

iCampus

Microsoft's \$25 million iCampus alliance with MIT, originally for five years but extended for an additional year, was established in October 1999 to create and demonstrate technologies that produce revolutionary IT-enabled teaching models and improved educational tools for higher education. This strategic initiative is managed by Microsoft Research (MSR) University Relations, whose mission is to build world-class partnerships with key universities and establish Microsoft (MS) as a leading technology partner for higher education.

Now completing its fourth year, iCampus has provided \$16 million to fund 26 faculty research projects and 23 student-run projects. As a measure of iCampus's impact at MIT, the iCampus projects have involved 96 courses with a combined enrollment of over 5,000 students. Over 300 MIT researchers, including 20 percent of all MIT engineering faculty and instructors, have worked on iCampus research projects.

Beyond MIT, about 35 other universities and 13 companies have been involved in collaboration resulting from iCampus projects, and MIT researchers have interacted with a dozen Microsoft product groups. Approximately 60 articles about iCampus projects have appeared in newspapers and magazines.

Since the beginning of the alliance, Microsoft's hiring of MIT graduates has tripled while overall Microsoft hiring of college graduates has remained flat.

iCampus is governed by a six-member Joint Steering Committee (JSC) comprised of three members from Microsoft and three from MIT. The current JSC members are Thomas Healy (MSR University Relations), Paul Oka (MSR University Relations), and Steve Drucker (MSR New Media Group) from Microsoft and Tom Magnanti (dean, School of Engineering), Vijay Kumar (assistant provost), and Hal Abelson (Computer Science faculty member) from MIT. Former Microsoft JSC members include Peter Pathe, Anoop Gupta, Doug Leland, David Salesin, Randy Hinrichs, and Sailesh Chutani. Executive sponsors for the alliance are Rick Rashid for Microsoft and Tom Magnanti, MIT dean of engineering. The Joint Steering Committee sets strategic directions, makes funding decisions, and provides ongoing project supervision and shaping of the far-reaching impact of the research. MIT's iCampus management coordinates closely with the MIT Council on Educational Technology, the MIT central body that formulates strategy for MIT's educational technology efforts.

iCampus Research

Each iCampus project is under the direction of a faculty member who serves as principal investigator. Students work on research projects for course credit or to fulfill advanced undergraduate or graduate thesis requirements. Projects have been funded at levels between \$100K and \$800K per year for one to two years.

Projects are proposed to the Joint Steering Committee in response to a request for proposals that is issued in the fall. Committee members meet with representatives of the

most promising proposals to help refine the scope by identifying complementary MS technologies and potential MSR collaborators.

This report concentrates on the following two major themes we view as crucial to the impact of information technology in higher education:

1. *Creating and disseminating learning web services.* Just as with enterprise information technology, the emergence of a robust web service infrastructure through .NET and other initiatives has enormous implications for educational IT infrastructure. iCampus is pioneering the development of a few global learning web services and initiating university consortia to promote shared infrastructure and shared services in higher education. The efforts—built on .NET—include:

- Remote access to shared physical laboratory equipment (iLabs)
- Shared services for writing instruction and essay evaluation (iMoat)

2. *Reinventing the higher education classroom with pedagogically sound educational technology.* iCampus has initiated major transformations in MIT's largest courses. Among the courses changed are freshman electromagnetism (MIT's highest enrollment subject), MIT's introductory computer science subject (taken by half of all undergraduates), architectural design, and Shakespearean drama. The impact has been felt in all of MIT's schools and thus responds to the needs of the entire curriculum—engineering and hard sciences as well as humanities and social sciences. Transformations include:

- eliminating large lecture classes and replacing them by small-group experiences supported by online multimedia instruction and embedded feedback
- designing project-based learning with simulations and gaming
- targeting location-based services that support learning
- using Tablet PCs to support distributed, collaborative design

iCampus has also sponsored rigorous assessment studies of these innovations. The results of these assessments are being integrated into the projects. Initial analysis supports the conclusion that IT-based “active-learning” systems are superior to lecture methods in fostering student learning. These are high-stakes, high-profile efforts. Given MIT's history of worldwide impact in curriculum innovation, demonstrated success here can be expected to stimulate similar transformations elsewhere in higher education.

