructional design, and assessment, for example), the discipline to which the technology is to be applied (disciplinary advances and applications), and technology (e.g., theory and practice of web services, for example). These three streams come together to form a fourth (e.g., previous achievements in creating remotely controlled laboratories and simulations for educational purposes). Any significant investment in course or program improvement using technology ought to draw on good practices and findings in all four of those areas.

Few faculty members have the time to keep up on all four fronts. The result, too often, are wasteful: reinventing the horse-drawn carriage when a few other institutions have already progressed to making automobiles.

2.1.3 Specialists, such as reference librarians, staff in information technology, and staff in teaching and learning centers, should work together to help faculty seek out relevant ideas and materials in their disciplines.

All these groups, including the faculty, need to reach out in order to work together. They will need to coordinate their limited time and travel budgets, discipline by discipline, in order to learn about advances around the world, and select those most appropriate for each academic program and course.

2.1.4 Regional and professional accreditors should evaluate institutional and departmental track records for importing and incorporating ideas and practices into the teaching, across the curriculum.

Accreditors should suggest methods that institutions can use to study their own performance, and develop criteria or rubrics that visiting teams can use.

Don't set the bar so high at the beginning that no one can meet it. Remember the goal: to help the institution and its degree programs improve more rapidly in response to changing needs and disciplinary progress. No faculty member, and no institution, can invent or discover more than a tiny fraction of the ideas and practices needed to adapt and excel. So the rate of importing new ideas, as well as creating better practices internally, needs to become much higher. This can only happen slowly but it must happen cumulatively.

2.2 Government Agencies and Foundations – Implementing Recommendation 2

2.2.1 Explore ways of providing faculty development opportunities in which *all* interested instructors nationally can participate.

The United Kingdom now has a Higher Education Academy that supports and accredits continuing professional education for faculty members in all disciplines, and certifies faculty who meet certain qualifications.⁷⁸ The aim is, over time, for British faculty to have expertise in

⁷⁸ For more on the Higher Education Academy, see <http://www.heacademy.ac.uk/>.

teaching as well as in their disciplines. It is beyond the scope of this report to make a specific recommendation of this type, but it seems to us that there is clear reason for foundations, accreditors, disciplinary associations, and others to consider whether an appropriate infrastructure can be supported in the United States and in other countries to help faculty, discipline by discipline, improve as teachers. One major goal of such an infrastructure would be to help faculty with the huge task of keeping up with developments and innovations in their disciplines, in education, and in applications of educational technology in their disciplines. Universities and colleges can often do an adequate job of helping faculty with relatively generic technologies (e.g., using their local learning management system) but they can rarely adequately assist faculty at the disciplinary level.

2.2.2 Provide grants to help faculty and departments adopt and adapt promising new practices for teaching in their disciplines.

Support online workshops, train-the-trainer strategies, and other methods to reach out to all interested faculty members who teach the relevant courses.

2.3 Corporations – Implementing Recommendation 2

2.3.1 When funding faculty to apply new technology to educational problems, insist their proposals build on relevant improvements from other institutions, especially developments in their own disciplines.

Use reviewers who are expert in these fields to help decide which proposals to fund and, where possible, assist interested faculty in learning about relevant developments in education, technology and their disciplines.

2.4 Additional Recommendations Specifically for MIT

2.4.1 Requests for discretionary funding for faculty to improve their teaching should be assessed against best practices worldwide.

Future programs analogous to iCampus and the d'Arbeloff Fund, as well as smaller grant programs, should assist and require interested faculty to base their own proposals on previous progress in relevant fields. Such programs should also use expert reviewers from outside the institution to aid in funding decisions, especially on projects of this size. Reviewers should have varied expertise: educational research, educational technology, best practices in the discipline and, for program such as iCampus, strategies for promoting widespread adoption.

For MIT to be a world leader in educational technology, interested faculty must build on relevant findings and achievements in educational research, technology, and educational technology in their disciplines. We sometimes got the impression that some MIT staff and faculty believe that the Institute was so unusual that, if faculty developed projects that fit their own needs, those projects would therefore be of international significance. But MIT is not unique. To best serve MIT students, improvements must draw upon, and improve upon, best practices in the world.

Recommendation 3. Nurture coalitions for instructional improvement, within and across institutions.

Whether potential adopters are actively searching for innovations or not, it helps innovations spread when innovators and potential adopters already routinely talk about instructional improvements in their disciplines. Finding D in the previous chapter discussed how different such coalitions can be. Based on our study, it appears that a) there aren't nearly enough such coalitions, b) too few faculty members participate in the ones that exist. Recommendation #2 is

crucial to increasing participation. Recommendation #3 deals with increasing the number and variety of such coalitions.

3.1 Universities – Implementing Recommendation 3

3.1.1 Develop and improve ways in which faculty members and students routinely discuss improvements in courses in their disciplines, within and across institutions.

Sometimes these conversations can be side benefits of the organization of academic work. The MIT Department of Electrical Engineering and Computer Science appeared to be almost unconscious that its approach to teaching multi-section courses had this side benefit, yet it was a crucial step to inspiring faculty to experiment with xTutor in their courses. The MISTI program enabled MIT undergraduates in China to disseminate information about iLabs, to discover the iLabs work of Prof. Zhu at Zhejiang University.

Other innovative strategies for fostering exchange among faculty have been devised consciously and thoughtfully. The Cambridge-MIT Institute was designed to encourage a variety of forms of collaboration between faculty at the two institutions, and one impact was the MIT-Cambridge collaboration around heat transfer iLabs. Kapi'olani Community College has a new practice which helped the dissemination of XMAS: faculty members can easily and publicly invite all their colleagues to come and visit their courses. Mark Lawhorn got an audience for his use of XMAS: faculty who could not only watch him teach but also talk with his students after class about the innovation.

3.1.2 Provide adequate support for faculty to participate in coalitions

This support can include recognition of the time it takes to participate in online discussions and read journals and online materials, as well as travel support to local, national and international conferences.

3.1.3 Offer special rewards for faculty who invest time to help assure that such coalitions work,

Reward faculty who volunteer time to serve on committees of associations or serve as officers, especially where that work helps the association focus more on sharing teaching ideas in the discipline.

3.2 Government Agencies and Foundations – Implementing Recommendation 3

3.2.1 Fund well-staffed, long-term, content-specific coalitions with the responsibility for reaching out to *all* faculty members nationally who teach that course or small group of courses.

Where possible these coalitions should be co-sponsored or hosted by the relevant professional association, which can also host its events at association meetings. The United Kingdom already has a network of subject centers that bears some resemblance to what we recommend here.⁷⁹

⁷⁹ For more information on the network of subject centers in the United Kingdom supported by its Higher Education Academy, see <http://www.heacademy.ac.uk/SubjectNetwork.htm>. The Academy, which is government-supported, also oversees an extensive program of continuing professional education and certification of faculty members in the arts and sciences of teaching.

It also makes sense to see such coalitions as an element of the scholarship of teaching and learning (SoTL). This concept of faculty work, originally outlined by Boyer (1997), involves using evidence, one's own as well as evidence gathered by colleagues, to improve teaching. SoTL is different from educational research in that it is the secondary discipline of the faculty member. Its primary goal is local findings: 'What can I learn from my students in order to help my students and my colleagues?' Such inquiries today are often handicapped by the fact that the faculty members involved know little or nothing about whether educational researchers and other faculty members in their disciplines have discovered in the past. They typically do not even know what terms to use in order to search the literature of education and technology generally or in their disciplines. Coalitions for instructional improvement organized around SoTL would have at least two benefits for faculty: helping them build on prior inquiries (methods, existence proofs, theories) and helping them share their own methods and findings with others.

Each subject coalition should harvest, evaluate and share good practices, materials, tools. Dissemination methods should include digital libraries with frequent broadcast mailings about instructional ideas, online workshops, special journal issues, and events at the relevant professional association(s). Use services such as MERLOT to make resources even more visible across disciplinary lines: although many innovations are content-specific, many others are interdisciplinary, so it is important to assure that networks work smoothly together. These coalitions should also prepare 'primer' material to help introduce novice faculty and graduate students to some of the most important findings, achievement and language of the relevant fields. The goal: equip faculty as efficiently and easily as possible with the basic tools needed to seek out relevant resources and to make their own improvements to their own teaching.

