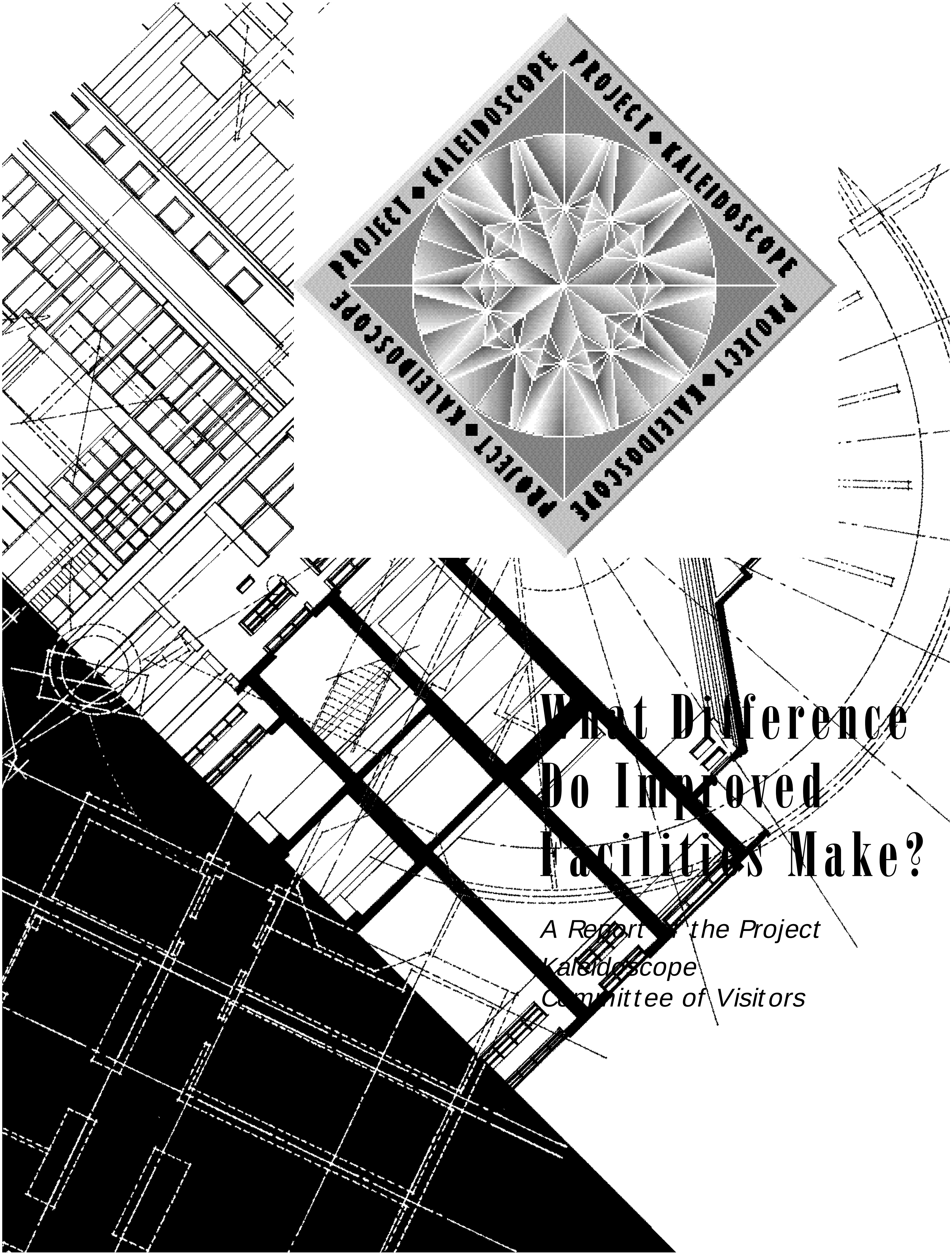

What Difference Do Improved Facilities Make?

A Report of the Project Kaleidoscope Committee of Visitors

Project Kaleidoscope (PKAL) is an informal alliance of individuals and institutions engaged in the work of transforming undergraduate programs in science, mathematics, engineering, and technology.

Since its beginning in 1989 with support from the National Science Foundation, the work of PKAL has been kaleidoscopic, giving attention to all aspects of the undergraduate SME&T environment—faculty, curriculum, facilities, as well as to larger institutional and national issues. From an initial base of primarily liberal arts colleges, colleagues and partners from other kinds of institutions—public and private, large and small—have joined in the work of getting science education right. Since Phase II began in 1992, nearly 3400 individuals from over 660 colleges and universities have participated in one or more PKAL activity. Phase III began in 1998.

Current support for Project Kaleidoscope comes from:

- **The Exxon Education Foundation—**
  For the PKAL Faculty for the 21st Century Program
- **The National Science Foundation—**
  Directorate for Education and Human Resources/Division of Undergraduate Education—
  For the Undergraduate Faculty Enhancement Workshops
  Office of Science and Technology Infrastructure—
  For the Facilities Committee of Visitors
  Directorate for Biological Sciences—
  For the PKAL F21 Leadership Institutes
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Undergraduate science facilities are expensive–to build, to maintain, to update, and to replace. For the number of students involved, the costs may appear disproportionate, particularly to faculty in other departments with higher enrollments.

There must be a campus-wide understanding about how building and sustaining strong programs in science and mathematics connect to the institutional mission of preparing students for the world in which they will live and work upon graduation. As science and technology have an increasing impact on all of life, colleges and universities have a responsibility to make a rigorous encounter with science and mathematics an integral part of the undergraduate curriculum.

—Project Kaleidoscope, "PKAL Volume Three–Structures for Science: A Handbook for Planning Facilities for Under-graduate Natural Science Communities." 1995.

The effect of attractive, well-designed, well-equipped contemporary spaces for teaching and learning may well be self-evident, but important to reiterate nevertheless: the performance and achievement of both students and faculty take on a new excitement and luster; curricular innovations abound; richer conversations take place–within and outside the building, inside and beyond the campus.

Knowing that this is so is one thing; demonstrating it is another. In this era of accountability, faculty and administrators must persuade both internal and external audiences of the benefits of any capital project, before and after its completion; outcome measures can be both quantitative and qualitative in nature. On the quantitative side, the most important impact for institutions is found in enrollment trends–not only rising numbers of majors, but also improvement in their retention; the number of students from other departments enrolling in science courses as electives; the degree to which programs attract and retain greater numbers of women and minorities. Corollary measures include increases in research involvement and output, for students as well as faculty; and post-graduate outcomes in graduate/professional school acceptances and job placements. Good scientific research also attracts greater numbers of external grants, and gifts to the sciences in general can also be expected to increase as reputations are enhanced by commodious spaces.

Qualitative measures are equally important though more difficult to document, and may be best framed as questions: does this building design add to the campus aesthetic? Do all students feel welcome in the building at all hours? Can those who walk through the spaces see science in action, and begin to understand the nature of doing science? Do the interior spaces encourage connections rather than isolation? To what degree does this building serve the entire campus community, beyond its central purpose as a setting for the study of mathematics and the various fields of science? How satisfied are the students, the faculty, the office and technical staff with the spaces? Do the new spaces address the needs of the future as well as those of the present?

The key to a facility that makes a quantitative and qualitative difference and is a cause for ongoing celebration lies in the careful definition of program goals before the design process even begins. This definition must be a collaborative effort engaging all members of the campus community; it must be seen by all as an investment in the future–of students, of the institution, and of society.

CHAPTER I: THE COMMITTEE OF VISITORS REPORT

Background

In 1997, with support from the Office of Science and Technology Infrastructure at the National Science Foundation, a Project Kaleidoscope (PKAL) Committee of Visitors (COV) made site visits to eight colleges and universities, representing the wide diversity of higher education in this country. All institutions had taken seriously the challenge to transform the environment for learning and had made a major investment of resources toward renewal of facilities and program. Through meetings with faculty, administrators, and students, tours of new spaces, and review of institutional materials, the COV sought to determine if and how the investment paid dividends in respect to student learning, as well as the extent of institutional transformation occasioned by the new and renovated spaces.

This report presents their findings. The Committee of Visitors found improved spaces are making a difference in that they:

- create the opportunity for strengthening learning, with greater student access to opportunities to 'do science,' from introductory courses through upper-level courses for majors
- introduced an increasing number of students to the art and excitement of doing research, thereby fostering critical thinking, problem-solving, and communication skills
- enable flexible scheduling and use, accommodating students with different learning styles and different career aspirations
- play a role in recruiting strong faculty, as candidates see the value the institution places on these disciplines and their commitment for the future
- accommodate emerging interdisciplinary thrusts in teaching and research
- feature expanded technology infrastructures that support programmatic reforms based on an increased use of instructional technologies, and bring to students a command of the tools of information exchange essential for work and life-long learning
- leverage the search for external support, making the institution more competitive in obtaining grants for research, curriculum, faculty development and instrumentation
- are an occasion for revisiting institutional priorities, and for considering the allocation or reallocation of resources so that those priorities can be funded over the long term.

