By Phillip D. Long and Stephen C. Ehrmann

FUTURE OF THE LEARNING SPACE

Breaking Out of the Box

Prediction is very difficult, especially of the future.
—Niels Bohr

For many people, the public image of higher education is the classroom: faculty talking, with students intently listening and taking notes. Students' progress toward a degree is measured by time spent in classrooms. The daily pulse of a college or university is largely dictated by the classroom schedule as bells ring and the halls fill with students and faculty rushing to the next class. Many educators, however, increasingly argue that such classrooms are largely ineffective as learning environments and that they should not continue to be built.[1] But what should take their place? In considering the future of the learning space, we will discuss (1) a few of the reasons why traditional classrooms are inadequate and need to change, (2) some ideas that break with these traditions, and (3) suggested areas for the planning team to keep in mind so that the team can come up with ideas for future learning spaces that are pioneering rather than imitative.

Changing the Classroom

The research on education is full of disappointing findings about what graduates can't do, don't understand, or misunderstand. Many college graduates are unable to apply much of what they have been taught.[2] Part of the problem may be the classrooms in which those students were taught: certain kinds of spaces make it too easy to teach by "delivery"—broadcasting knowledge from the instructor's mouth toward the student's brain—while making it awkward to teach in ways that, research suggests, can produce deeper, more lasting learning.

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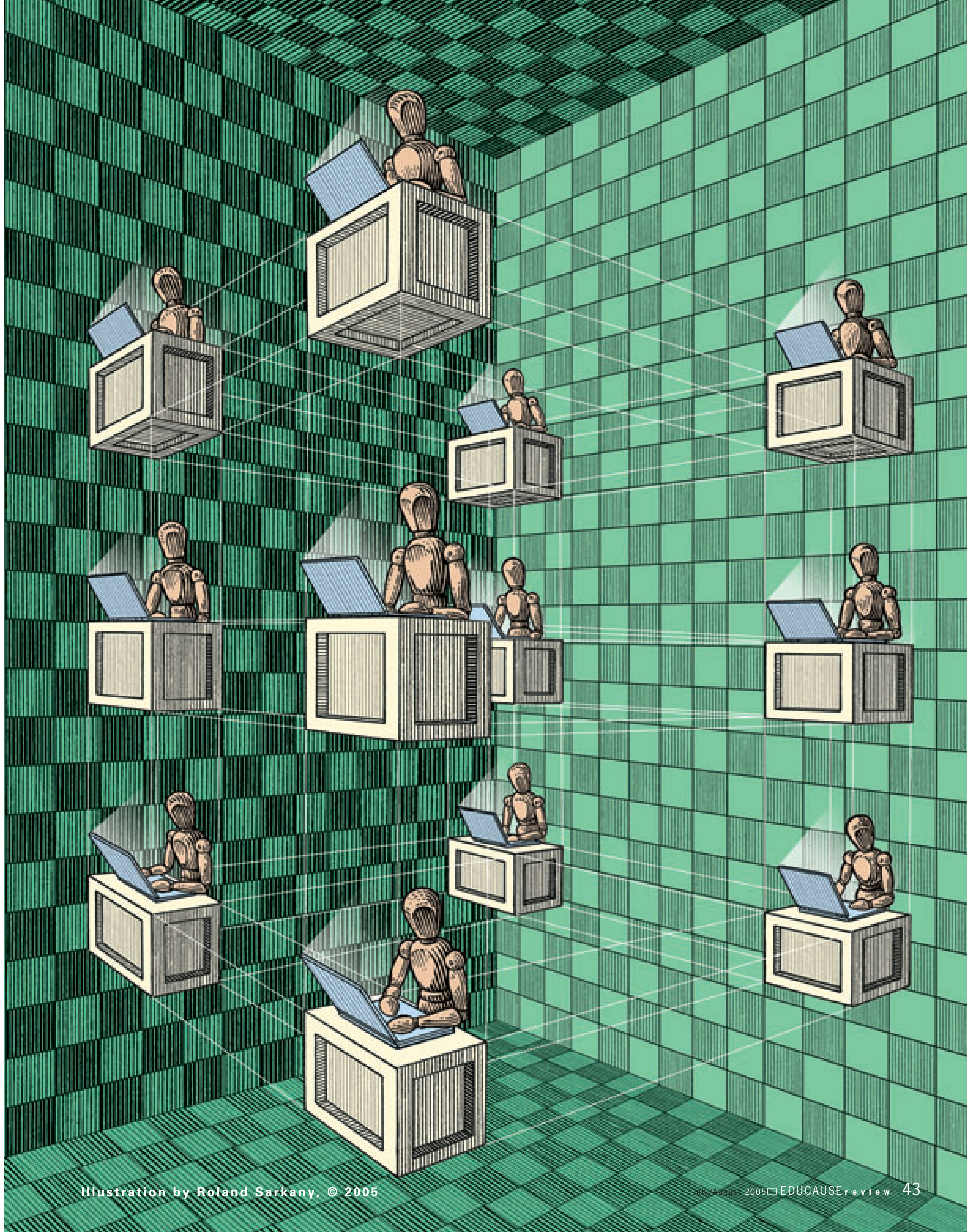
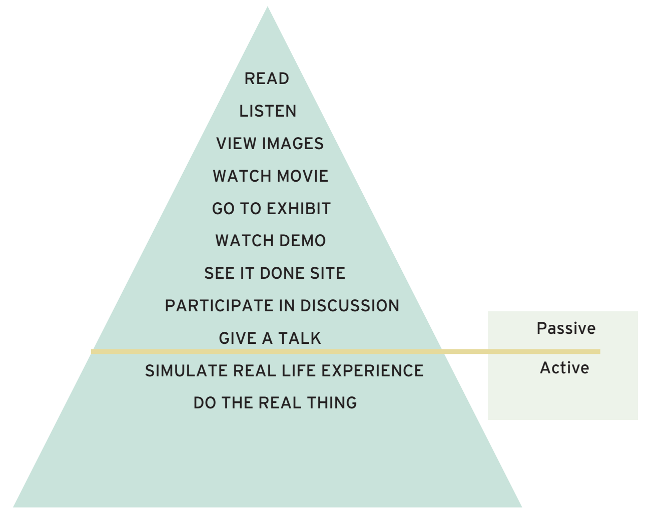


