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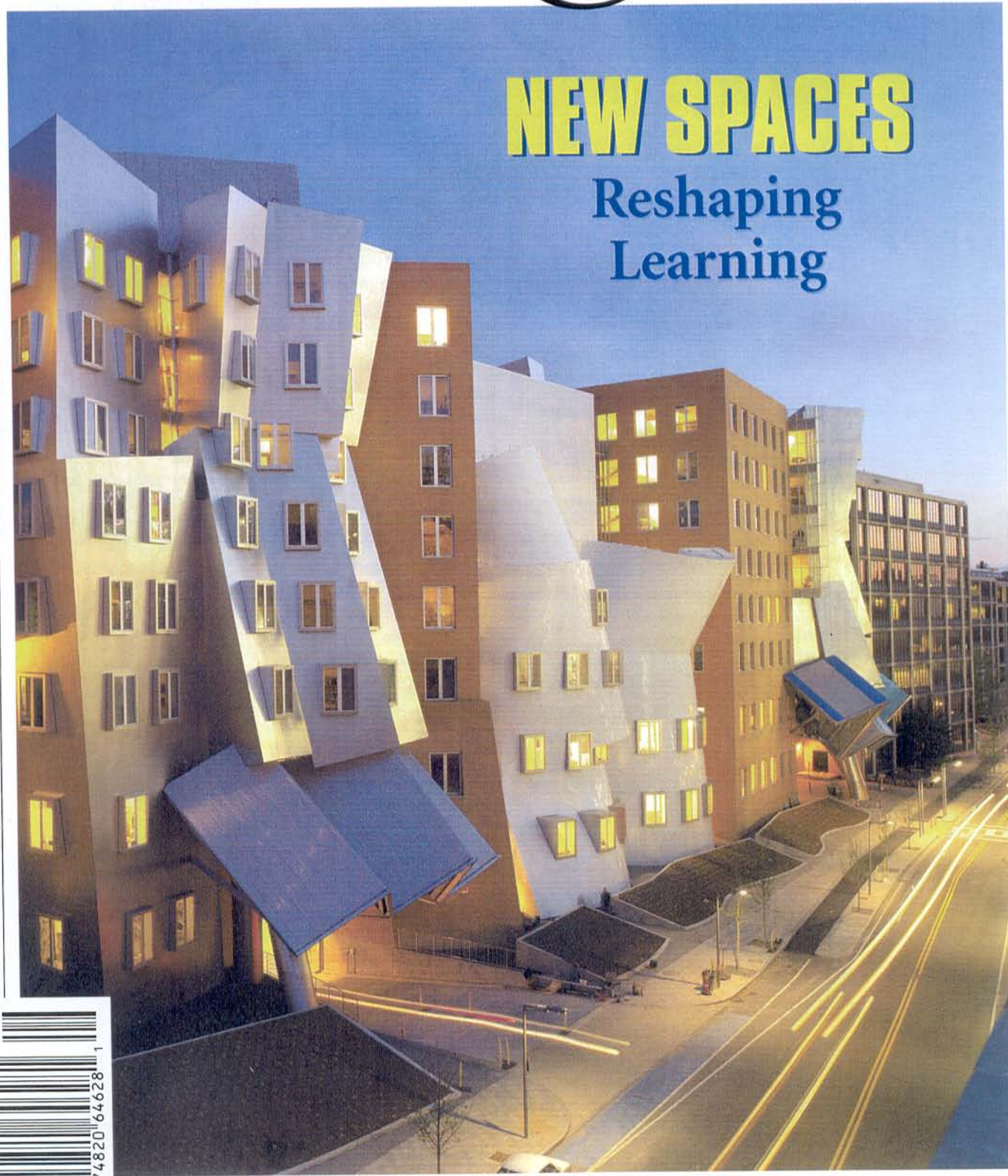
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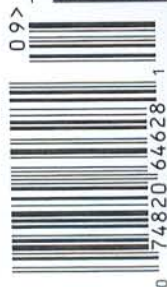
SEPTEMBER/OCTOBER 2004