Economics: Such networks won't work (and would be too expensive) if they were 100% subsidized, and would likely be too expensive if their work had to be supported entirely by fees. **So experiment with different economic models for long-term support of such networks.** A hybrid model based either on steady but partial subsidies, or government/foundation matching of user fees, may well be the best.

3.3 Corporations – Implementing Recommendation 3

3.3.1 Support the kinds of outreach networks described above through grants of money, equipment, and staff support.

In the 1980s, IBM helped start the National Technological University, a multi-institution consortium for offering technical and management degrees online, by providing staff support as well as financial support.

3.3.2 Investigate the feasibility of a service to help faculty members who teach comparable courses to share information on how they teach and assess, share materials, and even collaborate in teaching.

Step by painful step, 'course management systems' have begun to move outside the box of the course and become institutional learning management systems. These systems still operate inside institutional walls (other than the import of publisher materials). It would be of great advantage if the systems (or some other infrastructure) made it easier for faculty to find colleagues at other institutions who are teaching similar courses to similar students on similar academic calendars. It would be better still if that infrastructure facilitated collaboration among those faculty members.

One side effect of such a service would be to create more coalitions for instructional improvement. Such a service might be commercially attractive. If successful, it would be a powerful engine to help new ideas, materials and technologies spread rapidly across institutions.

3.4 Additional Recommendations Specifically for MIT

3.4.1 Study how various departments teach multi-section courses, and the impact of various teaching practices on the testing and sharing of ideas for teaching the course.

For example, are there other instances where such faculty teaching communities fostered the spread and adoption of innovative practices? What roles can undergraduates play in these course meetings? Does their participation inject new ideas or alter faculty and graduate student participation? Do some courses or departments have a culture that encourages especially frank and productive discussions?

Based on the experiences of the EECS Department with iLabs and xTutor, MIT might want to study this theme in MIT alone, or in concert with other institutions. In either case, it appears to us that this practice deserves more visibility inside and outside MIT.

3.4.2 As a collaborator in Sakai, MIT should consider whether Sakai⁸⁰ can and should support the kind of inter-institutional collaboration capabilities described in Recommendation 3.3.2.

Recommendation 4. Create more higher education-corporate alliances in order to support the development and dissemination of new educational technology materials and practices.

The successes of the MIT-Microsoft Alliance suggest that university-corporate alliances can accomplish things that the parties working alone would have found more difficult, or impossible. The challenges faced by the Alliance suggest some of the guidelines that such alliances should follow.

The single most important observation to make is that universities and corporations have different goals and capabilities (though not so different as it might seem). The need to produce a synthesis – something that neither party could do alone – is the reason for creating an alliance. Those very differences are, of course, what can make an alliance unless the parties plan and work to deal with the tensions.

One early problem: people on both sides may assume that the ‘alliance’ is a simple gift of money from the corporation to the university’s faculty. The corporation’s responsibilities end with the cutting of the check, and the university’s faculty are then free to use the money as they wish.

An alliance is appropriate when each side has something active to contribute to the ultimate goal. A few examples of these varied contributions, from the iCampus experience:

- MIT faculty had many ideas for how to use technology to improve their courses.
- Microsoft staff had substantive contributions to make to those educational ideas.
- Microsoft staff made many kinds of contributions to the project management and support process, helping to assure successful completion of projects.
- Microsoft contributed tools and ideas to the software development process.

This list is intended to be suggestive, not comprehensive. There were also tensions in the relationship, many of which were creatively resolved: over issues of intellectual property and

⁸⁰ Sakai is an open source learning management system being collaboratively developed by a coalition of universities, including MIT. For more on Sakai, see <http://www.sakaiproject.org/>.

liability, over issues of benefits of the funding for institutions other than MIT, and over evaluation.

Each party should clarify its own goals, and the goals of its potential partners, in order to design an alliance that can achieve goals that neither party could achieve as well alone. This clarity should extend to staff members and their units, as well as to the universities and corporations as organizations.

Does the university want collaborators and support for exploratory research, or is the main goal broad implementation of a new practice, for example? Is the corporation looking for products to sell? Great demonstrations for marketing? A broad-based change in technology use that could help increase demand for its products? A way to contribute to its community? What do the staff members get from the collaboration? What do their departments want to achieve?

If the parties are being honest with each other, it's likely that, at first, they will realize that their goals are not wholly compatible or fully achievable.

For example, a program that is designed to test a variety of exploratory novel ideas is not likely to achieve institution-wide or nationwide changes in practice, or definitive evaluation results. And, by the same token, a program that aims at producing nationwide or lasting institutional change will likely have to sacrifice many kinds of innovation in the interests of focus. These two kinds of initiatives differ in other ways as well: innovative, exploratory initiatives are usually relatively decentralized in structure, supporting a variety of parallel projects. In contrast, initiatives designed to achieve sustained, widespread, and documented changes in practice and outcomes may be more centralized and more varied in their activities – training programs, evaluative projects, market research, software development, space renovation, and many other types of work.

The contributions of educational institutions and corporations will differ by the goals of the alliance. For example, in a FIPSE-supported alliance in the 1980s, the corporations developed software while the colleges typically provided specifications and, as development proceeded, test beds and evaluation. In an initiative aimed at widespread adoption of new practices, the corporations might provide employment for graduates, external evaluation, and support from sales and marketing that might help spread ideas and practices more rapidly to large numbers of educational institutions.

The same kind of clarity is needed concerning the nature of the contributions each partner will make. Almost fifty years ago, Margaret Luszki (1958) studied many cases of interdisciplinary team research and found that a major cause of collapse was unintentional over-promising. A philosopher would be included in the team because 'philosophers know everything about ethics' or an economist would be included because 'economists understand everything about business.' Members of the team over-estimated the contributions of their new partners and then, when reality didn't meet hope, they often swung to the opposite extreme, erroneously concluding that their partners could contribute nothing at all. Universities and corporations often assume that they understand one another better than they actually do. In starting such an alliance, it's important for the partners to develop *realistic* expectations of one another, as soon as possible.

If the early conversations reveal incompatible aims among the parties (within the universities, within the corporation(s), and between them), we suggest trying harder to develop more limited and disciplined goals that can actually be achieved by the alliance better than the parties could do alone. **Put these goals in writing, and make sure that the parties have a shared understanding of what the words mean.**

Reaching a shared agreement is especially important because initiatives such as these often need to last many years. Staff on both sides are likely to change roles and it's important for

the success of the project that newcomers be chosen because they wish to continue pursuing the original shared goals.

This kind of upfront clarity is difficult to achieve in the real world, and many past initiatives in this field have been launched without clear, shared goals. The results, however, have often left a bad taste in the mouths of one or both parties, and a lasting reluctance to partner again.

In preparing action plans, partners in cross-sector collaborations should **be careful of calendars**. The schedule for preparing corporate budgets may not match the academic's calendars for preparing proposals. iCampus was able to cope with that because Microsoft had made a multi-year commitment of funds: MIT faculty did not have to write proposals and progress reports each year to justify funds for the next year, which was fortunate because the two calendars did not match. The calendar problems can extend to other elements of project management. For example, in a 1980s collaboration that involved Brown University, IBM, Apple, and the Annenberg/CPB Project, the cross-sector project was delayed a year because the product was to be tested in courses that Brown taught only once a year: a slight delay in the delivery of a product from a vendor resulted in a major setback for the project at the university.

4.1 Universities – Implementing Recommendation 4

4.1.1 Host corporate staff on campus to help make the alliance work:

One way to develop such realistic understandings, and to make an alliance work, is for the university to host representatives of the corporate research staff on campus, to help create the relationships that make the alliance function. MIT benefited substantially from the presence of Microsoft staff on campus: Microsoft staff worked with MIT faculty to help with proposals, aided in developing good standards of project management, and, as noted above, helped foster collaboration between MIT staff and Microsoft staff at other locations.

In some kinds of educational collaborations with corporations, government agencies or foundations, universities may also find it useful to arrange for faculty members to spend extended time on site at the partner institution.

4.1.2 Consider whether and how policies for managing external funds need to be aligned with the initiative, and vice versa, to assure adequate flexibility.