Illustration by Roland Sarkany, © 2005

Figure 1: The "Experience Cone"



Source: J. Huang, Harvard University Graduate School of Design, personal communication. Adapted from Edgar Dale, *Audiovisual Methods in Teaching,* 3d ed. (New York: Dryden Press, 1969).

The release in 1999 of *How People Learn* brought together the current knowledge about the neuroscience, behavior, and psychology of learning. These ideas can be organized around five themes:

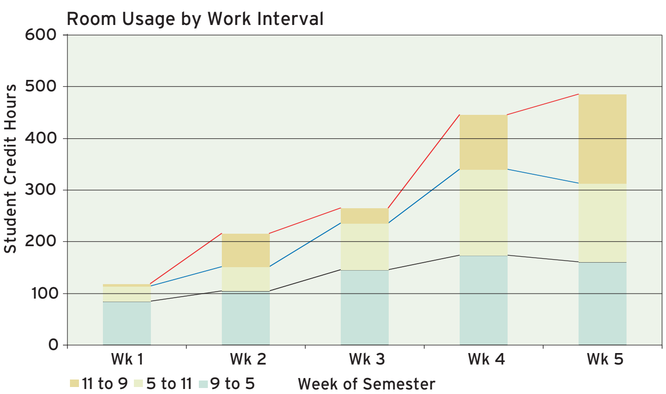
1. Memory, and structure of knowledge
2. Analysis of problem-solving and reasoning
3. Early foundations
4. Metacognitive processes and self-regulatory capabilities
5. Cultural experience and community participation

Learning, according to the authors, is regulated by both the biology and the ecology of the individual: "Learning *produces* development."[3] The classroom has been a critical, and costly, component of this ecology.

Thirty years earlier, Edgar Dale had described what he called the "experience cone," which orders different modes of learning according to their power (see Figure 1).[4] Retention is worst with the modes at the top of this cone and best with those at the bottom. More recently, authentic learning has been a topic in the teacher-preparation debate, with future teachers being "urged to use student-centered, constructivist, depth-versus-breadth approaches in their education classes"[5] yet finding themselves being taught by traditional teaching approaches. "Don't do as I do, but do as I say" turns out to be a particularly ineffective model for long-term behavior.

So the first requirement for some portion of classrooms of the future is that they support coaching and instruction while the student is doing what the student is learning to do. Students can learn meaning in a discipline when teaching/learning activities are organized around the core processes and tools of the discipline. Today this happens most often in the arts and, sometimes, in professions. For example, some engineering schools guide first-year and senior students through a sequence of increasingly challenging engineering tasks.[6]

Figure 2: Room Usage for Academic Coursework over the First Five Weeks of the Term



Source: E. Crawley and S. Immrich, "Process for Designing Learning Spaces, Case Study: The MIT Learning Lab for Complex Systems," presentation to NLII Learning Systems Design Workshop, 2004.

A second way in which facilities can foster learning concerns context. Imagine two novices learning French. One of them sits in an empty room, listening to a neutral voice recite French words and then repeating them. The other is in France, watching as French people talk with one another, gesture, and point. Even though the French is spoken more quickly and casually in France, the learner will be able to use situational cues to interpret what's being said. This is *situated learning.* Situated learning is important for many reasons, not the least being that the student learns about the circumstances under which it is appropriate to apply what has been learned: when the learning fits and when it doesn't.

A third important feature for a learning space is the ability to interact, on a variety of levels, with both experts and peers. It's no coincidence that at least four (faculty-student contact, student-student collaboration, rapid feedback, and communicating high expectations) of the seven research-based principles of good practice in undergraduate education have to do with interpersonal interaction.[7]

A fourth characteristic relates to "location, location, location." Where does academic learning really take place? We focus in this article on the rooms where instructors and students interact—because these facilities are expensive to create, renovate, and maintain and because they shape the daily schedule of most academic institutions. But of course much, perhaps most, learning currently occurs *outside* these rooms. An MIT study of how students in an undergraduate design course in the Department of Aeronautical and Astronautical Engineering spent their time over the semester demonstrated that students quickly extended their academic work beyond the course meeting time (see Figure 2). And when faculty and administrators in several workshops conducted by Steve Ehrmann were asked to describe the most significant learning experiences of their college years, respondents rarely mentioned classrooms. Instead they talked about other areas on and off campus. Our question, however, is "What kinds of classroom designs might

Classrooms should support the activities of effective learning: situated, collaborative, and active learning. What might such spaces look like?

be better at supporting important learning in college?"

In summary, these four ideas can be useful in imagining classrooms of the future:

1. "Learning by doing" matters.
2. Context matters.
3. Interaction matters.
4. Location of learning matters.