NEW SPACES

Reshaping
Learning



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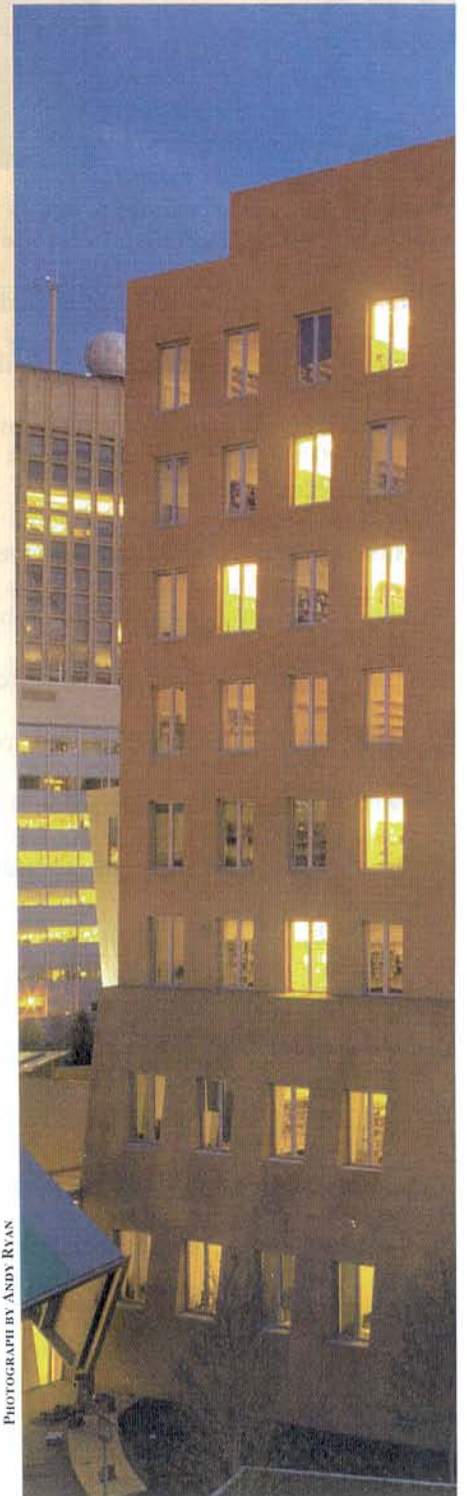


Science SPACES for Student 21st Century

BY JEANNE L. NARUM

Creative collaborations between campus leaders and architects, laboratory designers, and campus planners are resulting in a generation of spaces for undergraduate science that contribute both to the long-term excellence of the research and instructional program and to the humanity of the campus. These spaces are enhancing efforts to attract strong students and recruit and keep first-rate faculty. They enable the integration of research and education for all students, the hallmark of strong 21st-century undergraduate science, technology, engineering, and mathematics (STEM) programs.

Jeanne L. Narum is director of the Independent Colleges Office and founding director of Project Kaleidoscope (PKAL), an informal national alliance of educators, administrators, and other interested parties working to strengthen undergraduate programs in mathematics, engineering, and the various fields of science. Author retains the copyright.