COV Institutions

- Carleton College (MN)
  Center for Mathematics and Computing and Hulings Hall for Biological Sciences
  New: $21.5 million
- Claremont McKenna, Pitzer, and Scripps Colleges (CA)
  W.M. Keck Science Center
  New: $12 million
- Grand Valley State University (MI)
  The Seymour and Esther Padnos Hall of Science
  New: $41 million
- Kennesaw State University (GA)
  The Science and Allied Health Building
  New: $15 million
- Rensselaer Polytechnic Institute (NY)
  Walker Laboratory
  Renovation: $11 million
- The University of Oregon (OR)
  The Science Complex
  Addition and renovation: $45.6 million
- Washington and Lee University (VA)
  Parmly, Howe, and Great Halls
  Addition and renovation: $23.2 million
- Xavier University of Louisiana
  Norman C. Francis Science Center
  Renovation: $20.8 million; Additions

The Committee of Visitors

- Stanley Mertzman, Professor of Geology—Franklin and Marshall College
- Frank Rothman, Provost Emeritus and Professor of Biology—Brown University
- Dorothea Widmayer, Professor of Biology Emerita—Wellesley College
- Lee Walker Willard, Associate Dean (Trinity College)—Duke University

Coordinated by:

- Julie Monson, Education Consultant
- Jeanne L. Narum, Director, Project Kaleidoscope

The Committee of Visitors

The charge to the Committee of Visitors established by PKAL was to explore the question, *what difference do improved spaces make?* No previous effort had been undertaken to gather data and information on the impact of facilities improvements on: i) student learning; ii) faculty productivity; iii) departmental and institutional enrollments; and iv) institutional vigor.

These indices are complex and difficult to assess, yet the experience of the COV documents the return on what is for all institutions a significant investment of resources, in both time and money. From the beginning, the COV realized that the outcome of their project would be a valuable contribution to a better understanding of the costs and benefits of improved facilities. The methods they chose, while objective, sought evidence for their findings from many sources, some anecdotal. For example, they found discussions with students valuable, but these discussions did not yield answers to the same questions from campus to campus. Further, their efforts to document increases or decreases in enrollments were complicated by the fact that enrollments can change for many reasons, and it is difficult to isolate the effect of improved spaces from that related to program improvement. From their on-campus discussions and review of Project Kaleidoscope materials, the COV collected data, impressions, and opinions, and pulled these together with their own observations to evaluate impacts.

The report on the effect of improved facilities for undergraduate mathematics and the various fields of science grew out of Project Kaleidoscope's ongoing efforts toward strengthening the learning environment for students. While it is easy to assume that improvements such as modernized, well-equipped laboratories and expanded infrastructures that accommodate more extensive computer networks all contribute to more effective teaching and learning and greater institutional strength, it is important to document the actual influence.

There are lessons to be learned from the experience of the eight colleges and universities visited by the COV, and these lessons can be helpful to others: to faculty giving attention to how and where students learn, to deans seeking ways to attract and support strong faculty, and to presidents determined to focus institutional priorities on serving students and society more effectively.

There are further lessons to be learned from these stories about the return on such investments from the national perspective. These individual projects will make a difference nationally as well as locally.

Recommendations from the Committee of Visitors

From their analysis and interpretation of the experiences of planning and working in improved facilities, the members of the PKAL Committee of Visitors offer the following recommendations.

- To faculty and administrators at the nation's colleges and universities:
  - as the first step in planning improved spaces, set clear goals for student learning; do not underestimate the importance of planning that links the renewal of program and facilities
  - document the total need for improving the physical infrastructure for research-training and instruction in mathematics and the various fields of science
  - determine how to fund those needs over the long-term, including the allocation or reallocation of funds and the use of a variety of funding mechanisms
  - identify ways that changes in the practice of science, emerging technologies, and new understandings about the nature of learning are changing the undergraduate environment
  - plan buildings with basic systems that are adaptable, that will accommodate new directions in science and approaches to learning in years to come
  - use new spaces to enhance the learning community as they encourage interaction and add to the architectural distinctiveness of the campus.
- To staff of private and public funding agencies:
  - recognize that building a national capacity for research and development will not succeed if the physical infrastructure for educating the next generation of researchers and academics is inadequate to the task
  - develop multi-year plans to support renovation and construction of new facilities; avoid 'start and stop' programs
  - support the planning and construction of facilities that accommodate discovery-based learning for all students and a research-rich environment for student majors and faculty
  - urge colleges and universities to engage in careful, comprehensive, and collaborative planning leading toward systemic reform of their undergraduate programs in science, mathematics, engineering, and technology.

(**Note:** COV findings are presented on page 6 ff., and the justifications for the recommendations, based on COV findings, are on pages 17 ff.)

One principle undergirding this report is that public policy should encourage and support indigenous science and mathematics education. The physical and human resources necessary to support and maintain science and mathematics communities of learners must be made available on individual campuses. Locally-based research supports student-faculty partnerships that enhance the learning community, reinforces faculty professional activities, and exemplifies to students the dynamic that sustains the undergraduate teacher-scholar.

A second principle is that policies should address both long-term and short-term goals. Sustaining and adequate infrastructure is a costly proposition. Faculties, deans, development officers, and presidents as well as staff of governmental and private funding agencies, need to be clear about the long-term implications of decisions made to solve immediate problems. Too often effective programs are abandoned before they have achieved their purposes. Commitment to long-term sustained effort is absolutely crucial if change is to be productive.

—Project Kaleidoscope. "Volume One–What Works: Building Natural Science Communities." 1991.

The total estimated cost for deferred S&E research construction and repair/renovation projects in 1996 was $9.3 billion, including both projects that were identified in approved institutional plans and those that were not. Over three-quarters of all deferred capital project expenditures ($7.4 billion) were included in institutional plans. In addition, colleges and universities estimated a total of $2.5 billion in deferred repair and renovation costs for projects affecting central campus infrastructure. It is estimated, conservatively, that $.7 billion of this amount might be attributed to S&E research needs. Combining this $.7 billion with the $9.3 billion in deferred construction and repair/renovation projects yields a total of $10 billion in deferred research facilities and infrastructure needs.

—National Science Foundation. "Scientific and Engineering Research Facilities at Colleges and Universities: 1996." NSF 96-326.

We hope the findings and recommendations presented here contribute to an informed national dialogue about the need to pay greater attention to current infrastructure needs within the science, mathematics, engineering, and technology (SME&T) community. We further hope that this dialogue leads to action, to the establishment of policies and programs that enable the undergraduate SME&T communities to support this nation's economic growth, productivity, and innovation into the coming century.

The infrastructure problem faced by colleges and universities can be best addressed by a collective national effort. As a first step, we propose that this effort of documenting the impact of improved spaces on research and training, on the next generation of K-12 teachers, and members of the R&D and academic communities be continued and expanded. No single source is expected to fund needed renewal of infrastructure for undergraduate SME&T. Yet, for useful planning at the local and national level, some clarity is needed about the scope of the cost needed to ensure that the facilities and instrumentation can support world-class research and education.

Our nation's future will be undermined if we do not undertake a serious effort to see that present and future generations of undergraduates, at colleges and universities of all types across the country, do not have the same opportunities as the students on the campuses visited in preparing this report.

The eight institutions surveyed by the COV had completed projects totaling more than $195 million. A conservative estimate would be that there are nearly 600 science-active colleges and universities in the U.S. A simple calculation suggests the potential investment that is needed to achieve the level of facilities required by a world leader in science and technology. One national priority should be to address the chronic under-funding in infrastructure renewal on these campuses.

COV FINDINGS

New facilities enable an expanded technology infrastructure that:

- gives students greater access to data from external sources and from college networks at all hours of day and night
- supports a variety of programmatic reforms that require increased instrument use, making them more available and providing more independence in their use
- encourages greater institutional support for faculty and staff to use computers for more than word processing
- raises the expectations for and use of technologies across campus
- brings students a command of the tools of information exchange essential for work and for life-time learning.

Findings—*Teaching and Learning*

Improvements in pedagogy. Efficient, attractive classrooms and laboratories equipped with modern instrumentation and advanced computer technologies create an environment that encourages innovative teaching and expanded research opportunities for undergraduates. For example, at RPI, the replacement of formal lectures by interactive modes of learning (the "studio" method) is enhanced by the flexible, modular arrangement of furniture and computers in classrooms.

Six of the institutions visited incorporated advanced computer technology that, together with programs that train faculty in its use and potential, expand pedagogic opportunities. The modern technology permits increased access to and analysis of data generated with sophisticated instruments. In Carleton College's Huling Hall, for example, images that originate from electron microscopes can be sent throughout the building, displayed on a computer monitor for individual analysis by students, or projected for classroom viewing.

Student research. The importance of an undergraduate environment that is 'research-rich' was evident at several of the institutions visited. Dedicated space suitable for individual or group research projects made possible expanded opportunities for students to do truly experimental work– to do science as scientists do science.

Carefully planned adjacencies of teaching laboratories, research laboratories, and instrument rooms, as at Kennesaw State University, permit wide sharing of expensive, sophisticated equipment, a cost-effective measure.

Student/faculty interactions. The new spaces generate increased faculty-student and student-student communication and collaborations in several settings, with peer-learning taking place in informal settings in hallways and alcoves as well as in formal settings in classroom and lab.

Classrooms and laboratories have been designed to permit easy circulation of faculty, or grouping of students for discussion during laboratories. Social spaces adjacent to faculty office clusters, or at major intersection points of traffic, facilitate impromptu as well as scheduled get-togethers. At Xavier University of Louisiana, reporting of student research at local and regional conferences is stressed as part of their extensive student mentoring programs.

The COV found that the contrast to the previous facilities heightened the impact of new space on teaching and learning.