Projects of this sort often do not call neatly into pre-agreed categories such as “research” or “gifts” when it comes to using funds and dealing with institutional overhead. It may be important to ‘commingle’ funds from different sources, to use corporate funds to challenge or match foundation grants, or to pay staff who are also being paid through other sources. In cases such as these, institutional and government policies can sometimes hamstring initiatives. The initiative and the policies need to be understood and adjusted, at the start, so that the initiative is itself manageable.

4.2 Government Agencies and Foundations – Implementing Recommendation 4

4.2.1 Support more R&D projects with higher education and corporate partners.

Cutting edge research in cognitive science, engineering, or training may occur in universities, corporations, government agencies or non-profits. Foundations and government agencies ought to help create such cross-sector partnerships, through the design of their grant competitions and by proactively bringing parties together. In the 1980s, the US Department of Education's Fund for the Improvement of Postsecondary Education (FIPSE) supported a proposal from the League for Innovation in the Community College to create an incubator in which representatives of

colleges and corporations met twice a year to discuss joint ventures. Many such alliances were created by the League's incubator.

4.3 Corporations – Implementing Recommendation 4

4.3.1 Budget for staff who will work on campus to help make the alliance work

MIT benefited substantially from the presence of Microsoft staff on campus. To assure healthy collaboration between local faculty and staff at the partner institution, consider housing some partner staff on staff to act as liaison and project support. In MIT's case, this has many benefits beyond the technical: the Microsoft staff helped assure that good standards of project management were in play, for example.

For some alliances it is useful for the corporation to host higher education staff on site to aid collaboration and help the higher education staff learn about the corporation's side of the alliance.

4.3.2 Fund more collaborative R&D projects that involve faculty at multiple institutions working with corporate staff.

One way to increase the chances for wider adoption of software and associated ideas for using that software in teaching would be through collaborative development involving faculty from multiple institutions. The developers could be at several institutions, or development might be focused on one institution with a powerful role being played by a council involving faculty from several institutions as well as other experts. The Annenberg/CPB Project in the 1980s and 1990s oversaw the development of multi-million dollar projects using such advisory councils that involved representatives of different types of users, technology experts, and outreach experts.

4.3.3 Take responsibility for promoting adoption of ideas and materials emerging from the collaboration by allocating corporate staff and budget to the task.

Corporations often have better facilities for a) usability testing, b) marketing. In many collaborations, the corporation needs to play a strong role in spreading the use of project ideas and materials. In our experience, while corporations may lack insight into the culture of the adopting educational institutions, they may have capabilities than universities for planning and carrying out outreach campaigns. So outreach is one of several areas where it may be important for the university and corporation to think and work together.

For example, dissemination messages need to attract attention of potential faculty users and the staff who support them at institutions: in a few seconds, the message should make clear how and why the innovation could be of use. Once the users have decided that they might be interested, good adoption materials are needed. Adoption materials should make it clear to potential users a) what kinds of short-term and long term educational gains are possible, b) how the innovation can cost time, and save time, c) what other costs and preparation will be involved. The adoption materials ought to be painfully honest about these issues: honesty builds credibility

4.4 Additional Recommendations Specifically for MIT

4.4.1 Carry out an internal review of iCampus projects.

The MIT-Microsoft Alliance has produced a number of projects of great potential, beyond the five studied in this report. MIT should review all of them in order to decide whether and how institutional resources should be invested in the continued development and dissemination of the most promising of these projects.

Recommendation 5. Supply faculty innovators with central services in educational design, software development, assessment methods, formative evaluation, and/or in sharing ideas with others who teach comparable courses.

Many of the successes of iCampus were made possible, or enhanced, by services provided by MIT and Microsoft, and shared by two or more projects. And, in our judgment, some of iCampus's frustrations were due to a lack of such services. Few institutions of higher education allocate enough of their staff resources and budgets to provide a full constellation of support services needed for faculty members to create, test, and disseminate improvements in learning.

5.1 Colleges and Universities – Implementing Recommendation 5

5.1.1 Discover 'low threshold' improvements that individual faculty have made and then 'broadcast' these time-saving improvements to all interested faculty.

When we think of 'innovation,' the first thought may be large, grant-funded projects such as those funded by iCampus. But the bulk of the improvements that faculty members need to make in order to make instruction more authentic, active, collaborative, and feedback-rich are incremental: ideas and applications that are can be grasped, implemented and assessed with minimal effort, expense and risk. We call such ideas and applications *low threshold*.⁸¹

One important way to accelerate the spread of ideas and the improvement of teaching is to intentionally search for and distribute a large volume of such low threshold activities and applications To implement Recommendation #1 in this report, universities should gather descriptions of such low threshold activities and applications, and then disseminate them widely and frequently to faculty. One important source for such 'low threshold' ideas is the institution's own faculty: it's almost certain that any idea that helps one faculty member teach and save time, is an idea that another faculty member would love to learn. Another source of low threshold activities and applications is faculty members at other institutions who teach comparable courses. Special priority should be put on ideas that are also time-savers for the faculty who adopt them.

Distribute those ideas via e-mail and other means to all interested members of the faculty.

Interested faculty members might receive one such idea, a few sentences long, every day, or every week. The ultimate goal, over the years, is to make a series of incremental improvements, different in every course, that add up to large gains for students in authentic learning, active learning, collaborative learning, and feedback-rich learning at the institution.

5.1.2 Provide guidance for innovators on educational design and assessment (i.e., techniques for measuring what students are learning).

Most faculty members working on innovative uses of technology could benefit from help with learning theory and instructional design. The developers of TEAL benefited from many sources of such help, thanks to the relatively mature state of physics education research. Judi Dori of the Technion played an important role in helping faculty learn from the field of physics education research. SCALE-UP provided additional ideas and research.

TEAL was unusual in this respect. In our interviews with them, iCampus leaders said they regretted not providing more extensive and forceful assistance in this area to many of their project leaders. Universities should provide active oversight of projects receiving major funding from the university and, if this assistance is ignored to the detriment of the project and the students, withhold further support for development.

⁸¹ For more background on low threshold activities and applications, see <http://www.tltgroup.org/>

5.1.3 **Provide programming support so that projects use common tools and create well-documented software so that products are easier to maintain and disseminate..**

Centralized programming services have a number of potential advantages: expensive programming and project management tools can be amortized across many projects; skills and standards for project management can be developed and then used across many projects as well.

iCampus had many experiences demonstrating the need for, and the value of, sharing programming services. The first round of iLabs projects were developed separately by faculty and programmers in different departments, so each lab got its own version of what were, functionally, the same services (e.g., authentication). iCampus reacted by essentially forcing a fresh start on software development, intended to provide those services through shared architecture. CECI provides shared programming and administrative services that have helped iMOAT become self-sustaining while aiding cross-fertilization (several programmers have worked on multiple iCampus projects). CECI is also documenting iMOAT code.

Centralization is no panacea, especially if the centralized services are less than competent or responsive. The ideal for large projects such as those funded by iCampus is to have some creative tension between the ideas and capabilities of the innovator and the ideas and capabilities of the central programming staff.

5.1.4 **Provide services and support for formative and summative evaluation**

Innovative faculty members often lack the skills, time and interest for doing effective formative or summative evaluation.

For summative evaluation, there is also a potential conflict of interest between the innovator and the university (as a representative of both students and the ultimate funders of the project and of the program that supported it). A purely external summative evaluation is often not feasible however, since the full collaboration of the faculty member is important to a good design. So the evaluator needs to be candid and skillful in negotiating with all stakeholders.

Faculty and evaluators doing local, formative evaluation should agree before starting a project that all data should be accessible (with due anonymity) for use in formative and summative evaluation of the program as a whole.

5.1.5 **Provide dissemination/adoption support for innovative ideas and materials.**

Promotion of adoption of ideas, inside and even outside the institution, is in the institution's vital interest. It is simply not possible to adopt to changing conditions without adopting ideas from outside, and one important way for faculty to learn about new ideas outside is to export their own. In Chapter 9, Finding B, we described how difficult and unrewarding it is for innovative faculty to undertake such 'exporting' activities totally on their own. iCampus engaged an Outreach Coordinator and provided approximately 10% of its total grant (about \$2.5 million) in support of outreach activities. Universities and colleges should provide staff and budgets to support the wider, longer term use of selected, innovative ideas and materials to which their staff have contributed.

