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The iCampus Technology-Enabled Active Learning Project at MIT: An Interview with Phillip Long

by James L. Morrison and Phillip Long

Phillip Long, who until recently served as associate director of MIT's Office of Education, Innovation, and Technology, now serves as professor of innovation in educational technology and director of the Center for Educational Innovation and Technology at the University of Queensland, Australia. He also continues to work at MIT as a visiting researcher in the Centre for Educational Computing Initiatives. In July of 2008, I had the opportunity to interview him at the Campus Technology Conference in Boston. We talked at length about iCampus, a recently concluded seven-year, $25 million R&D effort (funded by Microsoft Research) that focused on building technologies that enable more effective learning.

James L. Morrison [JLM]: Phil, although the details describing the iCampus project are described in the project's website, what to you are its most salient outcomes?

Phillip Long [PL]: Initiated in 1999, iCampus was a research collaboration between Microsoft Research and MIT. Its goal was to create and implement technologies that could effect revolutionary change throughout the university curriculum. Although MIT's initial iCampus relationship with Microsoft is completed, additional funding was extended to cover the dissemination and assessment of some 60 R&D faculty projects and 30 student projects developed during the initial contract. The most important results of iCampus emerged from its team-oriented active learning projects and the exciting uses of technology that facilitated these projects.

JLM: How did this project reach beyond MIT?

PL: In addition to ensuring that iCampus projects were released in a form that someone other than the developer could use, funds were set aside to provide additional materials and support staff that could help facilitate their adoption and use. For interested institutions, we not only provided source codes and documentation but also assisted them in making the applications work within their institutional contexts. For example, one project was Technology-Enabled Active Learning (TEAL), which was developed by John Belcher, a physicist at MIT. John was the lead faculty member teaching a highly rated introductory physics course, yet despite his course's popularity, the average attendance three-quarters of the way through the semester was about 40%. To some extent, that's just MIT. Students are overscheduled; they have lots of things vying for their time, and they try to spend it in the most effective way they can. Even a captivating lecturer takes up time that students could be spending doing other things. However, John wanted to attempt to remedy the problem and thought, "If attendance is the issue, I've got to be more dynamic in my delivery." So he took acting lessons and, according to his course evaluations, did an even better job in the classroom; disappointingly, however, he delivered these improved lectures to the same 40% of the class. Class attendance remained unaffected by his efforts to improve the lecture format.

John and others at the Institute were also concerned that the drop-out/failure rate for the introductory physics course was in the 14% range. Some people would say 14% is not that high. But remember who's taking this course: These are MIT students. Chemistry and biology are only getting a dropout rate of 5%, so why is it 14% in physics? John applied for an NSF grant to get support for changing the course but was told that while his ideas were interesting, he needed to connect more with contemporary physics educators who were doing work that might strengthen his own. NSF gave him a planning grant, and he looked outward.

John had heard about the terrific work that Bob Beichner was doing at North Carolina State University using an active-learning approach. With iCampus funding, he borrowed much of Bob's pedagogy and design and then redesigned his course using a studio-based model for teaching physics, where students are taught in a specially designed room with round tables. Students are pretested on their competency in physics and then organized into peer teams of three based on the pretest scores. Each team includes high-, medium-, and low-scoring students in order to maximize peer instruction opportunities. Students argue the answers to concept questions and then use clickers to report their responses. Then the professor presents a mini-lecture to set the framework for a lab project. Students do hands-on experiments in the same room; lecture, lab, and recitation are combined in one space.

The results of learning assessments suggest that learning gains are significantly better with this structure than with the more passive lecture approach. These results are consistent. We have now measured them longitudinally over four years, and the same delta increment in improvement persists across all four years relative to the students who took the lecture course. (Some of these results are available in publications listed on TEAL's iCampus project page.) As a consequence, the physics department at MIT has adopted TEAL as the standard way that introductory physics is taught. This approach allows living-room style active learning to be taught to 560 students. It is taught in these special rooms that seat a maximum of 117—with up to seven or eight sections offered. (Most of the time, sections are smaller, tending toward the 80-90 student range.)

JLM: What role did technology play in this redesign?

PL: The class and the space are pretty technology heavy, in part because it's MIT and that's the way we approach these kinds of things. Each table of nine students has three computers, one per team of three students; its own projector; its own ceiling-mounted camera; and its own whiteboard. This setup is designed to allow students to share work that might be of value to the rest of the class. For example, while circulating throughout the class, the instructor might see that table 12 is doing something really interesting to solve a particular problem. The camera pointing at the whiteboard for that table can then be switched on so that all of the screens around the room show table 12's work and the students at table 12 can talk about it. This kind of setup makes it much more difficult for students to avoid participating.