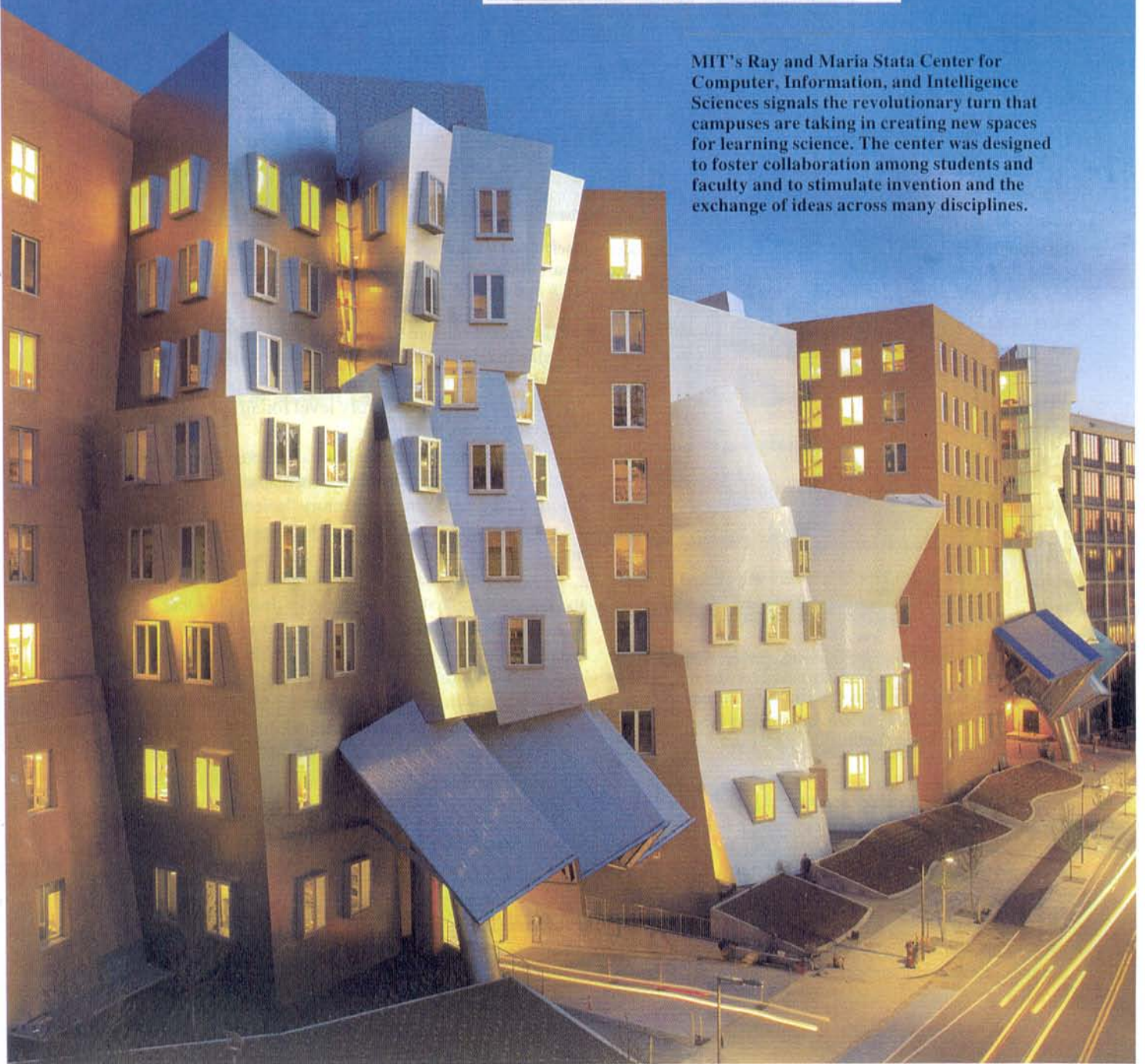
PHOTOGRAPH BY ANDY RYAN

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Cutting-edge teaching studios, such as MIT's high-tech distance learning classroom (top), enable students to connect with learning opportunities on campus and beyond.



MIT's Ray and Maria Stata Center for Computer, Information, and Intelligence Sciences signals the revolutionary turn that campuses are taking in creating new spaces for learning science. The center was designed to foster collaboration among students and faculty and to stimulate invention and the exchange of ideas across many disciplines.





Encircled by the glass masonry tower, student lounge areas (above) encourage a sense of community.



The University of Charleston's Clay Tower (above), which was designed to become a recognizable symbol for the university, contains a new library, as well as undergraduate science laboratories, electronic classrooms, distance learning/lecture spaces, and similar facilities.

But the impact of these spaces goes beyond that. Those experienced with planning new spaces often cite the words of Winston Churchill, "We shape our buildings and then they shape us." These buildings are changing the way students learn science and thus how science will be practiced in the 21st century. They are bringing new generations of students into the communities of science and preparing them for careers and for productive citizenship in a society in which science and technology have increasing influence.