Among the important contributions that such outreach staff should make in working with interested faculty:

- Working with faculty to develop **disciplinary channels of communication**: identifying listservs, web sites, conferences, journals and other appropriate ways to make the idea or material visible to potential adopters.
- Developing and transmitting **messages that can attract the attention of potential adopters**. Such messages often deal with ways in which the target ideas or materials can

be used to advantage and a quick summary of the investment or risk needed to adopt them. iCampus materials often made the mistake of focusing on how their software was innovative, rather than on why and how it might best be used.

- Developing ways for potential adopters to **experiment with the target ideas as easily and freely as possible**. iCampus made some of its software available online, for use directly over the Web or for download.
- **Handling some of the load when potential adopters call or visit**, either directly or by arranging for release time for the innovators.
- **Developing personal connections with important gatekeepers in relevant associations and institutions.**

5.1.6 It is sometimes appropriate to require development projects to attend to adoption issues from day 1.

iMOAT is an excellent case in point. Principal investigator Les Perelman recognized that widespread adoption was crucial to the survival of iMOAT, even at MIT, and so he invited potential institutional users to help design the specifications and then review designs and test software. iCampus then insisted that iMOAT also develop a business plan to support long-term operations and upgrades; that also focused iMOAT staff attention on the needs of adopters.

5.2 Government Agencies and Foundations; Corporations Funding Faculty Development Projects – Implementing Recommendation 5

5.2.1 Insist that faculty developing innovative uses of technology get all the kinds of help they need: educational design, programming, assessment, program evaluation, and dissemination; budget funds for these services where necessary.

Any grant will subtly either insulate the innovation and innovator from the institution (e.g., when the grantee does all the work with staff working exclusively on the grant) or integrate the innovation with the institution (e.g., when the grantee gets help from central services of the institution). The choice between these two options depends in part on the match, or mismatch, between project goals and institutional goals. Other things being equal, **if the goals of the project are a good fit with the institution, encourage the grantee to draw on core services and, ideally, strengthen the services as well as the project in the process. If there is a clash between the goals of the innovation and the institution's culture, such services should be budgeted for the project and under the control of the principal investigator and the funder.**

It's tempting to fund more projects by providing less funding per project. But projects without these kinds of support are less likely to be completed, to be educationally effective, to produce documentation of success, and to be disseminated.

5.3 Additional Recommendations Specifically for MIT

5.3.1 Provide specialized staff within Schools and departments who can help faculty members learn about educational developments elsewhere, develop their own innovations and adaptations, assess learning, evaluate their experiments, and disseminate their work to colleagues at MIT and elsewhere.

These innovations staff should work with central staff in units such as academic computing and the Teaching Learning Laboratory, but they should ideally be sited within the departments, and have disciplinary backgrounds that help them work with faculty on subject-specific innovations,

as well as technology and education backgrounds that help them deliver the range of services needed to support the development, evaluation, and dissemination of innovations.

We particularly stress the role of these specialized staff to find interested faculty, understand what they might need, and then actively seek out innovations elsewhere that faculty might adopt, including subject-specific innovations. “Not Invented Here” and “Not Invented by Me” are crazy slogans for over-committed faculty. The single best way to improve learning at MIT may be to increase the rate in which it selectively and wisely adapts educational innovations from outside.

Funding staff such as these obviously represents a choice about the allocation of resources. In some cases, they will be able to help the institution attract grants and gifts for instructional improvement. But the real test of their value will be whether they can help improve the effectiveness of teaching and learning in the departments they support.

5.4.2 Provide more support for units that can provide innovative faculty with assistance in educational design, programming, assessment, program evaluation, and dissemination.

The specialized disciplinary staff described in recommendation immediately above cannot work alone; they need to be supported by, and be intermediaries for services from, strong central units providing services in these areas.

5.4.3 Support iLabs Shared Architecture as a base service for the next five years.

Assuming that the review of iCampus projects recommended in 1.4.2 above supports the further use of the iLabs Shared architecture, MIT should assure faculty that the Institute will make the Architecture, and help in using it, available for at least five years. Faculty members are unlikely to invest their time in innovations that may disappear in a year or two, so a longer-term commitment is necessary. It will take years to develop and test additional types of experiments, and to evaluate the results of these educational innovations. Other comparable services may also be necessary to support faculty in implementing Recommendation #1: gradual improvement in authentic, active, collaborative and feedback-rich learning.

Recommendations in Brief

Recommendation 1. Improve education by making it more authentic, active, collaborative, and feedback-rich. iCampus software and ideas can provide useful elements for such a campaign.

1.1 Colleges and Universities – Implementing Recommendation 1

1.1.1 Decide, at the institutional and programmatic level, whether and how to implement this recommendation; include other stakeholders in the discussion.

1.1.2 Give preference in hiring to faculty candidates with a demonstrated preference for, and skill in, these types of teaching.

1.1.3 Grant release time for major course improvements, with preference to faculty who work together on the same course, or sequences of courses.

1.1.4 Use these goals as criteria for awarding discretionary funding for curricular development, new technology, space renovation, and other purposes, and as themes for soliciting funds from alumni, legislatures, foundations, and other sources.

1.1.5 Academic computing, the teaching & learning center, distance learning, the library and any other units responsible for professional development and course improvement should coordinate and organize their collective efforts around these goals.

- 1.1.6 Develop and maintain assessment procedures to guide progress on these goals within academic programs.
- 1.2 *Government Agencies and Foundations – Implementing Recommendation 1*
 - 1.2.1 Support model campaigns for curricular improvement within institutions.
 - 1.2.2 Support development of appropriate methods for assessing these teaching/learning activities and outcomes in the disciplines.
 - 1.2.3 Continue to support exploratory R&D.
 - 1.2.4 When considering new proposals for funding, recognize that, even at the proposal stage, it is possible to assess how adoptable the ultimate product or idea might be.
- 1.3 *Corporations – Implementing Recommendation 1*
 - 1.3.1 Support education/technology campaigns with money, corporate staff collaborating with university staff, dissemination support through marketing.
- 1.4 *Additional Implementation Recommendations Specifically for MIT*
 - 1.4.1 Move forward with these five projects.
 - 1.4.2 MIT should systematically review all educational innovations supported with major grants from sources such as iCampus in order to determine which deserve internal support for wider deployment or further development.

Recommendation 2. Create demand to adopt ideas and materials from other sources by encouraging all faculty members to improve and document learning in their programs, year after year.

- 2.1 *Universities – Implementing Recommendation 2*
 - 2.1.1 Assist and reward *all* faculty members who discover, adapt and share practices and findings from other institutions as part of the process of improving their academic programs.
 - 2.1.2 Alter procedures and criteria for hiring, promotion and tenure in order to find and support faculty members who will continually import ideas as part of their effort to improve and evaluate their teaching.
 - 2.1.3 Discretionary funding programs should challenge and support faculty to adopt best practices from around the world.
 - 2.1.4 Specialists, such as reference librarians, staff in information technology, and staff in teaching and learning centers, should work together to help faculty seek out relevant ideas and materials in their disciplines.
 - 2.1.5 Regional and professional accreditors should evaluate institutional and departmental track records for importing and incorporating ideas and practices into the teaching, across the curriculum.
- 2.2 *Government Agencies and Foundations – Implementing Recommendation 2*
 - 2.2.1 Explore ways of providing faculty development opportunities in which *all* interested instructors nationally can participate.
 - 2.2.2 Provide grants to help faculty and departments adopt and adapt promising new practices for teaching in their disciplines.

2.3 *Corporations – Implementing Recommendation 2*

2.3.1 When funding faculty to apply new technology to educational problems, insist their proposals build on relevant improvements from other institutions, especially developments in their own disciplines.

2.4 *Additional Recommendations Specifically for MIT*

2.4.1 Requests for discretionary funding for faculty to improve their teaching should be assessed against best practices worldwide.

Recommendation 3. Nurture coalitions for instructional improvement, within and across institutions.

3.1 *Universities – Implementing Recommendation 3*

3.1.1 Develop and improve ways in which faculty members and students routinely discuss improvements in courses in their disciplines, within and across institutions.

3.1.2 Provide adequate support for faculty to participate in coalitions.

3.1.3 Offer special rewards for faculty who invest time to help assure that such coalitions work.

3.2 *Government Agencies and Foundations – Implementing Recommendation 3*

3.2.1 Fund well-staffed, long-term, content-specific coalitions with the responsibility for reaching out to all faculty members nationally who teach that course or small group of courses.