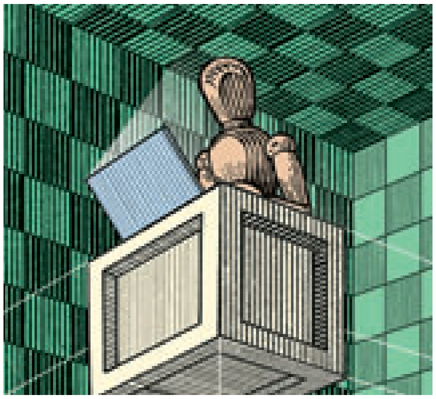
Breaking Out of the Box: Classrooms Designed for Learning

Classrooms should support the activities of effective learning: that is, situated, collaborative, and active learning. What might such spaces look like? Do any such spaces exist yet?

Buildings That Embody Professional Education

In the late 1990s, the Department of Aeronautical and Astronautical Engineering at MIT confronted the problem of teaching a twenty-first century subject in a turn-of-the-twentieth-century building. As the demand to do something about the decaying physical space increased, so did the need to address a new curriculum for a new age. There is nothing like the threat of self-preservation to motivate change. In this case, declining enrollments placed pressure on the department to do something different. Fortuitously, but perhaps catalytically, a major demographic bubble led to significant turnover in the composition of the departmental faculty, and a young department chair was appointed to lead the faculty through this difficult transition.

The department developed a curriculum model that stressed fundamental tenets of engineering set in an interactive learning framework of Conceive, Design, Implement, and Operate (CDIO)[8] systems and products. Using a structured approach to identify the abilities required for a contemporary engineer, a "requirements document" was generated to provide the CDIO "syllabus." This became the basis for building the workshop-laboratory-classroom environment.



A critical element in the design of new learning spaces is the need to design for change. Usage patterns measured over the years since the CDIO curriculum spaces were built have demonstrated that students are not always using the new facilities in the ways the faculty originally imagined. The department continues to adapt its spaces in order to best fit the curriculum as it is practiced by the students and faculty.

Buildings and Campuses as Learning Spaces

Architecture is no longer merely a container within which learning happens—buildings themselves can provide several dimensions of support for learning. In fact, the building system elements that work together to support learning are analogous to the functionality sets found in complex computer systems. Together, they form a *building operating system* (BOS).

The following are some of the technologies and learning activities that these new BOSs will need to support:

- Capture/replay "think through": processing real-time recording (ad hoc) without destroying the social comfort of the group and while providing appropriate degrees of privacy; particularly challenging will be capturing audio in small-group conversations that occur when large classes meet in a single room
- Writeable surfaces—everywhere in the classroom—that capture and store everything written on them (see, for example, <http://www.cc.gatech.edu/fce/eclass/>)
- Real-time blogging in the classroom—students building collaborative notes on the course site or a wiki
- Classroom chat rooms—for example, with a teaching assistant (TA) monitoring students' meta-conversation, including a TA-moderated Instant Messaging "back channel"
- Dynamically available bandwidth provisioned to and within a room, allowing students to safely access and download rich media objects without choking the local network segment
- Ubiquitous access to videoconferencing, so simple and intuitive that multisite conversations are "natural" extensions of classroom discussion
- Video/data-enhanced real-time capture and asynchronous discussion and annotation tools
- Tools enabling ad hoc guest instructors teaching from a distance to easily use the full set of classroom technologies

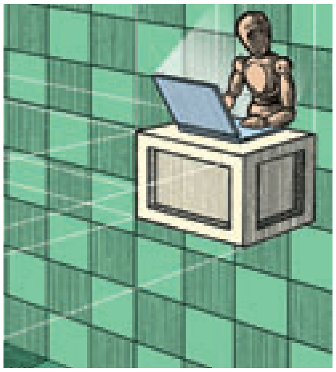
From Ubiquitous Computing to Situated Computing

Not all advances in learning spaces need to directly support more situated, active, and collaborative learning. Some can do this indirectly by reducing some of the wasted time and rigidity often experienced by faculty in today's high-tech classrooms.

Mobile devices and widespread connectivity have led to 100 percent access to information, always-on services, and "anytime, anywhere" learning. The place is becoming irrelevant. Thus, if important parts of learning occur when the learner is outside "classrooms," then the technology carried by, or available to, the learner in that space needs to provide appropriate capabilities. And the technology (mobile or static) needs to alert the learner about what can be done in that setting.

For example, imagine being able to embed, in specific physical locations, situational instructions that would tell students' devices how they should be configured and behave while in that local environment. After all, when someone walks into a physical space, there are signs that say to behave in certain ways, to keep one's voice down, not to eat food, or to prepare for a certain kind of activity. Likewise, students entering a testing space where high-stakes assessments are performed might find their laptop computers configured to restrict access to only certain network locations or to launch only specific applications.

Colleges and universities will need to shift their mixture of dedicated, discipline-specific learning environments, typified by laboratories and other spaces that remain technically defined, to a focus on (1) self-discovering virtual networks delivering secure services to portable devices that dynamically join and depart the building operating system, and (2) spaces supporting sets of interactions with corresponding technologies optimized for particular locally identified goals. At the lowest level, these two technical requirements mean that individual devices, whether fixed or mobile, can be interconnected to perform tasks that routinely go together.



Imagine you're a faculty member. For your class on Tuesday, you plan to display images, invite a colleague from another institution for a fifteen-minute Q&A with the students, and give a quiz. This sequence of information is already "known," since it's on your course schedule page. The building network in which your class takes place has an event profile generated by your schedule. The profile "knows" the tasks that some of the building infrastructure will be asked to perform on Tuesday at 3:00 pm (your course meeting time).