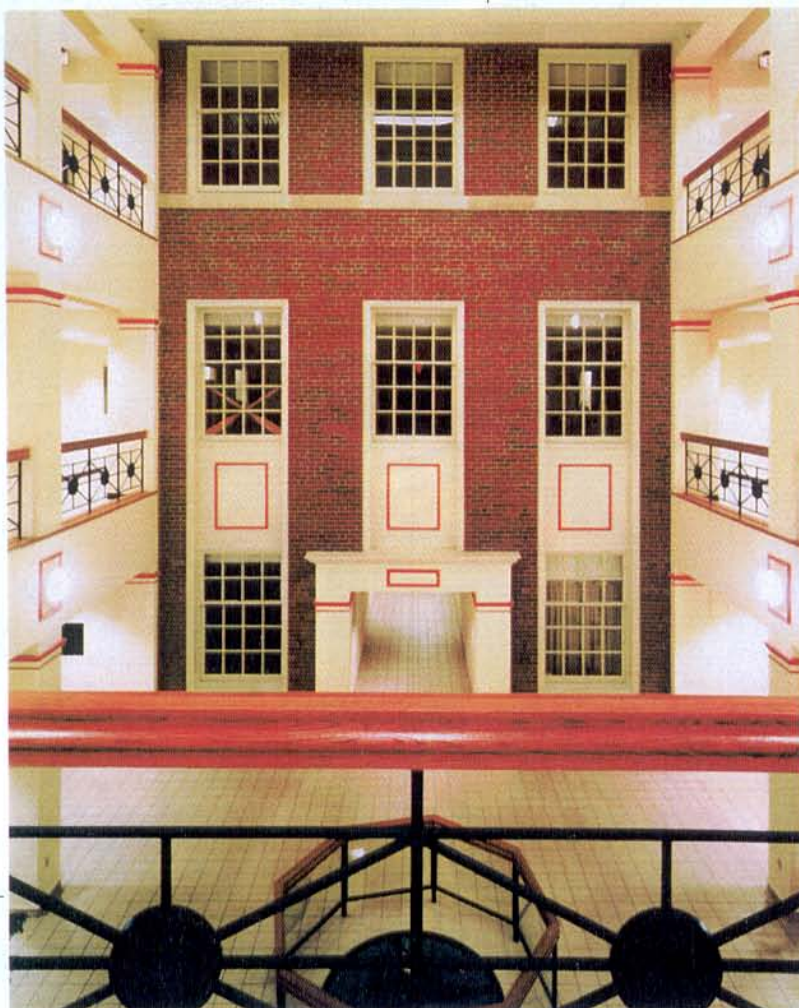
These new science spaces signal the critical role that facilities play in the education of 21st-century students, providing ongoing opportunities for "hands-on," laboratory-intensive science, from the introductory level for all students through capstone courses for majors.

Science is not a spectator sport. Someone once said science should have been a verb rather than a noun. These are spaces uniquely designed for 21st-century "sciencing," as they:

- support learning that is inquiry-based and makes connections;
- enable the 24/7 problem-posing and solving, exploring and discovering that is at the heart of doing science;
- recognize the increasingly social character of scientific research, teaching, and learning by facilitating interactions between and among students and faculty;
- reflect and foster the blurring of disciplinary boundaries that is a feature of contemporary science; and
- acknowledge the role of serendipity and story-telling in doing science—providing space for exploiting the unplanned and teachable moment, for sharing what is becoming known.

SOME HISTORY

Those who are shaping new spaces for undergraduate science can and are articulating clear visions of teaching, learning, and research for the future and translating those visions into physical spaces. This is one of the more remarkable stories from the past decade in American higher education, but how did this happen?



Susquehanna University's Fisher Science Hall houses teaching laboratories for biology, biochemistry, chemistry, geology, physics, psychology, and faculty research. PKAL's Volume III: Structures for Science Handbook features the new building as a model of how to plan an economical science facility.

Perhaps, as with all planning, timing is everything.

In the late 1980s, Sputnik-era science buildings were wearing out, at the end of the normal lifespan for buildings with systems as complicated as those needed for science. Failing temperature-control systems, corroded plumbing fixtures and gas lines, and inoperable fume hoods were just a few of the structural defects that surfaced routinely. Having to position umbrellas to shield teaching microscopes from leaky roofs was frustrating to faculty who knew all too well how deteriorating facilities were affecting the quality of their programs.

Equally frustrating to faculty were the unfortunate circumstances of having to deny a student an opportunity to serve as a research colleague because of lack of space and having to experiment with investigative pedagogies in spaces designed for the "sage on the stage."

This was, serendipitously, a teachable moment. These facilities were wearing out just when there was developing awareness of the kinds of learning experiences that attract students into STEM fields, keep them there, and motivate them

to consider a career in those disciplines. At this time, many were championing programs such as those documented in a study undertaken by Oberlin College in 1986, which stressed the value of undergraduate research as a robust learning experience. An emerging generation of pedagogical pioneers was suggesting new approaches to designing classes and courses, thus beginning to inspire colleagues at other institutions to examine their own practices in classroom and lab.

Much of this pioneering work was sparked and facilitated by a recognition of the potential of emerging technologies to transform interactions between people and information. These early reformers were also at the cutting edge in exploring how to turn insights about the ways people learn into learning experiences for their students, insights that revealed further deficiencies of Sputnik-era spaces. But mostly, the reformers were faculty passionate about doing science who wanted their students to have the same passion.