Learning Web Services

Web service architectures—which make it possible to modularize implementations, share infrastructure, create new services, and expose interfaces—are beginning to have an enormous impact on enterprise IT in almost every industry. The same is true in higher education, where scarce university resources such as expensive laboratory equipment are increasingly being connected to the web. Web services can consequently be the basis for a major new educational IT framework of software and services shared among universities and between universities and industry.

The iCampus Joint Steering Committee recognized this at Microsoft's first announcement of the .NET initiative and put into motion a plan to build major iCampus projects around web service opportunities. iCampus is evolving to explore web services as agents of change for how universities collaborate around shared educational resources and improve scholarship globally.

This section surveys two iCampus research projects developed on .NET that promote web services and shared infrastructure. This includes creating infrastructure for sharing laboratory equipment (iLab), and writing instruction (iMoat).

iLab: Sharing Laboratory Equipment via Web Services

We're building out a .NET-based infrastructure for putting laboratories online. Because laboratories are scarce resources, we're exploring ways that multiple universities can share them.

The iLab project is developing a set of foundational services that provide web-based access to laboratory equipment so that labs can be accessed across campus or across the world. As an example, students 12,000 miles away in Singapore are currently using MIT's microelectronics laboratory to perform transistor characterization experiments. We are working with MIT's OpenCourseWare project to make these services available to any university, and we are considering the creation of a consortium to promote shared laboratory equipment via web services.

Core services, such as status, identity, reservations, storage, events and notifications, are being defined and implemented with .NET. A core "lab server" service manages access to the physical lab equipment, mediating access by users, administrators, and providers of enhanced services such as authentication of users and archiving of measurement results.

Under iCampus sponsorship and direction, MIT launched a program last year to encourage the development of web-accessible laboratories across universities worldwide. Web-based shared laboratories being developed at MIT include microelectronics, polymer crystallization, chemical reactor and gas chromatograph, heat exchanger, and vibrating structures. In the long run, all university laboratory facilities could form the core of a global shared resource for science and engineering education. Once organized and discoverable through Universal Description, Discovery, and Integration (UDDI), they engender a new class of opportunities for third-party provisioning, hosting, and outsourcing of laboratories and laboratory equipment for higher education as well as for industry.

iMoat: Shared Services for Writing Instruction

Universities today operate largely as "IT islands," rarely sharing infrastructure around core educational or administrative activities. The MIT Online Assessment Tool (iMoat) illustrates how the increasing reliability of web services changes the IT landscape and results in a major infusion of shared and outsourced IT services into higher education.

iMoat is a .NET-based web service that enables universities to collaborate in administering and grading essay exams. It permits universities to set up websites where students register, view essay questions, and submit their responses. The system stores the responses and provides workflow and tracking for administering and grading the exams.

iMoat has also established a large repository of essays (students opt in when submitting) that has the potential to become one of the premier research databases for writing analysis.

iMoat is designed for large-population exams such as the writing placement exams taken by all entering students at most universities. Administering these exams via the web is a major convenience for both students and administrators, but few universities are able to develop or maintain their own installation. It is highly attractive for universities to subscribe to such a shared service, as initial presentations of iMoat at national conferences of writing teachers have already confirmed.

iMoat was first deployed in beta test during summer 2002 as a shared implementation used by MIT, Caltech, the University of Cincinnati, DePaul University, and Louisiana State. The system was used to grade over 4,000 essays, including the writing placement essays for much of MIT's fall 2002 and 2003 entering classes. The iMoat project has continued to expand, launching a major university consortium for supporting and sharing this web service.

Reinventing the Classroom with Educational Technology

The first major iCampus theme explores web services as agents of change for how universities collaborate around shared educational resources. The second major theme focuses on transforming the classroom where the potential roles for technology are varied and vast. Rather than scattering resources throughout educational technology, the iCampus steering committee chose to concentrate on experiments that address the possibility of eliminating large lecture courses and replacing them with active, small-group experiences supported by information technology.

The projects selected sparked fundamental reworkings of MIT's largest courses to demonstrate the effect technology could have on scaling education, improving learning outcomes, and demonstrating innovative uses of technology in a distributed, wireless environment that uses both Unix and Microsoft technologies.

These efforts have required major institutional commitments from all of MIT's departments and deans, as evidenced by multiyear rollout plans. iCampus has required intensive data collection and analysis aimed at assessing these experiments to produce scientifically sound conclusions of these new techniques. The impact has positioned both MIT and Microsoft as the thought leaders in educational technology research.