When you enter the classroom to prepare for the session, the building network registers your presence from the RFID tag on your ID, retrieves the profile, and notifies the relevant devices using Internet 0 protocols.[9] The display devices are activated, waiting for the video source. The computer uploads the information about the planned quiz to the network so that when the quiz is started, the router configuration for the room disables external IP access, limiting students' browser and search tools. (Though you had hoped to disable the peer-to-peer communications, the student privacy board ruled to limit the dynamic setting of access control on personally owned machines.) The room lighting configuration is modified according to your preferred lighting pattern, and capture tools in the room prompt you with default names for the class session, date, and storage location so that you can modify these if you wish. By default, your capture profile will record and store the video, audio, and any surface writing (what was once known as "writing on the board"). You've also elected to have key words generated; these will be included as metadata to the lecture text that is recorded, digitized, transferred to text, and posted in the course online workspace. The room-management window on your portable computer accepts your "ok" to leave it as is, and you're ready to teach.

Students entering the room have the choice of opting into auto-attendance recording (showing up counts for 10 percent of the grade). Their preferred information-distribution channels are noted, and once their presence is confirmed, information is transferred from the course workspace to their preferred workspace. That might be their computer, their online workspace, or in some cases, their handheld device of choice.

Such a facility has several advantages, most notably the flexibility with which it can be reconfigured—hour by hour, day by day, year by year, decade by decade.

Many traditional facilities for situated learning—for example, laboratories and libraries—will also need to be reconfigured to better support collaborative work among people from different disciplines. Graduates who work skillfully in interdisciplinary teams will have been educated by learning, for a significant portion of their time, in interdisciplinary teams. Unless students have significant experience working in teams to draw from several disciplines in order to solve thorny problems, graduates will not magically master that skill set. So the facilities in which they learn and apply their learning need to be supportive of the work of (novice) team members.[10]

Distributed Real-Time Classrooms

Important aspects of higher education consist of one or more instructors helping a group of students understand something by talking to and with them. Research studies show that there is no special magic in delivering a presentation by saying the words to people who are physically present.[11] Whether the words are spoken or read, whether the message is heard or seen, whether the learner is nearby or distant, a presentation is a presentation is a presentation. On average, the learning results are the same.

So, should all lectures be translated into readings and digitized? We certainly need to go some distance in that direction. Faculty time is too precious to waste

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it doing something that a streaming video could do as well or better (students can replay streaming content as many times as they like in order to grasp a subtle point, and they can watch such lectures anytime and anywhere they need to).

However, there are many reasons why interactive lectures—lectures that are influenced, moment by moment, by the students—are likely to continue to be useful. If students feel that the instructor is paying attention to them, interactive lectures can help motivate them and make them think about what is being discussed. Faculty can adjust content "on the fly" in response to students and to recent changes in the discipline. Good lectures are the educational equivalent of good performance art, and some faculty are artists in this medium. Unfortunately, however, that's not true of all faculty all the time, so rethinking the balance of broadcast and engaged interaction can significantly leverage those face-to-face lectures with technology that augments collaboration.

Shifting some or most one-way presentations from face-to-face to homework (that process began years ago with textbooks and readings) frees time for more interactive formats, when students can schedule times to interact with faculty and other students. Asynchronous interaction and project work can be done when students are outside classrooms too. The challenge, as all faculty know, is how to be sure that students come to class prepared. Fortunately, technology can help.

To help students come to the classroom with a reasonable understanding based on the presentations they've studied online, on their homework, and on online discussions, faculty need to provide:

- engaging instructional materials,
- online feedback that can help students get past common stumbling blocks,
- online feedback that can help students understand whether they are ready for class, and
- online feedback that can help the instructor understand the students' state of preparedness as they arrive in class.[12]

Once students arrive in the classroom, the faculty member can help students deal with difficult ideas and nuances and then can prepare and motivate students for the next round of work away from the classroom. What kind of classroom space is most effective and efficient for this? Ideally, such learning spaces should support several key activities:

- Students need to be able to hear what the faculty member and other students say and see what other people show, even if objects are small and many students are in the course.
- Students need to be able to replay this material, perhaps instantly.
- Students need to be able to try something someone suggests, then and there.
- Students need to be able to work for short times in small groups, observing and critiquing one another's work.
- Students need to be able to respond to questions, from their peers as well as from the instructor.
- The lecturer needs to be able to display student response patterns and use them to provoke further discussion.

Large lecture halls that are technology-enabled constitute one way to meet many of these goals and constraints simultaneously. But such rooms can be a trap: they can be inflexible and expensive to re-equip as new technologies appear and then disappear, and the productivity of the investment in the spaces shrinks every moment they're left empty, day and night.

In the next few years, a better solution may be a distributed classroom. Students could meet in face-to-face groups in relatively small rooms that are, in turn, networked through high-bandwidth interconnections with the instructor. Researchers at Fraunhofer IPSI's AMBIENTE division call such spaces "cooperative buildings."[13] These meeting rooms might be dozens of feet apart or thousands of miles apart. The meeting rooms might also serve other functions—such as conference rooms, library rooms, or offices. These environments combine real-world objects with virtual elements to create a whole greater than the sum of its parts. Students in each room would interact with each other and the instructor

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through interactive walls. They could share objects on interactive tables, or if a full room of technological affordances isn't available, they could simply sit in a communication chair to participate individually with the virtual class groups. The interactive wall is gesture-based, so that students can move information around the wall or throw and shuffle objects to the other locations with accompanying audio cues.

How would such large, distributed courses be organized? Large classes and their constellations of meeting rooms might be supported by a single large institution, a state system of institutions, or a coalition of institutions and employers (offering situated learning for interns as well as regular employees). We predict that the pioneers of such distributed courses will be (1) large, research-intensive institutions that want to make better use of highly interactive, well-known faculty and (2) coalitions of smaller institutions that want to offer a dramatic array of courses and lecturers to their students.