The key point of this chronicle is that the transformation of both facilities and programs could and did happen at the same time. Without such a timely convergence of needs and oppor-



The University of Iowa's Seamans Center, with its dramatic atrium, brings much-needed cohesion to a fragmented existing facility that had lacked social and study areas. The new building contains research and teaching laboratories, state-of-the-art computer classrooms, a student-learning center, and a commons area.

tunities, the story of 21st century spaces for undergraduate science might be different. The highly interactive, research-rich, community-based learning that was being recognized as *what works* places special demands on the physical infrastructure—demands that could not be met in existing spaces.

But it was not concern about the quality of the learning environment that sparked the facilities revolution that has taken place over the past decade. What really fueled it was the worry of major research universities that their buildings for science and technology research, again mostly Sputnik-era, were deteriorating in the same manner as were spaces dedicated primarily to teaching in those fields. The problem was discussed with some urgency in offices on campuses, within national educational and scientific associations, and in the hallways of the

U.S. House of Representatives and U.S. Senate. These discussions led to the 1989 Academic Research Facilities Modernization Act.

Without such renewed federal attention to the relationship between the quality of facilities and the quality of the nation's scientific and technological enterprise at that time, today's story might be different. The 1989 Act provided both funds (limited to be sure) and a rationale for transforming the physical infrastructure of the nation's scientific and technological enterprise.

Equally important, it required applicants for federal funding to make the case for their project in the larger context of national need and of local potential to build and sustain high-quality programs. By requiring such "planning in context,"



Seamans Center classrooms, such as this College of Engineering lecture hall, have increased access to modern electronic learning facilities. This enables closer linkages between the programs within the Colleges of Engineering, Medicine, Liberal Arts, and Business, as well as with other universities.



Augustana College's four-story science facility is built around a central atrium stairway with convenient commons areas for students and faculty. The building includes various-sized "smart" classrooms, lecture halls, laboratory discussion rooms for physics and chemistry, and research laboratories.

this federal initiative challenged institutions considering new spaces for science, technology, engineering, and mathematics to think about more than making current spaces safe.

Those supporting the Act also challenged federal staff. Sketchy notes from one House hearing considering the bill reveals a direct charge from an unnamed academic leader:

When you focus on infrastructure support for training the next generation of the national workforce, your goals should be to support facilities modernization that helps institutions create and sustain the kind of teaching and learning that is student-centered, experiential and hands-on [and that] helps them in building and maintaining spaces that work for programs that NSF, NIH, and other federal



Wheeling Jesuit University's Donahue Hall (below) was a mid-1950s modern box that now has an updated exterior, new science and computer labs, academic classrooms, and lecture rooms. The new structure includes an addition that accommodates animal facilities for the Psychology Department and a greenhouse for the Biology Department.



Santa Monica College's new multi-disciplinary science center (above) includes a three-story laboratory building and a two-story classroom/faculty office building separated by a linear courtyard. A computer learning center and two large lecture halls are housed in the buildings. Life Sciences and Physical Sciences labs include video projectors for audio-visual teaching and integrated computer use.



and private agencies are now implementing, projects focused on:

- improving introductory courses;
- improving laboratories for majors;
- providing opportunities for students to do independent study—to do science as scientists do science;
- providing opportunities for faculty to work in interdisciplinary research teams;
- strengthening preparation of K-12 teachers;
- integrating scientific literacy into the undergraduate curriculum;
- providing opportunities for faculty to remain current in their disciplines;
- utilizing the capacity of technology to build connections within and between campuses;
- getting all students—men and women, from different ethnic backgrounds, and with different career aspirations and levels of preparation—captured by the excitement of doing science, by the wonder of the natural world as revealed by that study.



The new structure's design literally puts science on display by including a lab block that sits across the atrium. On each level of balconies, laboratories can be viewed easily through large windows.



The A.J. Palumbo Hall for Science and Technology at Carlow College is a three-story facility with an atrium/social space that is in between—and surrounded by—walking balconies.

This is, indeed, a brisk summary of goals for renewing undergraduate STEM programs. Then and now, these set the stage for facilities renewal.