Findings–*Institutional Impacts*

Enrollments. The interplay between new facilities and enrollments is complex. Science *majors* increased at most, but not all of the institutions. Total science *enrollments* increased at a faster rate than total institutional enrollments, apparently due at least in part to the new facilities. Such enrollment increases also reflected greater institutional attention to attracting non-majors into the study of science and mathematics. Reflecting national trends, the enrollment increases were concentrated primarily in biology and computer science. At Carleton College, which maintains a steady-state in total enrollment, science enrollments increased *after* the new facilities were opened.

Faculty. The most visible impacts of improved space were on morale, which improved greatly at all of the institutions, and faculty effectiveness. Faculty noted that their time can now be redirected in constructive ways (working directly with students) and away from such issues as safety of obsolete equipment. The improved meeting spaces, both formal and informal, have led to increased faculty interactions between departments. A positive effect on recruiting strong new faculty as a result of up-to-date facilities was mentioned at Grand Valley State University, Kennesaw State University and the University of Oregon, and is likely to be the case at the other institutions as new searches take place.

Planning. The COV found ample evidence of the value of an open, detailed planning process, with broad involvement of various sectors of the campus community, including administrators, students, staff, and faculty colleagues from all disciplines.

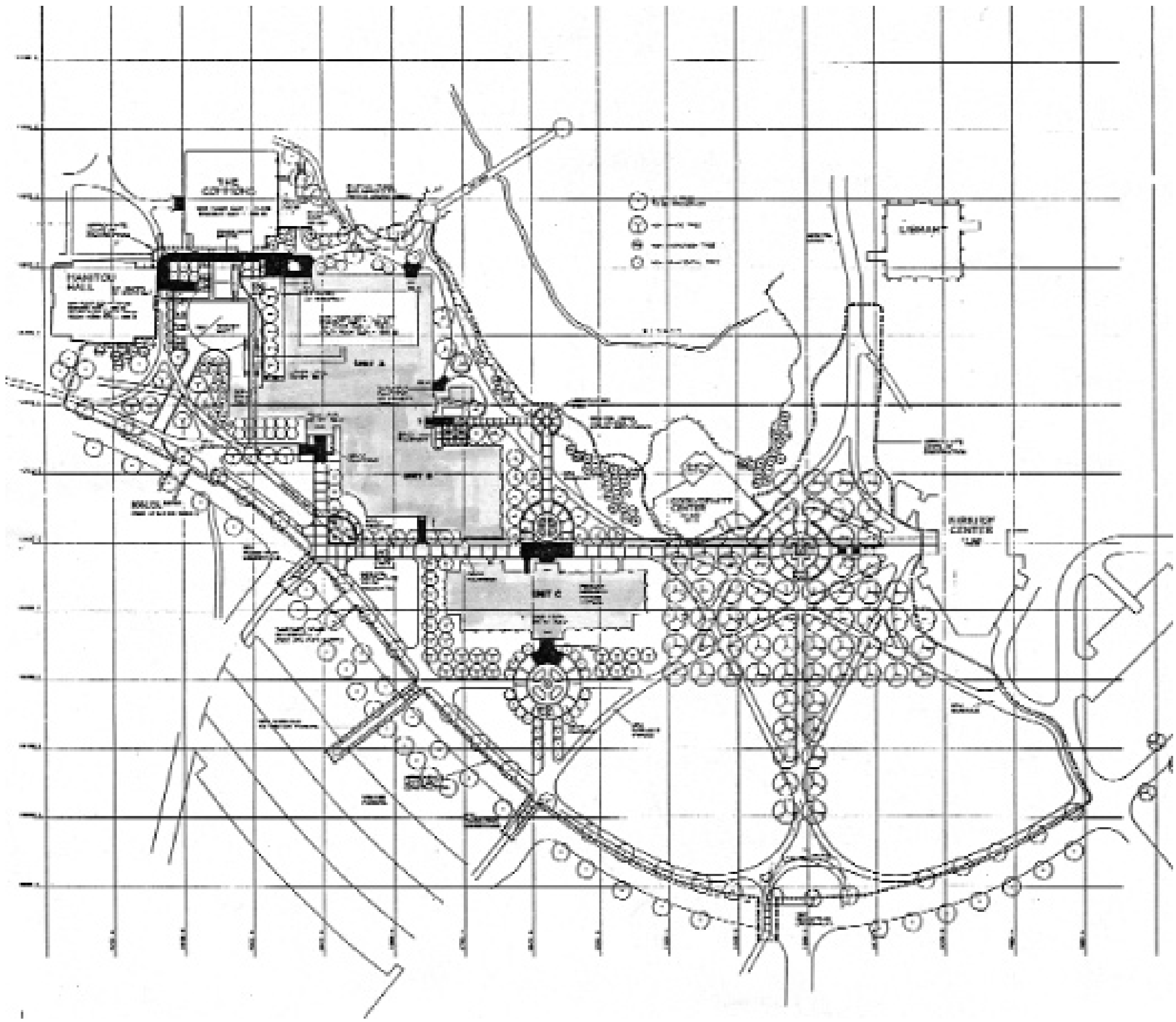
This was most evident at the University of Oregon, which has a rich heritage in campus-planning policy, dating back to the early 20th century. Leaders of the science faculty who were to become the users of a nine-building complex were involved in all stages of the planning and played the major role in the decisions taken. Faculty from non-science fields were also enlisted in the planning. A strong faculty/administrative “shepherd” provided leadership and continuity during the long process. The resulting complex of buildings has reinforced the University’s commitment to interdisciplinary Institutes, by “horizontally” integrating each Institute on a contiguous floor of various connected departmental buildings.

The planning process at several institutions served to educate various constituencies about the activities of the others, and brought to the fore institutional versus disciplinary priorities.

COV FINDINGS

Improved facilities, with spaces designed to accommodate a community of scholars:

- encourage communication between students and faculty and informal use by students
- make science a more visible and more central part of the education for all students
- support the development of programs that bridge the disciplines, and offer students opportunities to develop majors that link the sciences with other disciplines
- play a significant role in attracting strong new faculty to the campus.



In all eight projects, architectural siting and distinction were important design criteria. At the University of Oregon, the new buildings connected and hid old ones that were unattractive anomalies on the campus. The science complex now forms a new and beautiful segment of campus, which is visited and used by all members of the University. At The Claremont Colleges, the Science Center is a handsome structure strategically located at the corner of the three abutting campuses of the colleges that together administer the Joint Science Department. The Science Center at Washington and Lee University, joined by bridging two historic science buildings, fits in with the existing historic nature of the campus yet provides a sophisticated modern facility that opens up the back half of the campus and creates a new campus axis.

Facility Issues. Major physical space issues varied at each institution. Informal spaces for student and faculty interaction, while often singled out for their importance, were sometimes scaled down due to budget cuts; classrooms were also scaled down at some institutions. However, the value of community space was emphasized in the personal interviews, and was quite evident in the tours through several of the new facilities. Issues in regard to safety and accessibility were also addressed in the planning.

Financial Issues. The COV noted a strong two-way synergism between new building projects and grant funding.

At Xavier University of Louisiana, selection by the NSF as a “Model Institution for Excellence” helped to generate the programmatic needs for improved infrastructure. At other institutions, the availability of a first-class facility strengthened applications to external agencies for program, faculty development, and equipment.

Operating costs rise with expanded or improved science facilities. For example, Padnos Hall at Grand Valley added 30% to total academic space utilities, and required hiring an extra engineer. The COV found that, most often, plans had been made for covering these costs.

Once opened, new science buildings can play an important role in future fund raising. Several of the elegant structures visited are used by development, university relations, and admission offices for presentations to donors, friends, and prospective students and parents.

These buildings, individually and collectively, are a visible commitment to quality undergraduate programs in science, engineering, technology and mathematics, and a reminder that such programs will be a hallmark of institutional excellence for the 21st century.

COV FINDINGS

Improved facilities make a difference as they:

- ♦ provide space for expanding enrollments, particularly in biology and computer science
- ♦ affect enrollments by attracting exciting and excited students to the campus
- ♦ support greater involvement with teachers and students in regional elementary and secondary schools
- ♦ offer students spaces for research and study that are safe and easily accessible.