3.3 *Corporations – Implementing Recommendation 3*

3.3.1 Support the kinds of outreach networks described above through grants of money, equipment, and staff support.

3.3.2 Investigate the feasibility of a service to help faculty members who teach comparable courses to share information on how they teach and assess, share materials, and even collaborate in teaching.

3.4 *Additional Recommendations Specifically for MIT*

3.4.1 Study how various departments teach multi-section courses, and the impact of various teaching practices on the testing and sharing of ideas for teaching the course.

3.4.2 As a collaborator in Sakai, MIT should consider whether Sakai⁸² can and should support the kind of inter-institutional collaboration capabilities described in Recommendation 3.3.2.

Recommendation 4. Create more higher education-corporate alliances in order to support the development and dissemination of new educational technology materials and practices.

4.1 *Universities – Implementing Recommendation 4*

4.1.1 Host corporate staff on campus to help make the alliance work.

4.1.2 Consider whether and how policies for managing external funds need to be aligned with the initiative, and vice versa, to assure adequate flexibility.

⁸² Sakai is an open source learning management system being collaboratively developed by a coalition of universities, including MIT. For more on Sakai, see <http://www.sakaiproject.org/>.

- 4.2 *Government Agencies and Foundations – Implementing Recommendation 4*
 - 4.2.1 Support more R&D projects with higher education and corporate partners
- 4.3 *Corporations – Implementing Recommendation 4*
 - 4.3.1 Budget for staff who will work on campus to help make the alliance work.
 - 4.3.2 Fund more collaborative R&D projects that involve faculty at multiple institutions working with corporate staff.
 - 4.3.3 Take responsibility for promoting adoption of ideas and materials emerging from the collaboration by allocating corporate staff and budget to the task.
- 4.4 *Additional Recommendations Specifically for MIT*
 - 4.4.1 Carry out an internal review of iCampus projects.

Recommendation 5. Supply faculty innovators with central services in educational design, software development, assessment methods, formative evaluation, and/or in sharing ideas with others who teach comparable courses.

- 5.1 *Colleges and Universities – Implementing Recommendation 5*
 - 5.1.1 Discover ‘low threshold’ improvements that individual faculty have made and then ‘broadcast’ these time-saving improvements to all interested faculty.
 - 5.1.2 Provide guidance for innovators on educational design and assessment (i.e., techniques for measuring what students are learning).
 - 5.1.3 Provide programming support so that projects use common tools and create well-documented software so that products are easier to maintain and disseminate.
 - 5.1.4 Provide services and support for formative and summative evaluation.
 - 5.1.5 Provide dissemination/adoption support for innovative ideas and materials.
 - 5.1.6 It is sometimes appropriate to require development projects to attend to adoption issues from day 1.
- 5.2 *Government Agencies and Foundations; Corporations Funding Faculty Development Projects – Implementing Recommendation 5*
 - 5.2.1 Insist that faculty developing innovative uses of technology get all the kinds of help they need: educational design, programming, assessment, program evaluation, and dissemination; budget funds for these services where necessary.
- 5.3 *Additional Recommendations Specifically for MIT*
 - 5.3.1 Provide specialized staff within Schools and departments who can help faculty members learn about educational developments elsewhere, develop their own innovations and adaptations, assess learning, evaluate their experiments, and disseminate their work to colleagues at MIT and elsewhere.
 - 5.3.2 Provide more support for units that can provide innovative faculty with assistance in educational design, programming, assessment, program evaluation, and dissemination.
 - 5.3.3 Support iLabs Shared Architecture as a base service for the next five years.

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Attachment 1: Glossary of Terms Used in this Report

Active learning: Chickering and Gamson (1987) wrote, “Learning is not a spectator sport. Students do not learn much just by sitting in classes listening to teachers, memorizing pre-packaged assignments, and spitting out answers. They must talk about what they are learning, write about it, relate it to past experiences and apply it to their daily lives. They must make what they learn part of themselves.” Active learning has been defined in at least two ways: one focuses on what’s visible to others about learning. Chickering and Gamson, and this report, use this definition. The other definition focuses purely on what goes on inside the learner’s mind; in this sense, learning is active when the learner is continually querying and challenging experience, even if that is done silently. By this definition, a lecture can be an active learning experience if the learner treats it that way.

Authentic learning: Learning is called ‘authentic’ to the extent that the student’s activity and audience are like those of the world in which the student might work and live after graduating. For an engineer, listening to a lecture, no matter how gripping and informative, is less authentic than working on a realistic design problem, then testing the resulting product, and being assessed by professional engineers. Tasks for students are termed authentic when they are as real, messy, and compelling as those found in the world of work. Assessment when a) the student has carried out an authentic task, and b) when the feedback resembles that of the real world – does the device work? Is the client pleased?

Coalitions for instructional improvement: Any set of educators whose routine interactions make it normal for them to discuss how they are teaching, and how they are trying to improve learning, in their courses and academic programs. Team teaching, professional associations with a focus on teaching, listservs that support teaching discussions in a discipline, and certain inter-institutional alliances such as the Cambridge-MIT Institute are all examples of coalitions for instructional improvement. Coalitions create the routine, trusted communications patterns that help ideas move and improve.

Collaborative Learning: when learners work together on a task designed to help them master ideas and skills more effectively than if they had each worked alone. Part of the power of collaborative learning comes from mutually beneficial peer instruction. The students who are a bit ahead learn by helping their peers catch up. The students who need to catch up learn because their peers have only recently been in the same situation as they are, and can help them over the hump. Many kinds of learning can occur through collaboration.¹

Curricular software: software that is content-specific. By this definition, a course management system like xTutor is not curricular software; however, the Scheme course built on xTutor is. The same is true for the semiconductor device characterization experiment (an iLab) and TEAL. XMAS is close to being curricular software, because it does include Shakespeare resources, but it is also a flexible curricular tool that can be applied to other kinds of courses.

Educational Technology Initiative: A spending program whose goal is to encourage wider, more successful educational uses of technology. This report focuses on two types of initiatives, Educational Technology Explorations and Education/Technology Campaigns.

Educational Technology Exploration: An initiative whose goal is to explore or invent many types of educational uses of a technology by support of a variety of faculty-led development projects. Explorations are defined more by their technologies than by their educational goals. Their success should be measured by the importance of the discoveries or inventions made by the

¹ For an example from MIT of the power of collaborative learning, see Ehrmann (undated)

best of their projects and by benefits gained by the students in those pilot tests. Progress toward those educational goals is therefore usually difficult or impossible to assess. iCampus is an example of an Educational Technology Exploration.

Education/Technology Campaign: An initiative whose goal is to create a particular, relatively well-defined educational improvement (e.g., in a university). The campaign's goal is, by definition, partly defined by the capabilities of a technology. The success of the Campaign should be measured by progress (e.g., of that university) toward that goal that is the direct result of the campaign. TEAL is an example of a university-level Education/Technology Campaign. Its primary goal was to improve conceptual understanding and attendance in first year physics courses, and its physical technologies were specially designed classrooms equipped with personal response systems, simulations, and laboratory equipment.

Feedback-rich learning: Learning experiences that provide frequent, compelling, and rapid response to what learners do. Science laboratory experiments, personal response systems, online feedback for computer science programs, and online discussions annotated with video illustrations are examples of rich, rapid feedback provided by these iCampus projects.

Low Threshold Activities and Applications: An activity or application is 'low threshold' for the potential adopter if it can be grasped, learned, used, and assessed with minimal effort, expense and risk. In fact many LTAs are time-savers and risk-reducers. An LTA is an activity or application that can be appreciated in seconds, learned in minutes, and assessed after use just as quickly. It involves little or no expense for either the user or the institution. "Low threshold" is a relative term, relative to the potential user's skills and interests and to the infrastructure which supports that person. An idea that is attractively low threshold for one person is something that a second person is already doing, that would be difficult for a third person to learn, and is uninteresting or inappropriate for a fourth. For more on LTAs, see <http://www.tltgroup.org/ltras.htm>.

PI: Principal Investigator. The faculty member or members in charge of an individual iCampus development project.