Smaller institutions often have a few students who want a certain upper-division course—but too few to support a face-to-face course. A coalition of such institutions would have plenty of students to support a whole constellation of such courses, some taught by faculty at each institition. This would allow small, isolated institutions to offer some of the course and program variety that is now the sole province of larger institutions.

Distributed courses are being pilot-tested today. A technologically scaled-down version of this approach is being used in professional development. For example, an organization called Learning Times facilitates sessions using real-time tools for teachers across New York City. Groups of educational professionals at hundreds of sites log in concurrently. They hear from and interact with a remote expert/facilitator but then return intermittently to discuss the topic face to face with people in their own group (or in online breakout rooms). This contextualizes the topic to the local school site. Then the expert returns a few minutes later to debrief, synthesize, and hear from some of the sites.[14]

Although technologies involved in

current "light" pilots are not terribly expensive, they are not yet scalable for large-scale implementation. Such larger-scale use may not be far away, however.

Making Technology Disappear

Future classrooms will have the remarkable quality of being both technologically sophisticated and technologically invisible. The best of future classroom technologies will simply become part of the fabric of an effective classroom environment, unremarkably essential.

Classroom technologies will need to interoperate in ways that currently exist only in research labs. Devices will need to link together through shared event systems. Examples are the EventHeap underlying the Stanford University iRoom software (http://iwork.stanford.edu/), and its recent commercialized offspring from Tidebreak (http://www.tidebreak.com). In operation as a research environment for over four years, the iRoom components include touch-screen displays, interactive murals, haptic input devices, scanners, and cameras.

Equally important, these new classroom technologies will need to be perceived as natural extensions of current classrooms, enabling natural interactions. A current design goal among these futuristic communications environments is that they be easy to use. For example, IBM has a large interactive display, the IBM BlueBoard, to support content sharing among BlueBoard users and easy access to each user's network information. Using RFID tags, a person quickly logs into the board and communicates with other online BlueBoard users or gets personal information tailored to the individual user's preferred interaction profile. Shared large-scale display interfaces support particular kinds of collaborations, with domain context that is natural for each work type. This is the marriage of large interactive displays with domain-based content recognition.[15]

When these technologies were deployed, a critical finding is that their use is related to their context. When tools like these were put in hallways to support spontaneous, ephemeral information exchange, they were ignored. People wouldn't use them because they were too invasive. Only when the tools were moved to more situationally appropriate spaces—designated group meeting rooms, for example—did experimentation and ad hoc use begin.

Research in collaborative computing environments has led to general design guidelines that apply directly to future classrooms.[16] The variety of different, individually task-specific digital devices will continue to increase, making interoperability of heterogeneous tools essential. Despite different software versions, brands, and input and output devices, they will all have to work together. The current stovepipes of interoperability by manufacturer or brand must be overcome. Standards movements are gaining momentum but have a long way to go and need both corporate and community support. The devices must work in spite of transient network outages and changing system components, without full-time tending by an army of trained technologists. Robust design must recover from failures and prevent outages. Easy-to-use interfaces make the use of technologically sophisticated collaboration tools cognitively less demanding. Learning how to use the system from the experiences of others is critical for these new classroom technologies to be adopted by a community.

Creating Pioneering Learning Spaces

The previous articles in this issue address the design of the learning space (Johnson and Lomas) and the creation of the learning space (Wedge and Kearns). They present compelling issues and strategies for assessing and making the complex tradeoffs that are required to go from learning theory to design principles to design process and finally to the physical construction that realizes the intentions of a classroom or building design plan. Rather than duplicate their discussions, we offer here three areas for the design planning team to keep in mind when inventing pioneering learning spaces: (1) activities and facilities; (2) forms and functions; and (3) desired characteristics.

Activities and Facilities

In order to invent new kinds of learning spaces, members of the planning team

The iRoom components include touch-screen displays, interactive murals, haptic input devices, scanners, and cameras.

need to be able to envision activities and facilities in a sufficiently vivid way (through visits, videos, descriptions, supporting research).[17] Such activities and facilities need to be described at two levels: (1) "elemental activities," that is, the actions that people take from moment to moment (e.g., speaking and being heard); and (2) "programmatic activities," that is, programs of activity (e.g., an engineering student needs to repeatedly brainstorm, do engineering design, build what has been designed, and test what has been built).

In a survey, focus group, or interview,[18] faculty and students should be asked about the relative importance of each of the following capabilities of the new learning space. How important is it that the new space

- enable the use of basic computing/connectivity,
- enable the learner or the teacher to discover, import, and display information easily, including the ability for a student in a large class to point within an image, or images, while explaining, "comparing and contrasting," or asking a question,
- enable participants to hear and speak,
- enable participants to see one another's faces,
- enable faculty members to spot patterns in students' thinking in order to adjust instruction,
- enable participants to review previous classroom communication,
- enable students to talk with one another during class sessions,
- enable a shift from a plenary format to small-group work, and back,
- enable the use of outside experts,
- enable students to use one another as learning resources,
- enable faculty and students to use the classroom easily,
- enable participants to interact spontaneously, other than through course activity, and
- enable participants to store bulky materials during, and between, course meetings?

Complementing this set of prioritized elemental activities are programmatic priorities. As noted earlier, the redesign of the "Aero-Astro" building at MIT is an example of faculty organizing their thinking about space around a rigorous inquiry into the nature of engineering activity.