University of Oregon Science Complex
Eugene, Oregon

Design Architect: Moore Ruble Yudell
Santa Monica, CA

Executive Architect: The Ratcliff Architects
Emeryville, CA

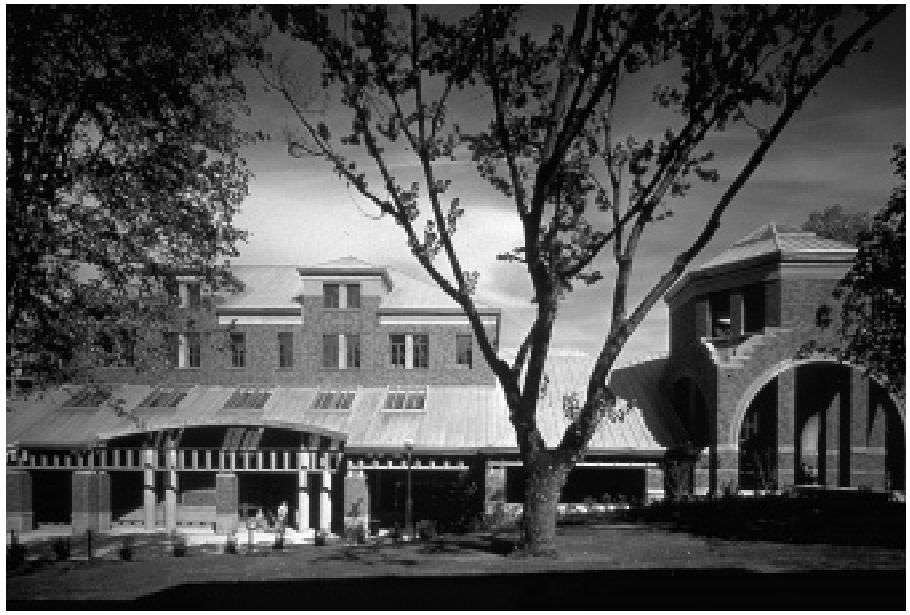
Associate Architect: Brockmeyer McDonnell
Eugene, Oregon

Lab Consultant: McLellan & Copenhagen
Cupertino, CA

Size: 250,000 SF new
97,000 SF renovated

Construction Cost: $40 million

Completion Date: 1989



West facade of Geology building

Moore Ruble Yudell and The Ratcliff Architects were the architects for the University of Oregon's new research laboratories and teaching spaces for the Biology, Physics, Geology, and Computer Science departments as well as expanded facilities for the Science Library. When we were retained for planning and design, two conditions seemed critical to the direction of our efforts. First, the original beaux-arts campus plan of 1914 had formed an elegant and successful armature for campus growth until the 1950's, but in the fifties, sixties and seventies this had been abandoned as new buildings ignored streets, quadrangles and each other. Secondly, in the seventies Christopher Alexander had worked with the university planners to write *The Oregon Experiment*, which called for user participation in the development of socially and physically sensitive patterns.

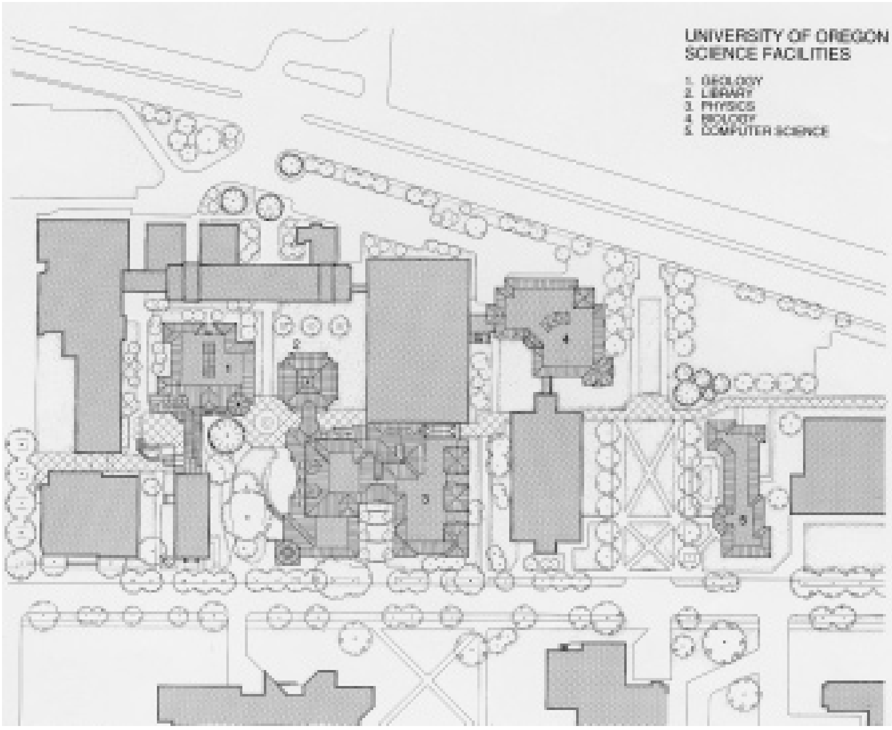
We thus took as our challenge the restoration of the historic relation of buildings to streets and courts and we hoped to use the new buildings to restore the original spatial and visual continuities of the campus, both on the scale of the campus plan and in the use of a palette of material: patterned brick, cast stone trim and copper roofs.

Our planning and design process integrated aspects of Alexander's Oregon Experiment with our own experience in participatory planning workshops. All major constituents of the campus were represented and helped shape the buildings at a departmental as well as site-planning level.

The buildings function in multiple ways. They are discrete free-standing buildings housing individual departments, organized vertically. They also connect horizontally to form interdisciplinary relationships critical to the way in which the sciences function. Bridges between departments house the offices of interdisciplinary "institutes." More informal connection is made along a "science walk" that links all buildings through a series of arches and courts.

Each building has a series of important social spaces, from informal areas near clustered offices to departmental "hearths" to courtyards. The heart of the project is a four-story atrium, bounded by classrooms, conference spaces, research laboratories and institutes. This and other major meeting areas are designed to maximize a south-facing orientation especially important in the northwest climate.

Willamette Hall atrium



Site Plan

Laboratories, offices and social spaces all evolved in close response to the particular nature of research and communication of each discipline. The scientists collaborated with us in workshops to model their specific research patterns and needs. A flat slab concrete structural system has been established to maximize flexibility and to allow for appropriate bay modules for each department. Overhead mechanical services allow for quick changes in lab set-ups.


Courtyard and fountain

In 1994, a total of 40 percent of all research-performing universities and colleges had an approved institutional plan that included construction and repair/renovation projects that were either deferred or unfunded. The estimated cost of these project in constant dollars was $6.2 billion: $4.4 billion for new construction and $1.8 billion for repair/renovation. In 1996, 44 percent of research-performing institutions reported having an approved institutional plan that included construction or repair/renovation projects that were needed but that had to be deferred because funds were not available. These plans cited $7.4 billion of deferred capital project expenditures in constant dollars– $4.6 billion for new construction and $2.8 billion for repair/renovation. This total represents a $1.2 billion increase in deferred capital costs between 1994 and 1996, the majority for repair/renovation ($970 million) and the remainder in deferred construction costs ($259 million). Another 11 percent of research-performing institutions identified $1.9 billion of needed deferred capital project expenditures that were not included in an institutional plan– $1billion for new construction and $0.9 billion for repair/renovation.

—National Science Board. "Science & Engineering Indicators-1998." NSB 98-1.

The Need for Improved Undergraduate Facilities

Why are improved facilities needed? The campuses reviewed by the COV had a common story about the inadequacy of former spaces and structures for science.

Enrollments. Of the institutions visited, three had been experiencing dramatic increases in institutional enrollments (Grand Valley State University, Kennesaw State University and Xavier University of Louisiana), and most were responding to greater student interest in science/mathematics, creating higher course enrollments.

Obsolescence. At some institutions, facilities that were renovated or replaced dated from the early years of the 20th century and were manifestly obsolete. Even when facilities had been built more recently (during the Sputnik-inspired building boom of the 1960s), they were inadequate as contemporary learning environments. With time-worn systems, these outmoded facilities required significant work merely to achieve minimum safety standards and to meet current codes.

Obsolescence was evident from several perspectives, including:

- *pedagogical approaches:* facilities were outmoded in that their designs reflected out-of-date styles of teaching and learning
- *new directions in science:* facilities did not encourage the interdisciplinary interactions that are increasingly a part of research and education in the scientific and technological worlds
- *technologies:* emerging educational technologies that required updated infrastructure configurations of classrooms and labs could not be accommodated
- *research-rich environment:* the role of research and research-training in the education of undergraduate students was not recognized in planning for spaces built over 30 years ago.

Equally critical was the emergence of a new educational vision. Revisiting institutional missions and seeking to attract a broader student audience to the study of mathematics and the various fields of science, the COV institutions had determined that these fields of inquiry needed to be more visible. The fields needed to be seen as a more integral part of the undergraduate experience, and as a fitting preparation for a wide range of vocational and leadership opportunities for all students.

Conclusions

For over a decade, leaders of higher education have recognized that the environment for learning science and technology must change. The self-evident advantages of new, carefully planned facilities to maximize the benefits of these changes have been emphatically confirmed in the present study. The COV found rich synergism among curricular innovation and faculty and student morale, externally-funded grant support for programs and equipment and new facilities. The impact of new and renovated facilities has been significant. The students learning in these spaces will make an important societal contribution in years to come with the skills and capacities they are developing.

Has the investment demonstrated positive results and how do you know?

The COV answers to this question should be of value to other institutions in the process of planning for new spaces and structures for undergraduate programs in science and mathematics. Understanding how these spaces make a difference should also inform current discussions at the national level about shaping the future of these undergraduate programs.

What we learn from these eight projects advances our understanding about the relationship between the potential to develop human resources essential to shape our nation's future in a world of unprecedented scientific and technological opportunities; we also better understand the potential of the infrastructure that supports education, research-training, research and development in science and technology, mathematics and engineering.

As more undergraduates are exposed to science and mathematics in facilities that allow them to 'do science' under conditions that more closely resemble those found in contemporary and future work settings, they will be better prepared to move into positions in business and industry and academe that require scientific and technological skills. Equally important, these students will be better prepared for the difficult judgments about the economic, environmental, and ethical dimensions of science and technology that they will be called upon as citizens to make.