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Attachment 2. Educational Technology Explorations and Education/Technology Campaigns

One of the more visible features of the educational technology landscape over the last several decades has been the ambitious educational technology initiative: an effort that is intended to be high profile, well-funded, and result in (at least) a large number of courses making some use of technology to support learning.

Not all educational technology initiatives are this ambitious. Each such initiative has been unique. Nonetheless, our analysis of iCampus has helped us realize that many of these past initiatives have two ambitious goals:

- A. Exploring how a new technology can produce pioneering improvements in education through ambitious faculty-led projects focusing, more often than not, on assignments and courses. These projects where successful are intended to help the students in those particular classes, in spectacular ways if at all possible. Meanwhile, it is hoped that these same projects will lead almost inevitably to
- B. Sustainable improvements in teaching and learning across whole academic programs (for some initiatives, programs in many institutions). Through these larger scale improvements, and accompanying rigorous evaluations, technology's essential role will be dramatized and publicized

It is not a good idea to design or publicize an initiative giving equal weight to these two different goals. They deserve different structures, different funding priorities, different stakeholders, different assessment, different adoption resources, and different time horizons. Their requirements are so different that attempting to achieve both goals with a single initiative risks failure on both fronts.

A. Educational Technology Explorations

Educational Technology Explorations are defined by their support of a variety of projects (usually faculty-led) which are, within broad limits, varied in their focus, exploratory and creative in their strategies, and focused on development (software, methods for using technology, educational materials). The strategy has sometimes been called "Let a Thousand Flowers Bloom." The assumption is that the successful projects (those that result in effective changes in the faculty member's own course) will then spread: the hard work is coming up with the initial idea and putting to a 'proof of concept.'

Their success is appropriately measured by the degree to which the students in these courses seem to benefit from the new practices and the degree to which innovative faculty in the same disciplines also interested in technology find the new ideas compelling.

Examples of Educational Technology Exploration

The Duke iPod initiative was an educational technology exploration. So were the Apple University Consortium, IBM Advanced Educational Projects, and the Inter-University Consortium for Educational Computing (funded by the Carnegie Corporation) of the 1980s. And iCampus, of course, has many attributes of an educational technology exploration.

Time Scale of Educational Technology Explorations

Explorations are usually conceived within the time scale of their grants (2-3 years typically). That short time scale makes sense because of their exploratory nature and the rapid change of

technologies. Explorations usually are prompted by the advent of a new kind of hardware, software or net capability. Because such technologies have an uncertain life and because a campaign may well be necessary to take advantage of the discoveries made in the exploration, explorations are usually planned to have a long enough life for ambitious projects to be conceived and implemented, but not much longer than that. iCampus had a longer time horizon, but that doesn't seem to have affected many of its projects in this regard; iLabs is a notable exception – iCampus had the time and the interest in implementation so it forced a redefinition of the iLabs strategy, building the Shared Architecture in order to make a Campaign possible.

Hazards faced by Educational Technology Explorations

As this report has shown, the biggest problem faced by Explorations is their assumption that the successful projects are their own reward. If their grants are small, this may be sufficient. But when grants total hundreds of thousands of dollars or more, then long term use and widespread adoption is likely to be needed in order to justify the original expenditure. Achieving that may well require a Campaign, and the Campaign may be costly – more costly than the original development effort. Funders should plan for this. Sometimes in the past, however, funder attitude has been, “our job is innovation; let someone else handle the expense of promoting adoption, once we've shown that something is worth adopting.” But too often that second party has never shown up, and the initial investment in exploration has been largely wasted.¹

B. Education/Technology Campaigns

An Education/Technology Campaign is primarily defined by its educational goal, a goal that guides almost all the work of the Campaign, a goal that is usually clear enough that progress toward it can be measured, e.g., larger enrollments working toward and earning degrees, better writing skills, greater availability of blended courses. It is also defined by some strategy for using technology as a partial means of achieving that goal (e.g., online learning programs require technology, as well as marketing, faculty training, and other elements).

Examples of an Education/Technology Campaign

The Sloan Foundation's Asynchronous Learning Networks program is an example of an education/technology campaign. The hallmarks of a campaign topic: a clear educational goal (clear enough that measuring progress is easy to conceive) and a clear role for computer technology in advancing that goal. Sloan has campaigned for years to extend access to higher education in ways that didn't depend on location or schedule (the educational aim) through the use of the Internet (the technological means). As funded projects have illustrated, Sloan realized that technology was necessary but not sufficient to pursue this aim. Its projects are therefore pragmatic and varied: institutional innovations, evaluation strategies, association meetings, data collection, attempts to inform public policies, and a range of other steps.

Time Scale of Campaigns

It takes many, many years to create large-scale change in activities and outcomes, even when (perhaps especially when) powerful new technologies make the improvement possible. Such improvements have already occurred, of course. For example, in writing, revision is now a fundamental part of how students learn to write, and how writing is taught. That's a fruit of word

¹ Ehrmann, an author of this report, saw this happen many times during his 18 years as a program officer with The Fund for the Improvement of Postsecondary Education (FIPSE) and with the Annenberg/CPB Projects at the Corporation for Public Broadcasting.

processing but also of about 15-20 years of campaigning to change the nature of writing instruction.

Sponsors and Structures for Education/Technology Campaigns

Educational/Technology Campaigns usually require multiple sponsors, each contributing in a different way. Faculty in colleges and universities have students and ideas. Vendors can provide technology and expertise. Cash may come from vendors, foundation and/or government.

Structure: Some campaigns have unified leadership. This typically occurs when the campaign is developed to change a single institution (Project Athena, as a campaign, had the goal of changing MIT) or at least a single lead funder (the Sloan Asynchronous Learning Network campaign). Many campaigns, however, are decentralized, with little or no central control. What makes them campaigns is the shared focus on achieving a widespread, lasting change in practice and taking steps together that have a reasonable chance of achieving that goal.

Hazards Faced by Education/Technology Campaigns

The biggest hazard faced by Education/Technology Campaigns is distraction. It takes so long to complete a campaign that there are many opportunities for changing events, including the advent of new and hot technologies, to derail the Campaign. Several of our recommendations, below, deal with strategies to keep a Campaign focused over the many years required to achieve its objectives.

Selected Recommendations for Education/Technology Campaigns

Because distraction is perhaps the major goal faced by a Campaign in its many years of effort, the follow strategies are selected to help create and maintain focus.

- A. **Goals:** Focus on an educational improvement for which there is an exceptionally compelling, widely felt need by faculty, students and the external stakeholders of the university or universities. For example, an academic program that feels its existence is imperiled can be highly motivated to make bold programmatic changes. The compelling nature of that need will be required to help the campaign retain focus over the many years needed to achieve its goal. If the technology and other factors can make dramatic gains possible, that can help, too.
- B. **Reinforcement:** Focus on a need where success can be reinforced by substantial and tangible gains for the program, and where loss of focus might lead to loss of resources. For example, the goal of increasing enrollment and graduation rates provides positive rewards for success, and negative reinforcement if the program regresses (enrollment and tuition fall).
- C. **Coalition:** Build a coalition of stakeholders with a keen and, where possible, a material interest in achieving the educational and technical goals of the Campaign. Coalition members, too, can provide positive and negative reinforcement.
- D. **Begin evaluation before day 1** (e.g., assessing how the activities are currently carried out, before the campaign has begun, what incentives support the activities, and what barriers currently inhibit them). These evaluation findings can help trigger the positive and negative reinforcement needed to keep the Campaign focused, especially if the goal is to improve a skill or other outcomes less tangible than “increase enrollment” or “save

money.” An often-overlooked priority for software development in Campaigns is evaluation of usability of software, beginning with the design.

- E. **Schedule and budget for adoption-related processes from the beginning of the campaign** so that developers of new materials are working with the interests of a wide range of potential users in mind, not just their own.
- F. Plan to **fund the variety of activities that, together, can help the Campaign achieve its goals**: coalition building, development of materials, training, policy analysis, cost modeling, development of new assessment tools, dissemination, and many other pragmatic tasks.