But what if the institution wants flexible facilities that serve a wide range of fields? What starting place might facilitate that discussion of pioneering physical and virtual learning spaces? A good beginning can be found in the framework for accountability developed by the Association of American Colleges and Universities, describing the five defining outcomes of a liberal education:

1. Strong analytical, communication, quantitative, and information skills—achieved and demonstrated through learning in a range of fields, settings, and media and through advanced studies in one or more areas of concentration
2. Deep understanding and hands-on experience with the inquiry practices of disciplines that explore the natural, social, and cultural realms—achieved and demonstrated through studies that build conceptual knowledge by engaging learners in concepts and modes of inquiry that are basic to the natural sciences, social sciences, humanities, and arts

3. A proactive sense of responsibility for individual, civic, and social choices—achieved and demonstrated through forms of learning that connect knowledge, skills, values, and public action and through reflection on students' own roles and responsibilities in social and civic contexts
4. Intercultural knowledge and collaborative problem-solving skills—achieved and demonstrated in a variety of collaborative contexts (classroom, community-based, international, and online) that prepare students both for democratic citizenship and for work
5. Habits of mind that foster integrative thinking and the ability to transfer skills and knowledge from one setting to another—achieved and demonstrated through advanced research and/or creative projects in which students take the primary responsibility for framing questions, carrying out an analysis, and producing work of substantial complexity and quality[19]

These defining outcomes are about what graduates can *do*, not just about what they know. To achieve these outcomes by the time they graduate, students need to have spent a good deal of their time communicating, calculating, inquiring, taking action in the wider world (e.g., service learning), exploring other cultures (sometimes by actually going to other places while staying in touch with their institution and faculty), working in teams with people from other cultures, and pulling together the strands of what they have learned in order to tackle authentic problems in their fields.

If institutions are to achieve demonstrable gains in these five outcomes, students and faculty will need their facilities to support several fundamental activities that will occupy much of their time:

- They need space in which to practice such activities, alone and in teams.
- They need space in which to receive coaching and assessment.
- They need space in which to acquire knowledge—explanations gained through some mix of reading, listening, and watching.

To this point, we have analyzed the need for learning spaces in terms of elemental and programmatic activities. Several other goals and constraints also should be considered in the exploration of new learning spaces. For example, classrooms ought to be at least *attractive* enough to make being in them pleasant and rewarding. They may not be Starbucks, but they shouldn't be penal cells either. Better yet, can classrooms create a sense of drama as students enter them, meeting after meeting? What characteristics of a space could create such excitement and anticipation?

Another goal for facilities is *connectedness*—that is, a sense of connection to the culture and past of the institution and to the professions or disciplines under study. Traditionally, this has been achieved through posters under glass, or paintings of professors, or photos of past students, or display cases with "do not touch" student projects. How can classrooms of the future create a better sense of connection and belonging?

The process of adding value to spaces to enhance both their attractiveness and their connectedness is influenced by the current state of technology, in the absolute sense and also in how the current state-of-the-art is realized on a given campus. At the present time (mid-2005), we find one way to increase attractiveness and connectedness is the use of large-format digital displays. In the future classroom, displays should be large enough in context to allow the student to "enter" another place—for example, a video of a past student talking about a project, a video wall connecting two distant classrooms, a video of an experiment that will be performed later in class, or a display of artifacts that the student can manipulate and explore.

Families of Forms and Functions

It doesn't make sense to expect every space at an institution to support all the kinds of activities and functions described above. Instead, for both educational and technological reasons, it may make sense to optimize some facilities for certain functions. Instead of meeting in

A building designed today will change electrical systems once, furniture at least twice, and software systems fifteen times or more.

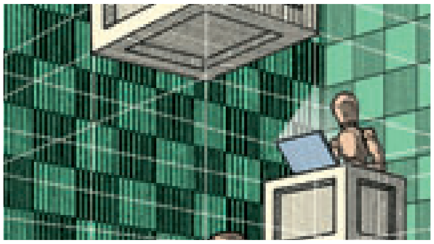
the same classroom every time, classes might move from room to room during the term, depending on what students (as a whole class, in small groups, or working alone) need to do.

A typology for such specialized learning spaces might include the following:

1. Thinking/conceiving spaces (spaces for deliberating)
2. Designing spaces (spaces for putting structure, order, and context to free-ranging ideas)
3. Presenting spaces (spaces for showing things to a group)
4. Collaborating spaces (spaces for enabling team activities)
5. Debating or negotiating spaces (spaces for facilitating negotiations)
6. Documenting spaces (spaces for describing and informing specific activities, objects, or other actions)
7. Implementing/associating spaces (spaces for bringing together related things needed to accomplish a task or goal)
8. Practicing spaces (spaces for investigating specific disciplines)
9. Sensing spaces (spaces for pervasively monitoring a location)
10. Operating spaces (spaces for controlling systems, tools, and complex environments)

Any learning space can be used to support almost any elemental activity, if people are willing to make enough compromises. For example, a seminar room with a small roundtable can be used by a lecturer who speaks without interruption to twenty-five students crammed into the room. But each type of activity can be supported more readily by some learning spaces than by others. Identifying cohesive patterns of use and themes in which the elemental activities tend to be more common will provide some structure to an otherwise chaotic stew of technologies.

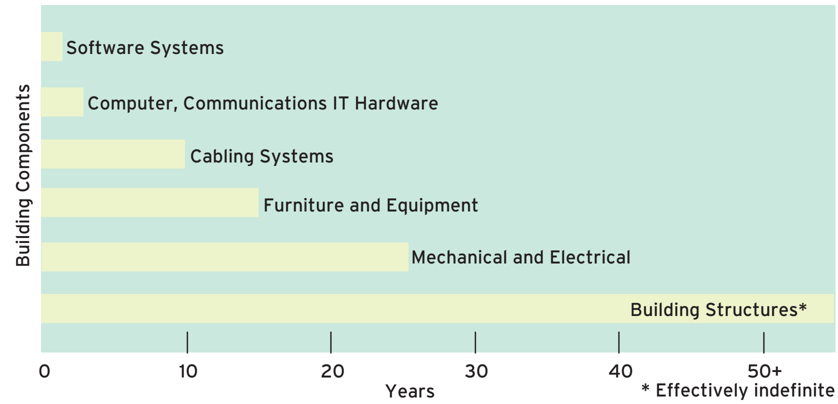
Colleges and universities likewise sit



in a broader social context, situated in communities that demand their services and attention. Internal versus external pressures may pit the needs and requirements of disciplinary programs against the interests and expectations of the town or city in which the institution resides. These demands translate into classroom requirements that extend beyond the requirements of the academy.