The heart of this report is in interpreting the human experiences that took place in the planning of and living and working in these new facilities. Every institution studied in the report discussed how the new environment affected human emotions and behaviors such as morale, inspiration, involvement, collegiality, cooperation, and social life. A building that does not welcome us, does not foster all sorts of team-work, and does not promote the vital connection among teachers and students, infrastructure and curriculum cannot contribute to improved teaching and student learning, to strong enrollments, to the potential for increased external funding, to greater research efforts and to ongoing planning for the future of the institution.

—Charles Weiss. The College of the Holy Cross.

KENNESAW STATE UNIVERSITY

The Sciences at Kennesaw State University entered the 21st century when they moved into the New Science Building. The building, opened in January 1996, has provided critical expansion space for classrooms and laboratory facilities, created space for student/faculty projects and directed research, and is spearheading the use of computer and audiovisual technology in teaching at Kennesaw. Adaptability, accessibility, and accommodating technology were all important design considerations.

The 104,000 GSF building was planned with two major elements– an office/classroom tower and a laboratory wing– connected through bridge corridors on all levels and an atrium on the lower two floors. The two wings share a common ground floor and mechanical and electrical systems.

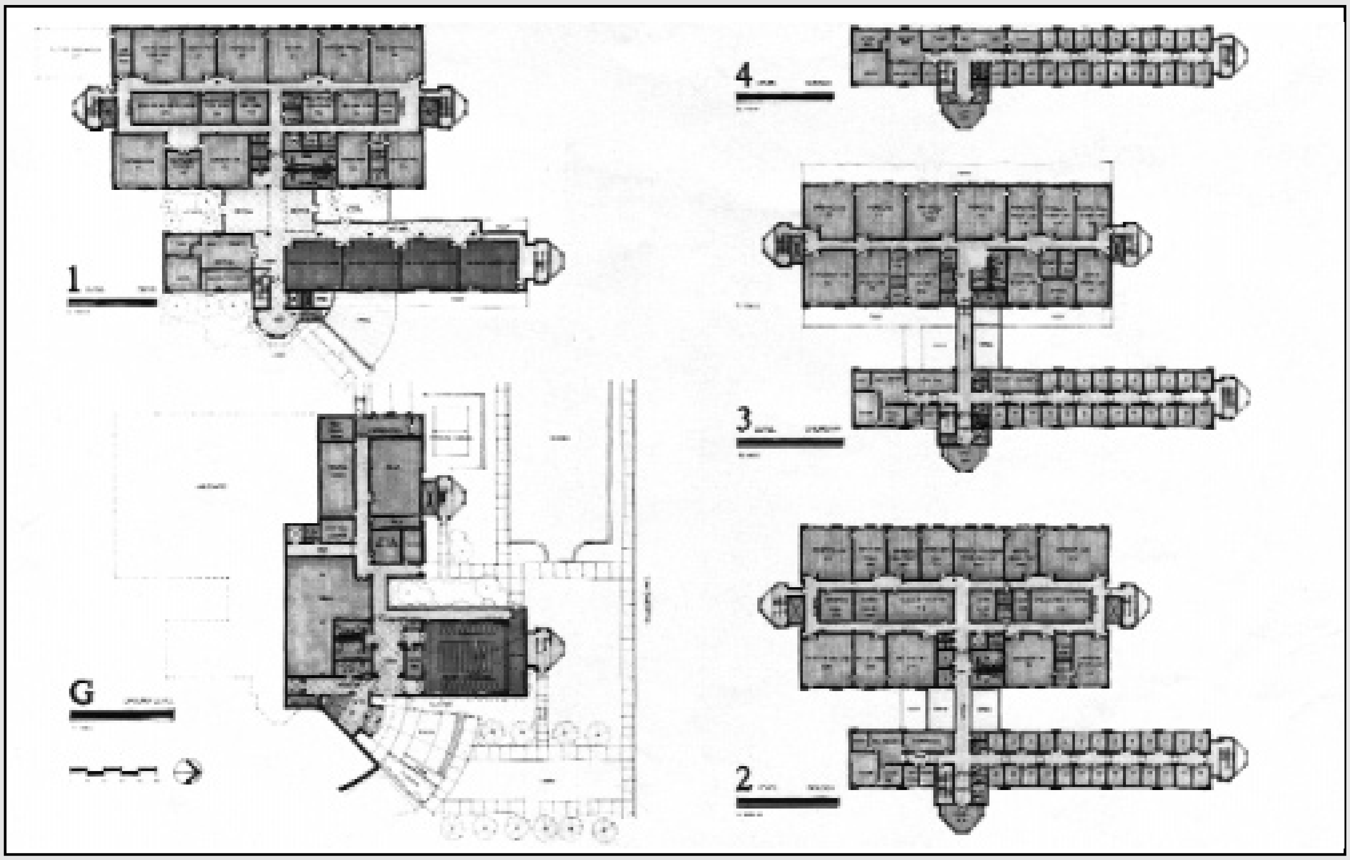
Classrooms provide a myriad of electronic learning environments for faculty and students. Faculty are fully supported, from blackboards to digital projection equipment (mounted in the ceiling or on roll-around units) with multimedia and Internet connections. Each room is also equipped with a Synergy® media-control system so faculty can retrieve media from satellite or reproduction equipment located in the main control room in the building. Internet connections in floor boxes support "islands" of workstation connections in each classroom. The classrooms have no windows so there is no glare on the media and computer workstations. The furniture allows students to work individually or in groups.

In the theater-style auditorium, which holds 200 people, media-presentation equipment and a control center enables high-tech presentations using Internet resources or other forms of digital media. Presenters can select among several pre-set media and lighting sources using control panels built into the podium. The facility provides for satellite conferencing and for small conferences and seminars; the auditorium is configured for media production technology, with conduit and cabling for use with video production and origination equipment.

Computer labs provide modern workstations. Servers with discipline-specific software lend diversity to the software options available; faculty have access to two Course Management Systems to manage and distribute curricula via the Web. The workstations are equipped for video and audio reproduction.

The laboratories were designed to be "generic type" facilities so that either biology or chemistry could use them. The layout of the lab wing floors provides an "O" corridor with labs on the outside and instrumentation rooms, special preparation rooms and project rooms on the inside. Stair towers located at the ends of the office and laboratory wings provide easy entry and exit to each floor. Welded vinyl floors and heavy-duty casework complement the attractive laboratory settings. Many of the labs have downdraft hoods (needed where exposure to solvents or preservatives is an issue). Chemical fume hoods are incorporated in all of the wet lab rooms as well as preparation/stock rooms; there are biological safety hoods in labs used for isolation or microbiology.

The infrastructure for computer and audiovisual technology provided by the new building has given faculty incentive to incorporate these components in their curricula. Dedicated space for student research projects has allowed for a robust implementation of the college's mission to train students in applied sciences. And the attractive space, particularly the atrium, has led to an increase of interactions among faculty and students. The building is featured on page one of Kennesaw's undergraduate catalog, and is the centerpiece of campus tours. Where Kennesaw used to lose students to other, better-equipped institutions, it now recruits students because of the facility.



CHAPTER II: JUSTIFICATION FOR THE RECOMMENDATIONS

The PKAL Committee of Visitors established six areas of inquiry to pursue in their evaluation of the impact of improved spaces.

A. Teaching and Learning

Questions Asked:

- *Has the new facility contributed to improvements in teaching and student learning, pedagogy, course structures, and content?*
- *What evidence supports claims of improved learning?*
- *Does the new facility contribute to (a) greater interaction among students and faculty; (b) more student involvement in research; and (c) improved integration of research and education?*
- *Is the new facility actually being used in ways intended by the faculty and the building's designers?*
- *Has the new facility contributed toward a cohesive campus community of science faculty and students?*
- *Are science and mathematics more visible on campus because of the new facility?*

Outcomes Determined:

1. Empowerment. Efficient, attractive classrooms and laboratories, equipped with modern instrumentation and advanced computer technologies, create an environment that encourages innovative teaching and expanded research opportunities for undergraduates. In highly technical new structures like the Center for Mathematics and Computing at Carleton, or RPI's Walker Laboratory, faculty are empowered to use technology to the highest degree for teaching and research. At these institutions, undergraduates have access to, and learn to use, sophisticated equipment for structured and independent research and learning.

Six of the COV projects incorporated advanced computer technology in their new or improved facilities. These improved spaces promote the kinds of learning and acquisition of skills that educators (and others) predict are needed by college graduates in our technological society, whether they follow careers in research and teaching, technology or other professional fields. Xavier has included computer technology in its new building. Technology was not at the forefront in planning for the Keck Science Center in Claremont, and the program is less effective as a result. It is difficult now to add technological infrastructure; to do so is very expensive and such a project must compete with other institutional priorities.

Improved, technologically-equipped laboratories support new ways of teaching and learning. Laboratory courses can be interactive and collaborative, project-oriented and hands-on, and enhance student and faculty interaction and problem-solving in teams. Many of the class and laboratory spaces in these new buildings were so designed and are flexible enough to adapt to future curricular needs.

Some faculty require assistance in utilizing educational technologies for teaching and research, and need encouragement to focus on teaching and engaging students in investigative laboratories and collaborative research. Where faculty are committed to these ways of learning, and receive technical support and collegial recognition, the results are quite amazing. RPI is an excellent example, where pedagogy–studio teaching–directed the design of Walker Laboratory. This structure, its equipment and infrastructure, support innovative instruction and learning.

Improved space creates the opportunity for improved teaching and learning. In order to take the greatest advantage of the new space, institutions may be required to fund added technical support for faculty, as well as to provide incentives for adopting innovative ways of teaching.