In this section we review two large-scale course transformations: introductory computer science and freshman physics.

Computer Science

Like so many other large lecture classes, MIT's introductory computer science subject 6.001 Structure and Interpretation of Computer Programs was taught in the traditional mode of two large weekly lectures (300 students) and two weekly section meetings (30 students per section). The goal of the iCampus Computer Science project was to study the effects of eliminating the large lectures entirely and replacing them with interactive technologies that enable students to learn at their own pace.

As a result of this effort, the lectures have been eliminated for the most part and a verifiable model for rebuilding online learning within engineering education has been established. Students access web-based lectures designed with PowerPoint audio narration. (The Computer Science faculty members developing the course contend that audio is superior to video for these purposes. Among other things, the audio segments accompanying each slide can be easily updated from semester to semester, whereas updating video segments would require an expensive production process.) The faculty researchers developed a platform for defining and administering a suite of online tutorial exercises. Students self-test during instruction, writing short programs that automatically validate against a test suite and report the results. (Related work by the same group of faculty include, in the computer architecture course, having students design circuits and having the system run these through a verifier; and in the artificial intelligence course, having student input proofs in a formal language and having the system automatically run these through a proof checker.)

Studies and models like these from MIT reinforce the overall goal that educational technology can boost comprehension of material by enabling students to learn at their own pace and schedule and obtain immediate feedback on their progress. More notable is that instructors can now spend more time developing new content and interacting with students.

Comparison studies indicate that the online material is *more educationally effective* than the live lectures in conveying both broad conceptual ideas and detailed technical content. Based on an assessment study of 168 students, preliminary results compare student performance on material covered in live lectures versus material covered in the online system, both broad concepts and technical content. To a high confidence level, online experience surpasses live lectures in both categories.

Physics

The goal of the iCampus Physics project is to incorporate active learning methods into the introductory physics classroom. This work is modeled after the studio physics effort initiated at Rensselaer Polytechnic Institute in 1994. The studio format combines lecture, recitation, and hands-on laboratory experiments into a single classroom experience where students work together in small groups, seated around a table, while instructors circulate about the class.

Animations and simulations are incorporated into course materials to help students visualize and understand the complex interactions in electromagnetism. Implementing

project-based learning at MIT required constructing a special classroom (construction not funded by iCampus) furnished with display technology, laptop computers, and physical laboratory experiments.

The experimental sections have been so encouraging that the Physics Department intends to switch first-semester physics to studio mode as well. They are also beginning to work with Harvard on integrating the model. If all goes as planned, freshman physics lectures at MIT will have been completely eliminated by the end of 2005 and replaced by active, technology-enhanced learning.

One major educational hypothesis behind this transformation of freshman physics is that the work with desktop experiments and simulations leads to increased conceptual understanding with no decrease in technical facility when compared to standard lecture methods. Assessment results are still being analyzed but seem to support this hypothesis.

The assessment team administered pre- and posttests to students in both the experimental (studio) group and a control (lecture) group. These tests were designed to measure conceptual understanding of the material. The impact a course has on conceptual understanding can be measured by comparing the average amount students improve from the pretest to the posttest.

Results show that for students at all academic levels, the improvement in the experimental group was higher than in the control group.

Overview of Other Faculty Research

The bulk of this report describes four projects in order to illustrate how the work funded at MIT supports coherent themes that are strategic to Microsoft. Following is a brief synopsis of some of the remaining iCampus faculty projects.

Simulations in Engineering Education

The Department of Aeronautics and Astronautics initiated a major curriculum transformation to support active learning and simulation. Microsoft Flight Simulator is integrated into nearly every course in the department. The faculty created modeling and analysis tools closely coupled to Flight Simulator so that students could simulate flying aircraft of their own design. *Result: Game-based simulation software can be used to engage students in rich experiential learning and improve their “real world” knowledge, if the simulation software imitates “real world” experience.*

Simulations in Mechanical Engineering

The creation of “active paper” as a medium for mechanical engineering design with Tablet PCs will be explored further as a result of our emphasis on simulations, shape recognition, and immersive feedback systems to generate human inquiry while engaged in active sketching. An early prototype of this work was demonstrated at a Bill Gates

review of Microsoft's academic programs. *Result: Software designed to simulate physics and mechanical engineering education around simulation software to improve learning.*