PROJECT KALEIDOSCOPE

In 1989, the National Science Foundation (NSF) supported a taskforce to outline the future of science learning in the liberal arts college community—a brief effort that laid the foundation for the continuing national alliance that is Project Kaleidoscope (PKAL). Translating NSF's initial charge to develop a roadmap for the future into a "kaleidoscopic" perspective on the undergraduate environment, early PKAL leaders

gave immediate attention to the capacity of current spaces to accommodate the kind of learning they were advocating.

Subsequent grants from the NSF to PKAL supported activities relating to facilities planning, in addition to those addressing curricular issues. In the early 1990s, PKAL sponsored a series of workshops and seminars to assist institutions preparing to apply for support available through the 1989 Academic Research Facilities Modernization Act, as well as to help campuses around the country move into and through the long and complex process of planning facilities for undergraduate STEM learning communities. Since 1992, PKAL has sponsored 26 workshops and other seminars, roundtables and na-

tional conversations on planning facilities for undergraduate science. Close to 500 colleges and universities have participated in these events and are using PKAL print and electronic resources relevant to space planning. Over 60 architectural firms are contributing to the work of Project Kaleidoscope.

Through PKAL workshops, consultancies, publications, and other means, the expertise of design professionals and STEM leaders experienced with facilities planning is being translated into lessons for novice planners. The over-arching message is the need to focus on *community*. When a facility succeeds—as a space for learning, teaching, and research in the undergraduate context and as a work of art—it is because community has been the goal and informed the planning process.

COMMUNITY AS GOAL

Scientists at all levels certainly need their private sanctuaries—study carrels, offices, and labs. Yet they also need the space to communicate their ideas and to collaborate with colleagues. Community as goal means developing spaces where the campus community can come together to do science and celebrate it as a central liberal art.

A central commons that acts as the town square distinguishes many of these facilities. These commons offer a welcoming entryway into a learning environment that becomes a second home for many students and faculty, a place where they can find their mail, materials relating to departmental matters, support services, and so on.

Through the design of their traffic and circulation patterns, the commons highlight the social context of science and technology, drawing people in and encouraging dialogue outside the classroom. This in turn fosters collaboration within and

among the various STEM disciplines' students and faculty, as well as with stakeholders beyond the campus.

The openness and hospitality that is a visible characteristic of common spaces is found also in the classrooms, offices, and laboratories that are the parts of the whole. The best of these spaces are also an embodiment of institutional mission and values. While enhancing the aesthetic quality of the campus, they incorporate attention to sustainability over the long term, reflect careful stewardship of institutional resources, attend to ease of maintenance, and leave opportunities for future adaptations.

The new spaces developed over the past decade dismantle the silos that have traditionally characterized the world of academic science, some of them disciplinary divisions that have been reflected in the architecture. When departments were housed in separate buildings, or when facilities were designed with the traditional "layer cake" approach to departmental

ecology (chemistry on top; biology in the middle; geology and physics at or below grade level) without easy access to colleagues, there was little of the natural cross-disciplinary interaction that builds and sustains community.

These older buildings, embodiments of the disciplinary silos, also cast in concrete an educational approach that no longer works. Today the design of spaces reflects the reality, for example, that undergraduate life science majors need a strong foundation in the physical sciences and in mathematics and that environmental science students also must be grounded in the physical sciences and in mathematics if they are to be prepared to address real-world problems as professionals.

Today, even at the undergraduate level it is not uncommon to find teams of faculty and students working in areas such as analytical physical chemistry, geoscience, environmental science, population biology, and other areas addressing critical issues at the interfaces of scientific fields. These interdisciplinary teams place new demands on spaces, including laboratories that are flexible, with portable workstations and clusters of the highly sophisticated instrumentation and technologies that have become commonplace in the learning and practice of science.

In creating these new interdisciplinary spaces, another silo—that between research and teaching—has been breached. Spaces for lecture and labs are enclosed within the same four walls, allowing for the back and forth essential to the learning and doing of science today. They accommodate the serendipitous interactions that advance science and give students a sense that they are part of a larger, vibrant scientific community.

COMMUNITY AS PROCESS

Providing a research-rich, 21st-century learning environment for undergraduate STEM programs is costly in terms of both time and dollars. For most undergraduate colleges and universities, facilities to house 21st-century learning, teaching, and research in STEM fields are the most expensive spaces to be built for decades—past or present.

Because the financial stakes are so high, everyone's attention is captured, and leaders on campuses that have undertaken the task have been determined to get it right. They know their charge is to do more than fix leaky roofs or add square feet to accommodate more students. They must think seriously about what kind of research-rich learning environment they want and for which students; about how to accommodate emerging fields of science and increasingly sophisticated technologies; and about how spaces contribute to the life and community of the entire campus efficiently and cost-effectively, for generations to come.