2. Reaching all students. To the degree that the student-centered learning promoted in some of these new spaces is flexible, collaborative, and self-paced, it serves the needs of diverse students from different academic and cultural backgrounds. At Kennesaw, for example, 40% of the students are enrolled part-time and, because of work or family responsibilities, have to fit education into their lives in a pattern that is different from that of more typical 18- to 22-year-old students. At Xavier, however, students have been remarkably successful in a structured environment primarily because of the University's extraordinary commitment to mentoring all students.

Attractive and accessible undergraduate science buildings make a positive statement about science. In the eight science facility projects discussed in this report, architectural distinction was an important design criterion, not in itself but in helping these buildings to be attractive and inviting to students. Older science buildings are often dark, ugly, smelly, and forbidding. These new structures are designed as attractive but serious, functional work environments (not unlike what graduates will encounter in their future work). They encourage informal conversation and faculty-student interaction, are open all hours of the day, and are equipped with advanced instrumentation and computer capability. It is difficult to document that more "learning" takes place in these spaces, but students and faculty using them think it does and their enthusiasm reinforces this impression. The "user-friendly" quality of some of the facilities the COV reviewed, such as the Keck Science Center in Claremont, Padnos Hall at Grand Valley or Oregon's science complex, conveys a message that all are welcomed in the pursuit of science. These spaces are not the inner sanctum of a few.

3. Research. Advanced technologies enhance research as well as teaching, although the two are viewed as strongly connected in these improved spaces. Faculty have greater opportunities for research and for collaborative research with students. Many of these new structures incorporate laboratories designated for student research, often conducted in teams with an interdisciplinary character. Students become familiar with the tools of science–instrumentation and computer technologies–and also with the ways researchers work together.

B. Enrollments

Questions asked:

- *Has the new facility promoted increased enrollments in science, technology, and mathematics courses and/or in the number of science and mathematics majors?*

- *Has the new facility had an impact on overall institutional admissions, enrollment, and retention of students?*

- *Has it resulted in greater attraction and retention of women and members of minority groups traditionally under-represented in these fields?*

- *Are more students encouraged to major in science and mathematics because of the new facility? Does the new facility attract the non-science major to science courses?*

Outcomes Determined:

While data on course enrollments and science majors give clues to the impact of a new facility, this information is difficult to interpret. Multiple changes take place at the same time and an increase in enrollments may not be the goal of an institution when it upgrades its science facilities. Still, the COV looked for and found enrollment growth following the opening of new science facilities, particularly in computer science and biology. Mathematics and physics enrollments appear to be stable or declining slightly. In some cases, enrollments increased dramatically after the opening of the new facility. In Claremont, enrollments doubled in the five years after the Keck Center's opening (1992–1997), and although some increase was expected and hoped for, this student response was considered somewhat overwhelming.

New science facilities at three institutions–Kennesaw State University, Grand Valley State University, and Xavier University of Louisiana–were prompted by dramatic increases in institutional enrollments. Science enrollments at these schools increased at a faster rate than total institutional enrollments and appeared to increase in response to the new science facilities.

In a steady-state-enrollment institution like Carleton College, science enrollments did increase after the opening of the Center for Mathematics and Computing and Hulings Hall, but, as in the other institutions, primarily in computer science and biology. Science majors also increased, although not at all eight institutions. At Oregon, majors in the sciences (1990–1996) increased, ranging from 40% in biology to 104% in computer science; enrollments declined slightly (-6.5%) in physics. At Washington and Lee and RPI, majors remained fairly steady, as did institutional enrollments.

There has been no documented effect to date on the effect of the facilities visited by the COV on the attraction and retention of women and members of traditionally under-represented minority groups. The new facilities do, however, provide new avenues for this goal. Grand Valley State University has a Minority Education Center Program. The Keck Science Center at Claremont is actively being used to attract more women into science, particularly by Scripps College. At Rensselaer Polytechnic Institute, the administration is openly worried about recruitment of women and minorities, whose numbers are not increasing. They hope that the studio system, with its built-in opportunities for group work and mentoring, will make a difference.

At Kennesaw State University, the opportunities for non-traditional students may, in time, draw more women and minorities into part-time programs. Xavier's growth and educational success, with a student body that is 89% African-American and two-thirds women, has national impact on science education in two significant ways: i) the college is becoming more national and less regional, with 23% of its students coming from outside the South; and ii) a greater emphasis on preparing students for graduate school, not only medical school, will increase the number of minority group members entering scientific professions.

Questions about non-majors relate to science literacy issues. Certainly, if the new facilities had not been built, enrollments may not have grown. Attractive new buildings attract more students, as suggested by the experience of the Keck Science Center in Claremont. In other institutions, the cause-and-effect relationship is more difficult to quantify. It appears, however, that new attractive buildings are effective in promoting science education among non-majors.

In terms of institutional admissions, the COV found that new science buildings were often used on admissions brochures, web sites and on tours of prospective students and their families. New science buildings are a positive recruiting tool, particularly in attracting top high school students. High quality science facilities may be instrumental in keeping institutions competitive in attracting high-quality students, and thus have a positive budget impact also.

C. Financial Issues

Questions Asked:

- *What has been the impact of the new facility on (a) the institution's budget and (b) the institution's fund-raising efforts?*
- *If there has been an increase in maintenance and equipment replacement costs because of the new facility, how have these costs been met?*

Outcomes Determined:

The COV identified financial impacts in three general areas:

1. Building Funds. Public institutions (Kennesaw State University, Grand Valley State University, and the University of Oregon), dependent upon state legislatures for large capital expenditures, may have to move quickly when selected for a new science facility. This presupposes preliminary planning and identification of space needs so the project can proceed when the funds are available.

For private institutions (Carleton College, The Claremont Colleges, Rensselaer Polytechnic Institute, Xavier University of Louisiana, and Washington and Lee University), expensive new facilities and renovations depend on support from foundations and alumni, institutional funds and debt financing, although federal grants may assist with research training space and equipment. RPI was assisted with a challenge grant from the Kresge Foundation; The Claremont Colleges received support from Kresge and the W. M. Keck Foundation. The opportunity to leverage funds was an important factor in institutional planning.

2. Operating Costs. Operating costs rise with expanded or improved science facilities. Utilities can increase 15 to 20%, as at Carleton College. At Grand Valley State University, Padnos Hall added 30% to total academic space

Hulings Hall Biological Sciences Building
Carleton College
Northfield, Minnesota

Prime Architect: The Stubbins Associates
Cambridge, MA

Associate Architect: Rafferty Rafferty Tollefson Architects
St. Paul, MN

Lab Design: Research Facilities Design
San Diego, California

Size:

Net Square Feet:	47,466
Laboratories	24,417
Offices	1,990
Support Services	13,331
Animal	2,189
Circulation	3,211

Total Net Square Feet: 47,466 NSF

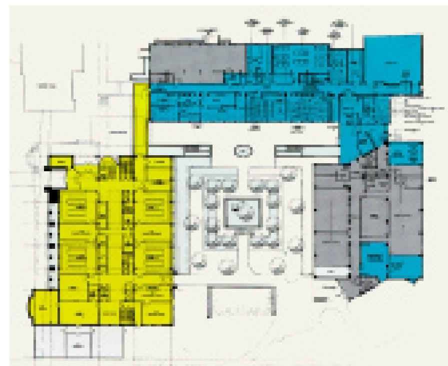
Total Gross Square Feet: 74,423

Construction Cost:
Confidential as per client request.

Completion Date:
September 1995 for laboratory and greenhouses
June 1997 for Olin Hall Renovation
June 1998 for Mudd Hall Renovation


Overall view

- Existing
- Renovated
- New


Ground Floor Plan

Background
The new and renovated science facilities at Carleton College are designed in response to an innovative program developed by the college to expand both teaching and research facilities in an effort to maintain excellence in science education.

Trend: Emergence of Combined Undergraduate Faculty and Student Research Labs

Opened to students in Fall 1995, Hulings Hall Biological Sciences Building was designed primarily for the biology program, but shares animal care facilities with psychology. The building enables faculty and students to explore the implication of this century's biological revolution, as well as the more traditional elements of biology, in fully contemporary laboratories.

The labs are adaptable for a variety of courses and encourage learning that takes place in a community where faculty and students are partners with one another and learning that is experiential and investigative for all students, from introductory courses through senior comprehensive exercises.

On the first floor in the new building, there is one restricted undergraduate research lab that is located between two teaching labs on the west side of the building. On the second floor faculty research labs are located adjacent to each faculty member's office.

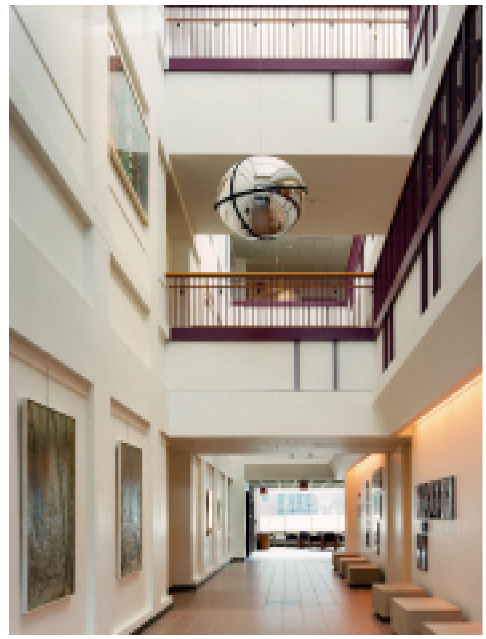
Trend: Desire to foster inter-disciplinary exchange.