Similar curriculum efforts have been undertaken by the departments of Mechanical Engineering, Civil Engineering, and Health Science and Technology. Once more, the emphasis has been to incorporate active learning into lectures using both physical models and simulations. Telepresence and remote white-board technologies have been evaluated for MIT's Internet 2-based collaborative courses with universities in Singapore. A cross-departmental effort within MIT's School of Engineering developed simulations and online curriculum for teaching fluid mechanics. *Result: This demonstrated the need for improving telepresence (n-way video conferencing) with a rich set of collaborative tools to enhance learning.*

Simulations and Distributed Collaborative Discussions in the Humanities

The Humanities Department is teaching Shakespeare with the aid of MRAS, a multimedia annotation system initially developed at MSR. Students combine video clips and writing to create and share multimedia essays. This project arises from the belief that multimedia composition will become a fundamental communication skill and that learning to create effective multimedia compositions will be a regular part of higher education, just as learning to write is today. *Result: Multimedia software is developed to discuss different productions of Shakespeare's plays, with accompanying text and discussion.*

Improving Collaborative Design with Tablet PCs

MIT's internationally famous robot design course is incorporating a .NET-based framework for teaching engineering design. The system was piloted by the International Design Contest held at MIT during summer 2002. In addition to the .NET software, students used Tablet PCs and tablet-enabled applications specially developed for the course. Microsoft has showcased this work in a case study and has featured it at Tablet PC launches. *Result: Software integrating collaborative design using Tablet PCs improves student design.*

Location-Based Tracking in Architecture

MIT's master's program in Architecture created a virtual community and location-based tracking software to identify location and access to professional architects across the world. This program is being carried out in collaboration with MSR's Social Computing Group. *Result: Location-based services with web interfaces improve architecture education.*

Basic Research in Gaming for Learning

We have inquired why gaming hasn't taken off in education. What are the reasons education and entertainment haven't historically mixed? Given the next generation of multiplayer, object-event-driven technologies that enable students to manage objects in rich, visual environments, we are exploring how to develop environments that use storytelling, strategy, object manipulation, consequential behaviors, and increased time on task to examine another platform for learning. Development and study of a collection

of immersive simulation games as prototypes for a next generation of educational games promises another breakthrough in learning.

Photologs by Children around the World

We awarded seed funding for a program that involved MIT undergraduates in collaborations with children in countries around the world in order to produce extensive photographic libraries and books that document what it's like to be a child in those countries. The Expeditions Project successfully created and marketed *Bhutan: A Visual Odyssey Across the Kingdom*—the largest book in the world—and is using the proceeds from the sale of the book to build a school in Bhutan.

Combined, these projects have produced over 40 published papers, 28 theses, and given approximately 210 public talks. Taken as a whole, these projects are helping to promote a shift toward technology-based environments that provide new forms of motivation, increase student time on task, and provide a rich feedback mechanism for long-term scholastic development.

Student Projects

In addition to funding faculty projects, iCampus solicits and funds projects designed and run entirely by MIT student groups. These projects are targeted toward creating web services that will enhance campus life. Student projects each receive one-year grants of \$50K, and to date over \$900K has been awarded. These student awards have generated good publicity for iCampus and for Microsoft on the MIT campus, but more importantly students have often demonstrated creative ideas for web services to improve campus life. The table below describes the life cycle of student projects.

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| November | Student RFP published and widely advertised. Web-based proposal system opens to MIT student community. |
| December | Groups with most promising proposals are interviewed and proposals are refined. Final selection is completed by the end of the fall semester. |
| February–May | As a condition of funding, all students receiving an iCampus grant must enroll in a for-credit spring semester course taught by an MS FTE. The course focuses on project management (using MSF best practices) and presentation skills. Weekly milestone deliverables ensure the projects stay on track. |
| June–August | Students can elect to pay themselves or hire others to work on the project over the summer. Some students have been offered Microsoft MSR internships in areas complementary to the project. |
| September–December | Project work continues as students return to school. About one-third of the students deploy their work in a fall semester course. |

iCampus has funded 23 student projects to date. Below are snapshots of five.

Shuttle Track

The Shuttle Track project has enhanced MIT's SafeRide shuttle van service by providing spatial location and estimated arrival times, viewable on a website. The team, comprised of MIT graduate students from diverse backgrounds, has integrated three key technology components—GPS hardware, communication devices, and display technologies—in a cost-effective, sustainable manner.