And the conflicts facing the classroom designer don't stop there. Another problem is that the life-span of various classroom elements age at different rates. Figure 3 juxtaposes a range of building components by their relative useful life expectancy. The variation extends by a factor of 30, from software systems (expected to last approximately one to three years) through furniture (estimated to last approximately fifteen years) to mechanical and electrical systems (twenty-five years) and finally to the building infrastructure itself (persisting at least fifty years and, more likely, double that or more). To put it another way, a building designed today will change electrical systems once, furniture at least twice, and software systems fifteen times or more. So what should the building look like when it's new?

Figure 3: Lifetime of Building Components



Source: S. Kelsey, Anshen+Allen, LA, Architects.

For these and other reasons, flexibility is crucial in today's design. Enrollments in particular subjects may increase or decline. New fields may appear. New modes of instruction may become popular. Designers need to walk a tightrope between facilities that are able to support qualitative improvements in teaching and learning activities and facilities that are also flexible enough to be adapted to changing needs and circumstances.

Characteristics of Future Classrooms
A well-designed classroom of the future will have the following characteristics:

- *The classroom is designed for people, not for ephemeral technologies.* This is a common perspective among today's architects, but it was lost for many years as technology requirements dominated the infrastructure. With miniaturization, the design of spaces can refocus on making the people—not the machines—comfortable.
- *The classroom is optimized for certain learning activities; it is not just stuffed with technology.* Classrooms, laboratories, or seminar rooms make it easier to do certain things. We intuitively recognize this, but there is less understanding about what learning activities students need to engage in, master, or at least be exposed to in order to become effective practitioners of their discipline.
- *The classroom enables technologies to be brought to the space, rather than having technologies built into the space.* Student-owned devices need to be enabled to support students' academic work.
- *The classroom allows invisible technology and flexible use.* The increasing computational power has diminished the need to centrally provision this resource; hence, computer cycles are no longer a constrained resource. Room availability, however, is. Classrooms were built to support industrial models of teaching, making them unusable for other human pursuits. The classroom of the future will be optimized for sets of functions and will be flexible for changing requirements.
- *The classroom emphasizes soft spaces.* The industrial teaching model has led to over-illumination, hard hallways, fixed-seat classrooms, and hard surfaces. The rooms are not comfortable. To paraphrase W. C. Fields, they're hardly fit for man or beast.
- *The classroom is useful across the twenty-four-hour day.* Students work during all hours of the day. This is not just because some students have jobs and other nonacademic commitments; engaged students will approach their work independent of the clock. Future classrooms should support students when they are able and ready to do the work.
- *The classroom is "zoned" for sound and activity.* Basic guidelines for multiple-use spaces recognize that different types of work have different implications for group spaces. Future classrooms pay attention to these differences, making variegated use more effective.

These characteristics of future classrooms embody principles that can be used to periodically review the state of the campus and to determine priorities for incremental renovations and larger-scale projects. This kind of formative evaluation and planning was suggested decades ago, in the mid-1970s, by Christopher Alexander. He suggested that such a periodic review, using principles developed and approved by the community, could enable organic growth and the emergence of an institution that could support learning in a better and more coherent way each year.[20]

Conclusion

Our ability to imagine the classroom of the future is shaped by changes in our own beliefs about learning spaces:

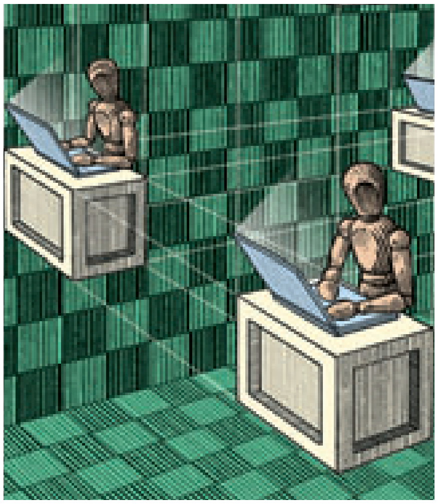
- *From* focusing on formal education, *to* emphasizing learning in both formal and nonformal settings
- *From* seeing college-level learning as being primarily about listening, reading, and taking notes, *to* seeing learning as being about situated action, collaboration, coaching, and reflection
- *From* assuming that academic work and rewards are neatly divided into compartments of research, academics, and community engagement, *to* assuming that learning spaces need to support a mix of all three of these functions
- *From* seeing faculty and students as the recipients of new learning spaces designed by specialists,

The classroom of the future will be optimized for sets of functions and will be flexible for changing requirements.

to using their dreams of better teaching and learning to shape pioneering new learning spaces

- *From* seeing the design and construction of a building or other learning space as a fixed goal, unchanging after completion,
  to envisioning a building as the beginning of an evolutionary process in a state of permanent flux and informed iterative change

The movie *Groundhog Day* tells the story of a man who gradually perfects his life when he is forced to live the same day over and over, moving from the surface features down to the fundamental issues of character. We live in a fast-changing world, as different from the world of *Groundhog Day* as one can imagine. And yet, for that reason, the kind of reflection that the movie depicts is even more important as we daily plan, create, and use learning spaces. What is sometimes called the "scholarship of teaching"—the widespread involvement by faculty and students in a process of inquiry—is an essential part of designing and using pioneering learning spaces. The college or university faculty, staff, and students should periodically ask three questions about learning spaces:



1. What are we as a course and as a community doing with the spaces we currently have?
2. How can we use these current spaces more completely and effectively to teach in the most ideal ways imaginable?
3. How can we improve our learning spaces so that we can organize our teaching and learning in even better ways?