Located on a prime site looking onto the main body of the campus, the new biological Sciences Building is an aesthetic reminder of the key role of science in the liberal arts education. However, the building is also designed to reflect Carleton's philosophy that learning makes connections to other fields of inquiry, suggesting practical applications related to the experience of students.

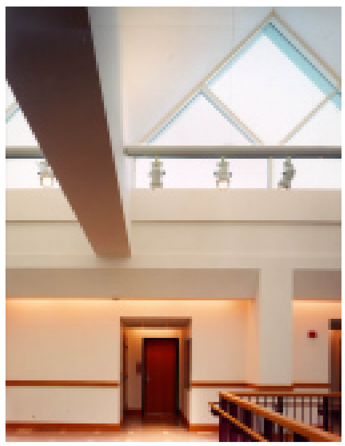
At Carleton, this philosophy takes the physical shape of the central atrium which serves as the formal and social heart of the building. It provides a sense of openness and collegiality and is used as an art gallery by the college in an attempt to bring the arts and sciences closer together.

> We feel we now have a concept that is the epitome of beauty, functionality, and belonging—an image that is uniquely Carleton"
>
> *Gerry J.C. Hill, Ph.D.*
> *Towsley Professor of Biology*

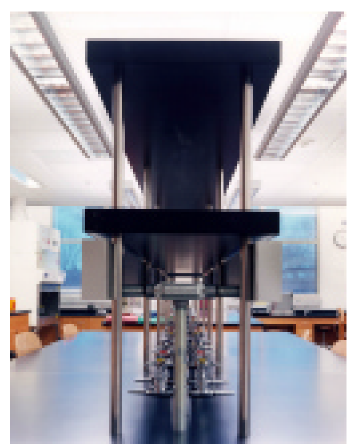
The atrium provides increased space for collegial exchange and collaboration, and also helps to eliminate physical barriers between the sciences and other Carleton programs such as art.



West facing clerestory monitors flood the atrium with natural light during cold winter afternoons.



Pendant mounted direct/indirect lighting fixtures reduce energy consumption and provide an enhanced visual environment.



Flexible laboratory spaces and service distribution systems will serve the college well into the future.

utilities and required hiring an extra engineer. Most often these costs appear to be anticipated and, with private institutions, incorporated into the project budget as endowment for operations and maintenance.

Larger and more sophisticated facilities and expanding enrollments lead to additions to staff and faculty: staff to provide technical support to faculty; engineers and laboratory technicians; faculty to teach more students. These costs are evidently more difficult to predict, but should be incorporated into a building's long-term financial impact.

The University of Oregon has a policy of self-contained building projects that are not to become a drain on other departmental budgets. These costs may be balanced, as the COV found at RPI, with the studio model of teaching. RPI faculty involved in teaching studio courses were more economically efficient in teaching more students with less time. Although this potential saving had up-front costs in faculty time to develop new curriculum, it promised to relieve a portion of the faculty salary budget in the long term.

3. Fund-raising. The completed projects appeared to have a positive impact on fund-raising in several ways. Faculty were more successful in obtaining grants for research, curriculum and faculty development, and equipment following the opening of the new facility. In fund-raising, success seems to breed success. Alumni are enthusiastic about the new structures, and this may enhance alumni giving; trustees engaged in the process of approving project budgets and setting campaign goals become advocates. Science facility improvements as successful as these eight can only add luster to a college or university campus, and this in itself enhances institutional fund-raising.

D. Faculty

Questions Asked:

- *Has the new facility had an impact on science and non-science faculty; on morale (positive or negative)?*

- *Has it had an impact on faculty efforts to obtain outside funding for research and teaching; on reform of the academic program; on interdepartmental cooperation and teaching; and on faculty recruitment and retention? Has it impacted tenure and promotion decisions?*

Outcomes Determined:

1. Effectiveness. The most visible impact of improved space was on faculty morale and effectiveness. Faculty were enthusiastic about their new departmental homes and energized about the effect of improved space and equipment on teaching and research. Often their prior "digs" had been scattered about the campus in cramped space that lacked equipment for research. Faculty time could now be redirected in constructive ways, for example, away from issues of safety or obsolete equipment. Faculty with whom the COV met mentioned improved productivity in their research and ability to obtain grants. Not all projects were designed to meet new pedagogical goals, but where they were, faculty now had spaces designed for innovative teaching (as at RPI). In Kennesaw's new Science Building, faculty had more involvement with student directed research programs and with outreach activities.

2. Interactions. All eight projects incorporated ingenious social space for faculty and students. One impact on faculty has been increased interdepartmental communication and greater informal contact with students. These institutions found that spaces that encourage informal and structured interdepartmental communication to be essential. In some projects, as at the University of Oregon, interdisciplinary interactions were enhanced by placing interacting academic units in proximity with each other.

3. Recruitment. These up-to-date facilities have had an impact on recruiting new faculty. This was mentioned particularly at Oregon, Grand Valley and Kennesaw (the three public institutions), where new faculty indicated how distinctive, sophisticated facilities had influenced their decision to accept positions. The new buildings provide improved research and teaching space, but they also reflect the value placed on science by the institution, and the level of support science is likely to receive in the future, all issues important to young faculty.

E. Long-term Planning

Questions Asked:

- *How does the new facility tie into the institution's campus facilities plan and long-term academic plan?*
- *Do the involved departments have long-term academic and facilities plans? Are these plans reviewed periodically?*
- *Did the need for, and construction of, this facility contribute to institutional or departmental planning?*
- *What science facilities needs are still unmet?*

Outcomes Determined:

1. Institutional Planning. From the institutional, academic, and facilities plans reviewed, the COV found each institution had procedures in place for long-term planning, although the plans, their adherence, and the planning process varied considerably. RPI follows a series of guiding principles rather than specific plans in establishing facilities needs. Even where a plan and procedure is in place, as at Washington and Lee, the trustees intervened to change the top campus priority from a student center to a new science facility. The impact of a major new facility on institutional planning can be a catalyst for testing and updating existing plans and policies campus-wide.

2. Science Planning–Facilities. Science facility projects can easily take up to 10 years with planning, fund-raising and construction. Testimony from faculty and administrators who talked with COV members bolstered the importance of involving users at all stages in the planning process. Projects appeared more successful and faculty were happier with the final outcome when faculty had been consulted and involved in the planning. At Washington and Lee, for example, faculty had very little participation in the planning of the facility and this is reflected in their attitudes toward the completed project.

Another key to project success appears to be a faculty or administrative "shepherd" who has release time to monitor and move the project along. In the absence of a shepherd the interests and preferences of faculty may be ignored. This is particularly critical when cuts must be made in the project. The University of Oregon planning process was remarkably successful, considering the scale of the nine-building project, and is well worth reviewing by anyone undertaking even a small construction project.

3. Science Planning–Curricular. The planning process can bring together faculty (science and non-science), academic deans, campus planners and architects, fund-raising staff, and budget officers in constructive ways to discuss institutional priorities, priorities in the sciences, campus facility needs and other issues. Discussions among faculty on current and future pedagogical approaches can promote a more cohesive academic program and identify specific needs (for example, handicapped access, computer networks or CD-ROM classrooms). Consultations with students can also be valuable.

XAVIER UNIVERSITY OF LOUISIANA

"The Science Addition"

Xavier University of Louisiana is building a 100,000 GSF addition to its science building, the Norman C. Francis Science Center. The addition (completed summer 1998) provides "state-of-the-future" laboratory and teaching facilities, with the latest multi-media and interactive technologies augmenting traditional classrooms and teaching labs. Labs are modular, allowing for maximum flexibility in planning for and using future technologies. The total cost of the new science addition and its related facilities is $20.8 million.

Xavier's commitment to student mentoring, high-quality student-centered learning, and its encouragement of student/faculty research and publications have driven renovations to the old science building, and are key parts of the design of the new addition. The addition is built around an institutional policy of promoting a vigorous student/faculty community. The addition also provides an example of the synergism between improved spaces and grantsmanship: laboratory renovations enhance student/faculty research which, in turn, leads to more support for science buildings.

A distinctive atrium enclosed in five-story glazed and curtained walls provides a central entry and circulation area for both the new addition and the existing building. The atrium facilitates cross-fertilization of ideas and interdepartmental (or inter-program) relationships. Sitting areas with marker boards and computers to foster casual student and student-faculty interaction are placed throughout the addition.

There is extensive use of daylight, with windows in every laboratory and office. Building materials and systems are environmentally sensitive; materials include brick, stone and renewable non-endangered wood. Energy efficient equipment and "smart-building" management systems help to minimize energy consumption.

The exterior of the building enhances the campus ambiance. The design reflects both the scale and style of the original Tudor-gothic buildings and the post-modern form of the latest construction on the campus. At the same time, the addition has its own distinct identity, and presents an image of dignity to the thousands who travel the intersection of Carrollton and Washington Avenues in New Orleans.


IPSC
OPTICS

"Loutit Hall was bulging at the seams. It was structurally sound, but had no classroom and lecture hall space. This new building has so much more room and better equipment. It's hard to compare with what went before," notes Dr. James Strickland, Emeritus Professor of Physics and faculty coordinator for Grand Valley State's Padnos Hall.