Attachment 3. People Interviewed for this Study

First	Institution	Title	Focus of Interview	
Hal	MIT	Prof. of Comp.Sci. and Eng	iCampus	12/21/05,8/27/06
Akintunde	MIT	Assoc. Prof. of EECS	iLabs	4/21/2006
Jordan	MIT (former)		iMOAT	8/15/2006
Paul	U Queensland	ITEE	HUB	6/22/2006
Phil	MIT	Sr. Proj. Mgr, CECI	iLabs	10/6/2006
Bob	NCSU	Prof. of Physics; Director of Graduate Program	TEAL	4/5/2006
John	MIT	Prof. in Astrophysics Division of Dept. of Physics	TEAL	2/27/2006
Peter	Mt. Holyoke	Prof. of English	XMAS	3/6/06,4/17/06
Jim	Windward School	Dir. or Technology	TEAL	9/25/2006
Duane	MIT	Assoc. Dept. Head of EECS	iLabs	12/05,7/25/06
Lori	MIT	Dir. of Teaching and Learning Lab	iLabs	8/22,8/28/06
Bob	Boston Univ	Pres. Of BU;former provost of MIT	iCampus	5/4/2006
Claude	MIT	Assoc. Provost; Prof. of Experimental Physics	TEAL	4/18/2006
Joel	UQ	undergrad	iLabs	3/15/2006
Frank	LSU	V. Provost for Acad. Affairs	iMOAT	7/6/2006
Clark	MIT	Prof. of Chem. Eng.	iLabs	12/-/05
Greg	MIT		XMAS	2/28/2006
Alex	MIT	Chr. Of MIT Corp.	iCampus	
Aime	Mt. Holyoke	Tech Support	XMAS	3/15/2006
Jesus	MIT	Prof. of Elec. Eng.	iLabs	12/05;6/19;6/26;8/28/06
Peter	MIT	Prof. of Humanities; Head of Literature Faculty	XMAS	12/19;4/26;5/2;5/3/06
Judy	MIT and Technion	visiting schoar at CECI	TEAL	7/24/2006
Peter	MIT	Sr. Lecturer;Prof. of Physics	TEAL	2/28/2006
Roger	UQ	ITEE	xTutor	6/23/2006
Jim	MIT	MIT Humanities Library	XMAS	3/27/2006
Sven	Stevens Ins. Tech.	Assoc. Prof. of Mech. Eng.	iLabs	4/7/2006
Chris	MIT	Programmer; Inf. Systems Arch. And Developer	iMOAT	12/19;6/7/06
Harriet	Northeastern	Prof. Coll. Of Comp. and Inf. Sci.	xTutor	10/4/2006
Dee	U of Oklahoma (ret.)	Past pres. of Prof. and Org. Devel. Network	iCampus	11/17/2006
Judy	MIT	consultant	iLabs	12/20/2006
Clifton	MIT	Prof. of Elec. Eng.	iLabs	4/28/2006
Denny	MIT	Prof. of Elec. Eng.	iLabs	6/30/2006
Ira		Andrew W. Mellon Foundation	iCampus	11/17/2006
Sean	MIT	Dir. of Intern Placement, China Prog.	iCampus	3/24/2006
Elizabeth	RIT	Asst. Prof., Dept. of Fine Arts	XMAS	3/31;4/28/06
Julie	MIT	Princ.Resrch Sci.Harv.-MIT Div Health Sci./Tech.	xTutor	10/3/2006
Nancy	LSU	Office Dir., Undergrad. Writing Prog.	iMOAT	6/15/2006
Jim	MIT	runs server for del Alamo	iLabs	4/10/2006
Judy	MIT	Educ.Systems Architect	iLabs	3/31/2006
Mary	Kapiolani CC	Tech Support	XMAS	4/5/2006
Tom	Microsoft	member JSC	iCampus	9/7/2006
Ken	U Minn	Prof. of Physics	TEAL	10/3/2006
Randy	Microsoft	Mgr. of Learning Science and Tech.	iCampus	9/7/2006
Peter	UQ	Sr. Lecturer in EMSAH	XMAS	6/23/2006
Charles	Colgate	ret. Prof. of Physics	TEAL	10/2/2006
Petere	Notre Dame	Prof. in Shakespeare Studies	XMAS	4/18/2006

The TLT Group: Factors Affecting the Adoption of Faculty Developed Academic Software

Charles	CalTech		iMOAT	9/8/2006
Geir	Uqueensland		iLabs	9/18/2006
Kathy	Northeastern	Assoc. Prof. of English	XMAS	3/30/2006
Eric	MIT	Prof. of Physics	TEAL	10/2/2006
Jane Ren-Hung	U Queensland	e-Research	XMAS	6/22/2006
Kjell	NCCU	Chr. Dept. of Comp. Sci. and Inf. Eng.	HUB	
Barry	Chalmers U. of Tech.	Prof. of Electronics	iLabs	8/21/2006
Leslie	MIT	Sr. Lecturer, Dept. of Chem. Eng	iLabs	10/17/2006
Marc	MIT	Research Dir. of CSAIL	xtTutor	8/22/2006
Michael	MIT	Head of Physics Dept., Prof. of Physics	TEAL	3/31/2006
Carolann	UQueensland	Pro Vice Chancellor Academic.	HUB	6/22/2006
Markus	WPI	Asst. Prof. of Physics	TEAL	4/28/2006
Jeffrey	Cambridge U	Prof. Dept. of Chem. Eng.	iLabs	6/13/2006
Shannon	MIT	Prof. of EECS and Assoc. Dir. of LEES	iLabs	6/28/2006
Markus	MIT	Admin., Grad. Prog. In Science Writing	iMOAT	8/3/2006
Steve	Kapiolani CC	Language Arts Professor	XMAS	3/16/2006
Alan	MIT	Director of CECI	iLabs	12/20/2005
Walter	Maricopa CCD		HUB	3/22/2006
Brad	MIT	Professor of Physics	TEAL	4/25/2006
David	RPI	Dir. Anderson Ctr. For Undergrad. Ed.	TEAL	9/20/2006
Phil	MIT	Professor of Physics	TEAL	4/24/2006
Brian	MIT	Sr. Strategist for Acad. Comp. Practices	iCampus	
Tomas	U Queensland	ITEE	HUB	6/22/2006
Per	MIT	Prof. of Comp.Sci. and Eng	xTutor	2/27;8/22/06
Tom	Chalmers U. of Tech.	Vice Dean, Dept. of Microtech. And Nanoscience	iLabs	8/21/2006
Chris	Mit	Dean, School of Engineering	iCampus	12/20/2005
Eric	CalTech	Support Staff, Dept.of Hum & Soc Services	iMOAT	9/8/2006
Leah	Windward School	Dir. of Middle School	TEAL	10/3/2006
Gary	Vanderbilt	Prof. of English	XMAS	2/17/2006
Joseph	Glendale CC	Faculty	xTutor	8/10/2006
Linda	Cornell	Dir. of Writing Workshop	iMOAT	7/6/2006
Haynes	Bentley	Dir. of Honors Program;Eng. Prof.	XMAS	3/13/2006
Marlene	MIT	Prof. of Mathematics	xTutor	10/3/2006
Dave	U of Cincinnati	Dir. of Composition Prof.	iMOAT	6/13/2006
Ann	Microsoft	former MS Research Prog. Mgr	iCampus	9/8, 9/18/06
Joanne	U Queensland	ITEE	TEAL	6/22/2006
Norbert	URI	Lect., Dept of Comm. Studies	XMAS	4/5/2006
Sahana	URI	Prof. Dept. of Comm. Studies	XMAS	4/5/2006
John	MIT	Staff, Physics Dept.	TEAL	12/19/2005
Aggrey	Cambridge U	Director of CARET	HUB	3/27/2006
Paul	U of Dar es Salaam	Dean, Fac. Of Elec. And Comp. Sys. Eng.	iLabs	7/11/2006
Irv	Microsoft	Prog. Mgr, MS ERP	iCampus	12/21/2005
Leslie	LSU	Dir. of Univ. Writing Prog.	iMOAT	6/7/2006
Dave	MIT	Dir. of Undergrad. Writing	iMOAT	12/05;5/06;8/06
Joel	MIT	Prof. of Physics	TEAL	5/31/2006
Bob	U Md	Prof. of Physics	TEAL	5/4/2006
Peter	MIT	Undergrad. Dean;Prof.of Physics	TEAL	3/28/2006
Greg	UQ	Lect., Sch. Of IT & Elec. Eng.	xTutor	6/23/2006
Carol G.	MIT	Prof. Dept. of Chem. Eng.	iLabs	12/20/2005
		Pres. Assoc. of Amer. Colleges and Universities	iCampus	11/17/2006