As we iteratively approach the classroom of the future, our understanding of both learning and technology will improve. The goal is not to leverage technology to make the future classroom approach an ideal learning environment. The goal is to reach beyond that ideal. *e*

Notes

1. See Roger C. Schank, *Virtual Learning: A Revolutionary Approach to Building a Highly Skilled Workforce* (New York: McGraw-Hill, 1997), and Nancy Van Note Chism and Deborah J. Bickford, eds., "The Importance of Physical Space in Creating Supporting Learning Environments," *New Directions for Teaching and Learning*, vol. 92 (winter 2002): 1.
2. The video series *Minds of Our Own* (1997) shows interviewers questioning seniors on graduation day. Many graduates were unable to apply basic ideas they had "learned" in courses in which they had received As, in high school and probably again in college. *Minds of Our Own*—three one-hour programs on constructivism—was produced by the Harvard-Smithsonian Center for Astrophysics and is available from Annenberg/CPB (see <http://www.learner.org/resources/series26.html>).
3. John D. Bransford, Ann L. Brown, and Rodney R. Cocking, eds., *How People Learn: Brain, Mind, Experience and School*, Committee on Developments in the Science of Learning, National Research Council (Washington, D.C.: National Academy Press, 1999), executive summary.
4. Edgar Dale, *Audiovisual Methods in Teaching*, 3d ed. (New York: Dryden Press, 1969).
5. Bransford, Brown, and Cocking, *How People Learn*, 204.
6. For example, capstone courses like MIT's 2.007, Design and Manufacturing I (see http://pergatory.mit.edu/2.007/). The course has not only published its content on MIT OpenCourseWare (see <http://ocw.mit.edu>), but the learning tools themselves and assistance in implementing them are being disseminated by the MIT iCampus initiative, promoting faculty-to-faculty engagement to implement educational technologies in teaching (see MIT iCampus, <http://icampus.mit.edu>).
7. Arthur W. Chickering and Zelda F. Gamson, "Seven Principles for Good Practice in Undergraduate Education," *AAHE Bulletin*, vol. 39, no. 7 (1987). For more on the seven principles and their relevance to teaching with technology, see the following TLT Group Web site: <http://www.tltgroup.org/seven/home.htm>.
8. For background on the Conceive-Design-Implement-Operate curriculum, see "What Is CDIO?," <http://web.mit.edu/aeroastro/www/cdio/overview.html>, and "Welcome to the CDIO™ Initiative," <http://www.cdio.org/index.html>.
9. See Neil Gershenfeld, Raffi Krikorian, and Danny Cohen, "The Internet of Things," *Scientific American*, October 2004.
10. Project Kaleidoscope (http://www.pkal.org) has assembled valuable resources and programs about the design of spaces that facilitate, nurture, and strengthen learning in the fields of science, technology, engineering, and mathematics. For links to the intersection between learning and physical space design, see <http://www.pkal.org/template0.cfm?c_id=3>.
11. Richard E. Clark, "Reconsidering Research on Learning from Media," *Review of Educational Research*, vol. 53, no. 4 (1983); Richard E. Clark, "Confounding in Educational Computing Research," *Journal of Educational Computing Research*, vol. 1, no. 2 (1985).
12. For a good book on this pair of feedback functions, see Gregor M. Novak et al., *Just-in-Time Teaching: Blending Active Learning with Web Technology* (Upper Saddle River, N.J.: Prentice Hall, 1999).
13. N. A. Streitz, J. Geißler, and T. Holmer, "Roomware for Cooperative Buildings: Integrated Design of Architectural Spaces and Information Spaces," in *Cooperative Buildings: Integrating Information, Organization, and Architecture*, Proceedings of CoBuild '98, Darmstadt, Germany (Heidelberg, Germany: Springer, 1998).
14. Personal communication from Jonathan Finkelstein, LearningTimes, May 12, 2005.
15. Aaron Adler, Jacob Eisenstein, Michael Oltmans, Lisa Guttentag, and Randall Davis, "Building the Design Studio of the Future," in *Making Pen-Based Interaction Intelligent and Natural*, Papers from the AAAI Fall Symposium, Arlington, Virginia, October 21–24, 2004, <http://rationale.csail.mit.edu/publications/Adler2004Building.pdf>.
16. Daniel M. Russell, Norbert A. Streitz, and Terry Winograd, "Building Disappearing Computers," *Communications of the ACM*, vol. 48, no. 3 (2005).
17. For one such framework, see The TLT Group's resource pages on learning facilities, especially the materials linked to this taxonomy of learning activities: <http://www.tltgroup.org/programs/Teach/Smart_Classrooms.htm>.
18. The TLT Group is developing such surveys for subscribing institutions. For information, contact Stephen C. Ehrmann at <ehrmann@tltgroup.org>.
19. Association of American Colleges and Universities, *Our Students' Best Work: A Framework for Accountability Worthy of Our Mission* (Washington, D.C.: AAC&U, 2004), <http://www.aacu.org/publications/pdfs/StudentsBestReport.pdf>.
20. Christopher Alexander et al., *The Oregon Experiment* (New York: Oxford University Press, 1975).

What is sometimes called the "scholarship of teaching" is an essential part of designing and using pioneering learning spaces.