Most often, this dreaming about the future is connected to the work of securing the financial support for the project, as potential supporters are more interested in investing in the fu-

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This 1950s science hall (left) at Chatham College was transformed in 1998 into a state-of-the-art learning facility equipped with the latest audio/visual technology. The original classroom's design, with a center aisle and raised platform for faculty, was reconfigured to reflect today's emphasis on creating teaching/learning spaces that are more intimate and that encourage collaboration (below).



ture than in remedying deficiencies of the present. But both dreaming and fund-raising take a long time. Undertaking a project as complex as planning, designing and constructing a new, state-of-the-art undergraduate science building is a momentous task. Community as process means persistently seeking out, taking advantage of, and building upon the knowledge and expertise, visions, and dreams of all stakeholders. And the iterative process of visiting and revisiting a "dream," articulating and testing it with a wide range of stakeholders, pays significant returns.

Indeed, one dean, after almost a decade of planning, said at the building dedication, "This project has been a defining moment in the life of our institution." This feeling arises because the campus community experienced the process of translating dreams into real programs and spaces, with linking their past and present to their future. New kinds of collaborative groups

(from within and beyond the sciences) have addressed hard questions and learned how to articulate and negotiate what matters to them, to welcome and respect a diversity of opinions, and to keep focused on the goal.

This learning was not automatic. There was a steep learning curve on many campuses, with faculty so frustrated with existing spaces they took pencil to paper to illustrate what might be—without regard to larger institutional issues, the changing context, or the need to answer fundamental questions. Such precipitous action led one chief academic officer to respond,



The chemistry research labs at Rowan University support shared faculty-student research activities at the undergraduate level. Student write-up areas (foreground) provide students with direct access to the labs as well as their own dedicated space in the building.

“You must be kidding—this is your plan for the future?” Another dean challenged chemists asking for renovation funds to tell him:

- In the context of the department’s role in the college, what are the aims, expressed as student outcomes or otherwise, that are the fundamental purposes of the department’s work?

- What is the theory underlying the department’s teaching? How do the concepts of a community of learners—about the personal, participatory nature of the learning experience and about the contextualization of science—resonate within your department?

- What are the methods to be used to implement the theory? For example, is there to be emphasis on faculty/student contact, a lab-rich environment, investigative or discovery labs, student groups, mentoring, etc.?

Sometimes, in order to answer such questions, faculty were given opportunities to play in a “sandbox.” Sandboxes

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allowed them to experiment, for example, with pedagogies and technologies that require different kinds of spaces or for building collaborating communities that cut across disciplines. Following his “you must be kidding” response, the dean gave his faculty a “sandbox,” the unused basement of the student center, where they experimented for two years with how to shape a learning environment (intellectual and physical) for their students. Without such first-hand experience, it is often difficult for faculty to understand the value of one pedagogy over another or the role that space plays in enhancing learning.

It is clear one of the most powerful stimuli of curricular and pedagogical change is planning and then completing the construction of new spaces and structures for undergraduate programs. The story of workshop physics at Dickinson College illustrates how the content and pedagogy of programs co-evolve with their space, particularly as the space comes to

embody insights about the way students learn the benefits of active, hands-on learning; the optimum number and configuration of students working in a collaborating team; the full integration of the computer as a learning tool; and so on.

But these building projects have an impact on students and student learning that goes beyond what happens in the new space when construction is completed and the move-in finished. One example: as part of the planning at St. Lawrence University, students were given disposable cameras and asked to document campus spaces that felt welcoming, that encouraged the fortuitous encounters that made them feel part of the scientific community. Students then prepared posters and defended their perceptions to campus leaders and architects. Inexpensive and unexpected “hang-out” spaces such as stairways won out over expensive, poorly used lounges.

Another example: Attention to environmental impact was threaded into the entire process and engaged the entire community at Middlebury College. During the demolition of the old facility, 97.4 percent of the building was recycled—from the concrete and glass to the metal and the wood. Students were involved in tracking the materials as they were recycled—where they went, their weight and the percentage of the total. Faculty report that it was important to have students involved in the analysis of the project, both as a learning experience and because the cost turned out to be only slightly more than if the building had been demolished and the remains trucked to already-burdened landfills in the region.