The TLT Group: Factors Affecting the Adoption of Faculty Developed Academic Software

Markus	UQ	Leader of iCampus Activity	HUB	3/23/2006
Warren	MIT	Prof. Mech. Eng.	iLabs	8/16/2006
Anders	Cambridge U		iLabs	6/13/2006
Charles	MIT	Prof. of EECS	iLabs	6/19/2006
Gene	SUNY Stony Brook	Prof. of Physics	TEAL	6/6/2006
Peter	U Queensland	ITEE	iLabs	6/22/2006
Chris	MIT	Sr. Lect. EECS	xTutor	2/27/06;8/15/06
Peter	Univ of Melbourne	Prof. Chemistry	TEAL	6/27/2006
Gary	U Queensland	Physics Dept.	iLabs	6/22/2006
Kim	MIT	Dn for Und. Research, Dir. of UROP	iLabs	8/16/2006
George	MIT	Assoc. Dir. of LEES;Prof. EECS	iLabs	6/19/2006
Richard	Cambridge U		iLabs	7/6/2006
Heather	MIT	Admin. Officer, Physics Dept.	TEAL	4/19/2006
Alan	MIT	Prof. of EECS	iLabs	7/17/2006
Kathleen	FSU	Prof. of English; Dir. of Grad. Prog Rhet/Comp.	iMOAT	9/22/2006
Steven	CalTech	Dir. of Hixon Writing Ctr.	iMOAT	6/14/2006
Belinda	MIT	Prog. Mgr. Shakespeare Proj.	XMAS	12/19/05;4/6/06
Shanan	Zhejiang	Prof. of EE;Dean of Sch. Of Cont. Ed.	iLabs	10/3/2006

Attachment 4: About The TLT Group, The Flashlight Program and the Authors

The TLT Group

The Teaching, Learning, and Technology Group is a not-for-profit organization, founded in 1998, whose mission is to help educational institutions improve their educational uses of technology. The TLT Group supports, and is supported by, its 150+ institutional subscribers around the world.

The TLT Group's work focuses on evaluation and assessment; teaching improvement and professional development; and planning-related issues. Its services combine consulting and training; evaluation tools and services; and free materials on its extensive web site. Its Online Institute provides workshops and webcasts to over a thousand participants a year.

Led by Steven W. Gilbert and Stephen C. Ehrmann, The TLT Group has provided keynotes, workshops, and other forms of assistance to hundreds of institutions and dozens of associations around the world. The TLT Group also collaborates routinely with a council of about a dozen associations, including the Association for Institutional Research (AIR), the Association of American Colleges and Universities (AAC&U), the Association of College and Research Libraries (ACRL), EDUCAUSE, the Historically Black College and University Faculty Development Network, the International Society for the Scholarship of Teaching and Learning, the League for Innovation in the Community College, MERLOT, the Professional and Organizational Development Network (POD), and the Society for College and University Planning (SCUP).

The Flashlight Program

Founded in 1992, The TLT Group's Flashlight Program for the Evaluation and Improvement of Educational Uses of Technology has won the ITC award (a two year college organization focusing on technology uses in education) for its contributions to research in distance learning. Flashlight is perhaps best known for its survey tools for evaluation, assessment and research, especially its Flashlight item banks and the Flashlight Online survey system, currently in use by 100 institutions. Staff and consultants associated with Flashlight have also conducted many external evaluations including, most recently, this study of the iCampus program.

The Authors

Stephen C. Ehrmann, Ph.D., Principal Investigator

Steve Ehrmann is one of the founders of The Teaching Learning and Technology Group. For thirty years he has been working on three related issues:

1. how best to use technology to improve education --for what kinds of improvement can technologies be most helpful;
2. helping educators use data to understand that improvement (including its costs and tradeoffs), guide it and accelerate it; This strand of work began with his Ph.D. dissertation, a study of several decades of the history of the MIT Department of Civil Engineering, focusing on the impact of computing in the department's revitalization in the early 1960s; and
3. designing programs to help faculty and their institutions improve learning by using computers, the Internet, and related technologies.

Since 1993, he has directed the award-winning [Flashlight Program](#) for the Study and Improvement of Educational Uses of Technology. Flashlight's tools, training, consulting and external evaluations have been used by academic staff at hundreds of institutions to guide their own uses of technology, on- and off-campus.

Dr. Ehrmann is also well-known in the field of distance education, dating back to his years of funding innovative research and materials in this field when he served as a program officer with the Annenberg/CPB Projects (1985-96). Before that he was a program officer with The Fund for the Improvement of Postsecondary Education (FIPSE) (1978-85) and as Director of Educational Research and Assistance at The Evergreen State College. (1975-77)

Dr. Ehrmann has spoken all over the world on hundreds of campuses, and at dozens of conferences on the uses and abuses of technology for improving education and on how to gather evidence to improve the outcomes of educational uses of technology. As a consultant, he helps design program evaluations and helps institutions develop strategies for improving teaching and learning with technology in programs and institution-wide. Steve Ehrmann has written or helped to write four books and over thirty articles in this field, on subjects as varied as the economics of courseware and the future of liberal learning.

His Ph.D. is in management and higher education from the Massachusetts Institute of Technology, from which he also received bachelor's degrees in aerospace engineering and in urban studies. He lives in Silver Spring, Maryland, with his wife Leslie.

Steven W. Gilbert, Co-PI

Steven W. Gilbert is President of The Teaching, Learning, and Technology Group, which he co-founded with Steve Ehrmann in January 1998. Previously Gilbert had been with EDUCOM since 1983, serving as Vice President, and then came to AAHE as Director, Technology Projects, in July 1993 where he developed the TLT Roundtable concept and the AAHESGIT Listserv. He also is a frequent guest speaker, consultant, published author, and keynoter at campus events and conferences, having visited more than 500 colleges and universities since 1994. He continues to moderate the TLT-SWG (formerly "AAHESGIT") Listserv for the discussion of issues related to education, technology, and change (currently about 6,000 subscribers).

At EDUCOM (now [EDUCAUSE](#)), Gilbert created and led the Educational Uses of Information Technology (EUIT) program and the EDUCOM Software Initiative (ESI) from 1985 through 1993. EUIT and ESI were volunteer programs involving 3,000+ campus and corporate officials, including 800+ voting participants. Gilbert also launched EDUCOM's Corporate Associates Program (1983-1993) promoting the active corporate participation and support of over 100 companies. Earlier (1984-1986), Gilbert developed and directed the EDUCOM Computer Literacy Project, surveying and facilitating the efforts of colleges and universities to help non-specialists use computers.

Before EDUCOM, Gilbert was a management consultant in philanthropy, advising corporations and foundations in the area of education and technology. His career began as a teacher and school administrator, including teaching mathematics and science at every level from K-12 at Princeton Day School, and teacher training in Princeton University's Teacher Preparation Program.

Gilbert's undergraduate degree in Mathematics was from Princeton University. He also earned an Ed. M. from the Harvard Graduate School of Education and an M.B.A. from the Wharton School of the University of Pennsylvania.

Flora McMartin, Research Staff

Flora McMartin is a founding partner of Broad-based Knowledge (BbK), a consulting firm focused on assisting colleges and universities in their evaluation of the use and deployment of technology assisted teaching and learning. BbK specializes in working with organizations in building their evaluation capacities and integrating evaluation into their management activities. Prior to her work with BbK, she was the Director of Member Services and Evaluation for MERLOT (an online repository and community devoted to encouraging the effective use of technology in the service of teaching in higher education) where she directed the development, implementation and evaluation of services for users and MERLOT partners. She has had extensive experience evaluating technology innovations in higher education, focusing especially in the sciences, mathematics and technology areas. Her research interests include studying the impact of computer mediated learning on student learning and faculty roles, the impact of assessment as a means for developing collaborative faculty workgroups and organizational change related to institutionalization of innovative academic departments and programs. Dr. McMartin received her B.S. in Art and M.S. in Higher Education from Iowa State University, and her doctorate in Education from the University of California at Berkeley.

Micul Ann Morse, Project Manager

Micul Ann Morse is a consultant serving as project manager for The TLT Group's work on the iCampus program.