JLM: As opposed to having the professor solve the problem on the whiteboard for the students?

PL: Exactly. Many of your readers will have read or watched Mike Wesch's talk and video that took YouTube by storm. Interested readers should also take a look at his digital ethnography YouTube channel where he talks about where and how learning happens in his anthropology class at Kansas State. He points out that the room is designed to instill in the student that learning happens while sitting passively and watching the stuff that happens in the front. We are actively, physically, intently trying to break that apart and say absolutely not. Learning happens when individuals interact with each other and wrestle with problems, problems that matter.

The active-learning approach in the physics department is an example of an endeavor whose impact has extended beyond our institution; we have visitors coming in from all over the world all the time to see how it's done. Our physics faculty members take time to talk to people about the approach, sometimes traveling to other institutions to share their expertise. For example, Peter Dourmashkin, a physics instructor in the department, and I just spent several weeks presenting examples of how you teach this way at institutions across Australia as part of the iCampus outreach effort. We got a bunch of people together, brought down our clickers, and taught a class on RLC circuits in physics. We'd teach for a few minutes, and then we'd stop and say, "Let's talk about what we just did. Why did we do it this way?” We would then explain the process behind what we were doing before continuing.

This trip is just one example of MIT's outreach efforts; it was made possible by the funding that Microsoft Research gave us to continue outreach for the iCampus project of which TEAL is a part.

JLM: Phil, can you give us other examples of how professors at MIT are pushing the instructional envelope?

PL: Many of the activities going on here reflect creative approaches that individual faculty members have taken to scratch a particular itch. For example, Professor Jesús del Alamo, who is a microelectronics engineer, teaches a semiconductor course. In his lab, he has some terrific technology for measuring the characteristics of semiconductor components. He wanted students in his first- and second-year undergraduate courses to be able to come in and use these devices so they could better understand how transistors work, how diodes work, etc. The problem for him is that each of these device setups consists of a collection of equipment that costs about $100,000. It's difficult to justify an undergraduate lab where the equipment costs $100,000 per setup. Even we can't do that! Yet the opportunity to use these tools shouldn't be limited to just graduate students; using research-quality tools is just as important for undergraduates as it increases their understanding of the field they're studying to enter.

So how does del Alamo make that experience more accessible to his undergraduates? Well, it turns out that when you're interacting with these devices, you're really interacting with the physical manifestation of the data on a screen. The test device has a bunch of buttons on it, and you program it to run a sequence of steps, applying a voltage across the drain terminal of a transistor starting at, say, zero volts and increasing to four volts in 200 mV steps. Similarly, you configure the gain terminal to go from zero to, say, three volts in 200 mV steps. You're physically doing that—measuring the transistor's response characteristics with an Agilent 4155B Semiconductor Parameter Analyzer, a state-of-the-art instrument for measuring the current-voltage characteristics of microelectronics devices—but you could just as easily make that device abstract and represent it as a software interface run off the Web. It's still a real device running real experiments and yielding actual data, but the device may be elsewhere and be accessed through the Web.

Okay. That sounds reasonable. People have been putting experiments on the Internet since the Internet came into being; there's nothing novel about that. The problem has been that in the past, they chose idiosyncratic strategies for doing so. It was a cottage industry in that regard; we had not yet thought carefully about how to create an architecture, design, and tools that were easily replicable and sustainable. Every faculty member chose what to do based on what he/she knew—for example, a certain programming language or a particular design approach—and that instructor put something up and it was great; it worked as long as the graduate student who was there when it was built stayed.

MIT went down that same path. We built a bunch of experiments and then put them online using these same idiosyncratic methods. And sure enough after a short period of time, they all started to bit rot in one fashion or another. Each time we put one up, we gained very little in terms of benefit for implementing the next one. We thought, "There's got to be a better way." iCampus gave us the funding to explore that through a project called iLab. Then Hal Abelson, a colleague, made the point that we should be thinking about this from an architectural point of view; that is, we should be thinking about how to use standardized services that all experiments can use to meet common needs.