Such a learning experience is consistent in many ways with current findings from research on how people learn. By bringing real-world problems into the classroom and calling for students to collect, analyze, and share data that leads to the solution of those problems, learning becomes more clearly “owned” by the students.

WHAT'S NEXT

In the spring of 2003, PKAL convened a roundtable of an invited group of 12 academics and 12 design professionals at the Cranbrook Educational Institute in Michigan to consider the “ideal science facility of the future.” The normal multi-year planning effort was compressed, with an iterative process of big-picture dreaming and hands-on space designing filling a weekend.

Papers by participants set the stage for the roundtable. They addressed the changing nature of science (interdisciplinary, technologically intensive); the persisting need for community; the growing awareness of the relationship between what is learned, how it is learned, and where it is learned; and technical advances in the realm of design and construction.

They concluded that “in 10 years, learning will take place wherever the learner happens to be, mostly through technolog-

ical support, student-to-student collaborations, and contact with teachers and with practitioners in the field. As a result, teachers will have developed new pedagogical skills, enabling them to enhance their own approaches to lecture, demonstration, and experimentation.”

As a consequence, the participants speculated, the classroom may devolve into several new types:

- a social center where relationships with students and faculty are formed, where teams are created, and where results of learning are communicated;
- a “black box” lab/classroom for learning (data collection, analysis, experimentation, etc.), with a centralized, remote “sound booth” for technical support; and
- a faculty workshop/classroom in a media center

where faculty come to learn about and experiment with new pedagogies.

Participants in the PKAL Cranbrook Roundtable described these 21st-century facilities as weaving together issues of community, technology, sustainability, and science in new ways. They concluded that traditional distinctions and boundaries between scientific disciplines would continue to erode and evolve and that an even greater degree of collaboration between disciplines will require buildings to be flexible at a level we have not yet realized.

They envisioned the continued development of materials and construction technologies that will allow buildings to interact with nature in a manner that is more sensitive to ever-changing climatic and environmental conditions. The STEM building of the future, they believed, will not only prove more flexible and sustain-

able than those of the past but will ultimately serve as the physical representation of the scientific values of openness to new ideas and boundless discovery.

One architect even suggested that we are moving from Industrial-Age buildings, designed to be machine-like for strength and efficiency, to buildings designed to be more biological: more flexible and capable of productive interaction with the environment and of catalytic connections to their users. The spatial relationships between labs, seminar rooms, offices, and conference spaces will be designed to encourage many different modalities of instruction and interaction. Not just a series of rooms, the scientific space of the future they envisioned will be delightful to visit because it is generous in its public and social spaces, light and bright in its interior, and full of opportunities to see science on display and people in action. It will be a place in which students feel their options for learning are maximized and their individual potential respected and realized.

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A Workshop Physics project at Dickinson College is providing valuable insights about the space needed for hands-on learning, the optimum number and configuration of students working in teams, and the full integration of the computer as a learning tool.

The goal is to create space that can support both traditional and emerging programs. The Cranbrook Roundtable participants thought that the design of cluster spaces might become a driving operating principle—clusters that promote disciplinary affiliations where they occur naturally while maintaining the ability to organize space by disciplines where appropriate. Such clusters could accommodate any science by supporting a common array of mechanical-electrical services, including zones of greater and lesser mechanical services to accommodate particularly “system-intensive” equipment.

Their flexible layouts would contain all the spaces needed by the community—labs for teaching and research, faculty offices, and student academic and social spaces. They would serve a wide range of inter-and intra-discipline/program subject matters—for example programs for K-12 teachers; courses for non-majors, including those that link to ethics and policy; and efforts to build linkages between academe and industry and other scientific and technological institutions.

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CONCLUSION

Robert Campbell, writing in April 2004 for the *Boston Globe* about the Stata Center, the new Frank Gehry building at MIT, commented: “It’s a place for human habitation. As such, it’s been thought about with a lot of intelligence.” A lot of intelligence has also gone into the planning of new spaces for science on many campuses over the past decade; many lessons have been learned, and there are many models already emerging from which the next generation of buildings can be imagined and realized.

It is clear that the next generation of science buildings, those now on the drawing board and those still being imagined by campus leaders, will be quite different from those built in the past, even as recently as at the end of the 20th-century. By learning lessons from successful and unsuccessful projects from the past decade, these new structures for science will reflect more intentionally and publicly than traditional buildings have what “sciencing” really means. ☐