GPS position information is transmitted over radio to a network server, where the data is processed and stored in a SqlServer database. The data collected is also used with forecasting algorithms for estimating the arrival times of the vans at various stops along their routes. The Shuttle Track website displays update-to-minute shuttle and route information and also hosts several web services that provide the same information via SOAP over HTTP. The team is also exploring different methods to display the information to users, such as schematic route maps, telephone interfaces, and public displays. An additional goal is to author how-to and best practice guides and make them available to other universities.

DevHood

DevHood (<http://www.devhood.com/>) is an online student community for college students all over the world to come together and learn about Microsoft and .NET technologies. Created by six MIT students on the .NET platform in early 2001, DevHood has grown to into a community with over 10,000 users from 400 colleges. DevHood incorporates a revolutionary user experience and rating system that integrates elements of a traditional role-playing game with an online community, providing user contribution metrics as well as an incentive for users to continue to take part in the community.

The Student Developer Community project is a .NET developer's community/website for college students worldwide. The focus is on students interested in learning about the latest in Microsoft technology and discussing software development. Students will revamp software user interfaces and add features, including college-specific themes, intercollegiate competitions, personal calendars, administration features, messaging and chat capabilities, class specific discussion boards, and mobile accessibility.

iQuarium

iQuarium strives to give people a hands-on introduction to the field of ocean engineering by placing an aquarium display screen in an easily viewed setting—in this case the Hart Nautical Gallery at MIT. iQuarium is a colorful, interactive aquarium display screen that features swimming fish and a visible flow field in their wake. The student team has created an animated fish screensaver with 3-D modeling and rendering software, based on libraries of empirical data that exist on fluid flow phenomena such as the complex vortices that form around live swimming fish.

Researchers usually collect this data in tow tanks and water tunnels. The tools to visualize this data are inaccessible to anyone other than researchers in the field; it takes weeks or even months to transform the sets of empirical data into visualizations using the latest software. For iQuarium, vertical flow field visualizations have been broken down into a library and brought together into a pseudo-real-time sequence that a user can control. Anyone who passes by the display will be able to see the vortices shedding almost instantly as the fish swim.

The iQuarium project brings hydrodynamics out of the lab into the hallway for everyone to gain a better understanding of the principles behind ocean engineering and fluid dynamics.

STEPS

STEPS (Software Tools for Environmental Study) has developed a mobile software application for environmental field studies that streamlines data collection and improves data accuracy. The project has created an electronic field notebook wireless PDA application that integrates the tasks of collecting data from environmental and GPS sensors, stores the data, makes computations in the field based on the data, and displays the data to the field-worker and to others through an internet site. The technical project objective was to create mobile field data collection software for the environmental professional.

The project also has a strong educational component focused on providing hands-on product development experience to undergraduate environmental engineering majors. Through a six-unit undergraduate seminar, students were exposed to Programming for Windows CE, technologies for field studies and entrepreneurship in the software industry. Students in the seminar built a system prototype that was field tested during an IAP trip to New Zealand and Australia, offered under the auspices of the Civil and Environmental Engineering Department. The team has recently been in talks with representatives from the government of India who are interested in deploying this technology.

CycleScore

Aerobic exercise is not often engaging or motivating, and it would be more effective if it were as much fun as playing sports. The aim of the CycleScore project is to determine what kinds of motivational experiences are most effective for the use of aerobic exercise machines and to increase a person's desire to exercise by providing an exercise experience that is entertaining, motivational, and fun.

Most mainstream fitness equipment in workout facilities offers a convenient workout that can be tailored to an individual's needs in an indoor environment. However, unlike activities such as individual and team sports, treadmills and cycling equipment can be tedious and not stimulating enough for many participants. As a result, people lose interest in exercising on a regular basis and suffer short-term and long-term health risks.

CycleScore has installed a working prototype of a stationary bicycle in MIT's Zesiger Center sport facility that connects an exercise bike to a PC and monitor. By pedaling the bike, riders control the flight of a hot-air balloon that floats above a mountain range on the attached computer screen. The harder they pedal, the higher the balloon soars—and the higher is the cyclist's motivation to continue. The student project leaders hope to make this technology available to gymnasiums throughout the MIT campus and to the greater Boston/Cambridge area in the future.

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More information about iCampus can be found on the web at <http://icampus.mit.edu/>.