What are those common needs? Every online experiment needs a way of authenticating and authorizing access to it. Every online experiment involves collecting data, so it needs to have some kind of data storage functionality. Many experiments require some mechanism for reserving access to a device, so a scheduling service is important. Once you start going down the list, you end up with a handful of core things that most experiments need. How do you implement them? Hal's suggestion was to use Web services, and the team did. As a result, instead of having to invent the functionality for authorization and authentication each time we created an online experiment, we grabbed an authentication service and plugged it in. We did the same thing with respect to data collection by finding a storage service and plugging it into the interface. Once we had those things taken care of, we could think about pedagogy and consider the experience we wanted the student to have when interacting with the device. We went beyond simply replicating what the physical experimental devices look like to build specific learning goals into the interface. That's the iLabs remote laboratory software architecture.

JLM: What's the future of iLabs?

PL: iLabs, originally funded by Microsoft, is continuing in its 10th year as a large-scale project. We're in the process of forming a consortium of educational, governmental, and corporate institutions to sustain it long-term. This is important because when you do something like this, an interesting thing happens: You build excess capacity that can be made available far beyond the originating lab or institution. Not only can access be distributed so that students at other institutions can take advantage of virtual experiments created elsewhere, but also, more importantly, because you have to build your experiment to perform well at peak loads and students always wait until the last minute to do their assignments, there is excess capacity that allows this sharing to occur without disadvantaging you or your students.

For instance, if you give an assignment on a Friday and you make it due the following Friday, students are going to do the work on Thursday night. As a result, the system has to be built to handle this peak load on Thursday night at midnight, regardless of how much (or little) it is used the rest of the week. That means that on Wednesday, Tuesday, or Monday, the handful of students working on the system are using only a fraction of the system's capability, and the rest of the system is therefore available to be shared. This creates a situation wherein my experiment—as long as I have dedicated and committed throughput for my students when I need it—can be made accessible to others at other times without jeopardizing my ability to acccess it at all. As a consequence, we think that there's a real opportunity for the iLabs architecture to create a corpus of experiments in multiple disciplines that can be shared worldwide, providing a global community of students with 24/7 access to hands-on, physical experimental devices as well as the messiness of real data. That's something we're striving for as there are students in the U.S. and certainly in the developing world that don't have any access to certain laboratory resources.

JLM: Where are you now with this effort?

PL: We have about 19 implementations of iLab experiments set up around the world, and we have a major partnership with universities in Australia. We have a grant from the Carnegie Foundation that is supporting the development of two hubs for laboratories in Africa and the construction of experiments for sharing within east and west Africa. So there's lots of interesting work going on. We're at the point where there is value, we think, in pulling these projects together under the umbrella of a structural consortium arrangement and thinking much more intentionally about how we sustain them. It costs money to do these things. Many of the experiments, once they're built, don't take a whole lot of additional money to run, but others do. So how do we apportion costs fairly? That's what the consortium is working on.

Right now, MIT and Northwestern University have a National Science Foundation grant, of which I am one of the co-principal investigators, to implement experiments in high schools to test the hypothesis that a single physical experiment paired with different sets of curricular materials can be useful across multiple grade levels. One of the experiments is a radioactivity lab that demonstrates, among other things, the inverse square law. High schools no longer can have radioactive material on campus. The experiment allows students to adjust the distance of the sampling tube, even impose absorbing materials in the path of the collector to measure their impact on the counts measured. The experiment is in Queensland, Australia. The students are are in Chicago. But in today's networked world, it doesn't matter. Studying how the world works through real experiments, collecting real data can be done without regard to geography. We pair this collection of real data with simulations. Why aren't the outcomes the same? What accounts for the variation in the numbers from the real experiments versus the simulation models? That's the difference between the real world and our representation of it. It's the space in which real learning can happen.

JLM: How will these be made available to classroom teachers?

PL: That's part of the NSF grant. We have a workshop scheduled for the grant members to pull together the high school teachers who are working with these experiments and help them build curricula that can be put into some high schools to test, and then there's an iLabs portal site available from MIT. People can go there, see how iLabs is designed, get information about accessing experiments, and download the open-source software. These projects are entirely open source, so you can implement experiments of your own using their architecture. And visitors can try it out; we have three experiments that are publicly accessible. Anybody can create an account on the fly and try to run a microelectronics performance test on a semiconductor if they wish. Register yourself at the bottom of the iLabs welcome screen and do a circuit experiment or a microelectronics experiment, or try one or the other of the experiments listed there and see how it feels to you.

JLM: Phil, thanks so much for providing concrete details about how MIT and its faculty members and students are serving as true exemplars in higher education. We appreciate the examples and the leadership that this great institution is providing for global education.

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