In 1996 construction was completed on the 159,000 SF Seymour and Esther Padnos Hall of Science, the final building of a 293,000 SF complex designed to meet burgeoning enrollments at Grand Valley State University (Henry Hall and the Student Services Building are the other members of the complex). The planning and design process that led to construction of Padnos Hall took seven years. The process involved faculty from the beginning in consulting capacities or as members of the planning committee.

Student research is taken very seriously at Grand Valley. Research is seen as an important learning tool, and as a way to develop a sense of community and foster a group learning ethic. One way in which Grand Valley students can get involved in research is through the Water Resources Institute (WRI), which has office, labs, and an information center in Padnos Hall. WRI was founded in 1986 to preserve, protect, and improve natural resources (particularly water). The Institute offers students the opportunities to conduct research while broadening their experiences and channeling their environmental concerns.

A unique offering at Padnos Hall is the Learning Center, located in a large room on the third floor, which is run by and for students. The Center is a place where students gather for help and tutoring by their peers, sign up and join discussion groups, and use computers for data analysis and simulations. It is a magnet for students and is an important factor in making learning fun at Grand Valley.

There are no less that 14 areas for students to study and gather in the building. The areas offer seating and table space, as well as extraordinary lighting and exterior views through solarium windows. Students now come to Padnos Hall to study, which did not happen in Loutit Hall. One student remarked that, "with the new building there is so much more enthusiasm to study. It's an exciting atmosphere and there is so much going on. When you walk in here, you just feel like you can't wait to get to class and discover something new."

Padnos Hall also combines art and science in a striking manner. A sculpted brain and the names of great scientists embossed on brass plates greet you as you enter the building. A series of photos, *Powers of Ten*, presents the universe from submicroscopic to galactic with each successive photo increasing in size by a factor of 10. Some faculty members believe the size of Padnos Hall may work against interaction. Yet even with its size, the Hall is attractive and inviting. The building is a combination of traditional and contemporary influences that result in a unique, enduring style.

Construction of new science facilities is a clear indication of an institutional commitment to remaining competitive and relevant in science teaching and research. As a Grand Valley biology professor said: "Buildings like Padnos Hall are essential to bringing Grand Valley into the next century, and it's a wonderful example of the kind of facilities Grand Valley will continue to need to ensure a relevant future. The fact that it's a much more invigorating, interactive environment for students and faculty is an important recruitment tool . . . The kind of growth exemplified by this building was crucial to my decision to take this job."

F. Physical Space and Planning Issues

Questions Asked:

- *What aspect of the new facility seems to work best?*
- *Did the process of planning the new facility contribute to better institutional understanding and support of science?*

Outcomes Determined:

When asked about major physical space issues, faculty and administrators at the eight institutions had quite different responses. At the University of Oregon, science faculty and administrators generally commented on the spectacular atrium and how the space has had "important emergent properties, fulfilling roles beyond those for which it was intended." At Grand Valley, the architect responded, "Our biggest challenge was keeping the existing facility functioning while the new structure was being erected around it." RPI is committed to a philosophy in which building design follows program support and, for the implementation of interactive learning, this may mean movable chairs on casters in square classrooms.

In general, a few space issues surfaced as important and sometimes overlooked. One of these was adequate space for telecommunications equipment: controls, switching equipment, and networks. These require rooms, not closets. Informal space for student and faculty interaction, while addressed in these eight projects, can be either overlooked or cut for budget reasons. The lesson of these eight project is that these informal spaces are often singled out as the most important spaces in the building, spaces that generate unanticipated benefits in contrast to the anticipated benefits of laboratories and classrooms.

The COV reflected on the failure to include science libraries in many of the projects, and would ask if this is part of a larger trend. They also noted that, in order to meet budgets, classrooms tend to be given lower priority than laboratories, and are inadequately equipped and as a result unimaginatively designed.

RENSSELAER POLYTECHNIC INSTITUTE

Rensselaer Polytechnic Institute (RPI) is creating a more interactive learning environment, one which engages students and makes them partners in the educational process. Interactive learning gives students opportunities to work in teams, much like in the real world. Students, faculty and graduate assistants can discuss problems as they arise, rather than at some later time. RPI's Strategic Principles of Interactive Learning include:

- Give students more control of the learning process
- Promote innovative and cost-effective pedagogies
- Promote relevant curricula
- Develop new learning environments and facilities
- Foster multidisciplinary/cross-school collaborations
- Reach out to new markets

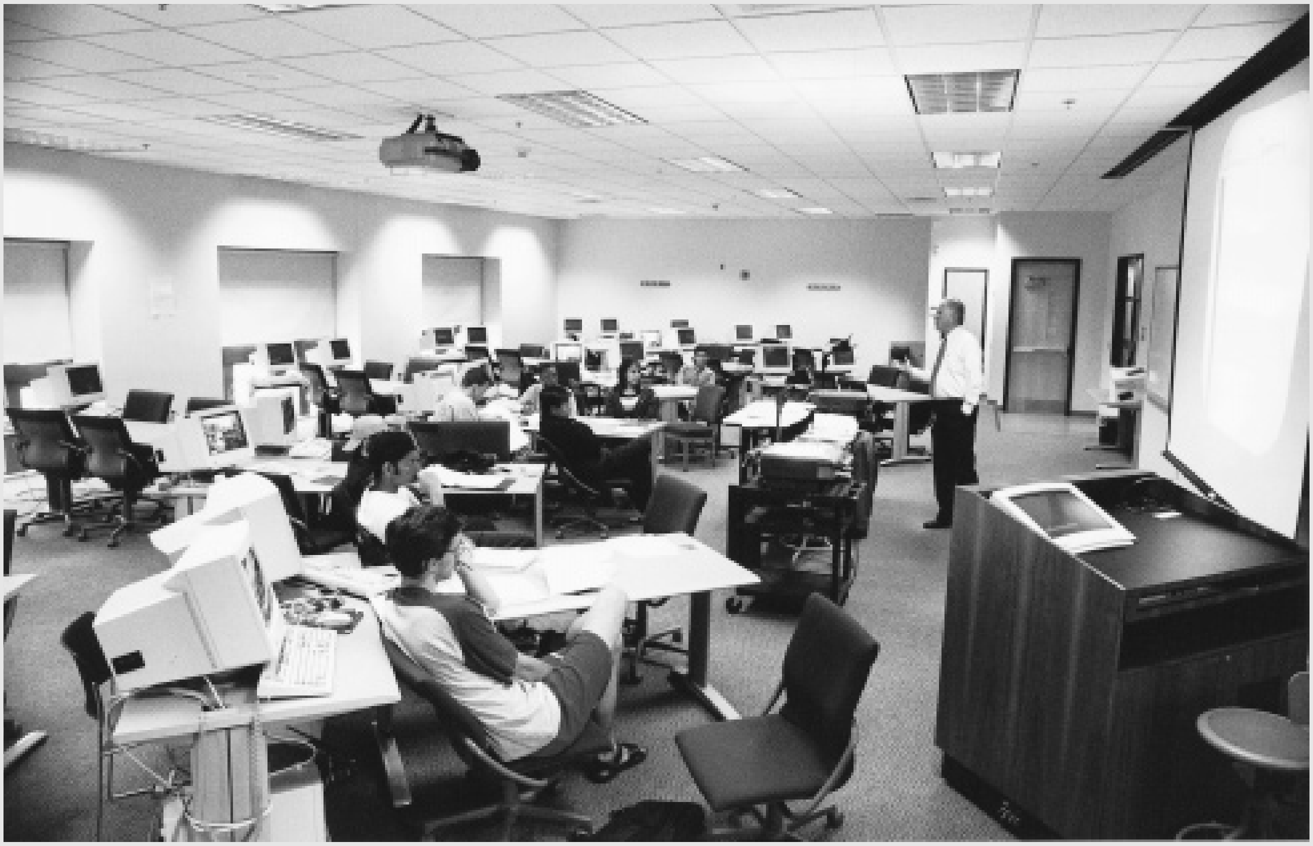
RPI renovated Walker Laboratory in 1994 to meet these changes in curriculum. RPI's Walker Laboratory, constructed in two phases (1904 and 1922), has housed instructional chemistry since 1904. Before the 1994 renovation, many of the original laboratory benches were still in use. The building was wasteful of energy, had no temperature control, and there was no computer networking on a large scale. The renovated facility has two floors devoted entirely to first-year chemistry classrooms, and laboratories in which all RPI undergraduates can take either chemistry or a highly innovative Chemistry of Materials course (a course specifically designed so engineering students could combine the principles of chemistry with the solid-state emphasis traditionally taught in materials engineering courses).

To foster the interactive learning environment, computer classrooms are separated from the laboratories only by window walls. In the classrooms, all computers are attached to the campus network and to the Internet, with the desks arranged in a "T" with two PCs on the top four seats around the leg of the T. The computer rooms can hold 64 students, with an instructor's podium and computer projection device attached to the instructor's computer. There are two screens in the rooms, one for the computer projector and one for a conventional overhead projector. The floors are raised and computer cables run underneath it; the floors are made up of square metal tiles that are easily removed so the room can be reconfigured. Carpet squares are on top of the tiles. Small rooms are available for students to relax and study in close proximity to the computer rooms.

The four laboratories in Walker used for instructional chemistry are wired for computing. Student stations have built-in keyboard trays and CPU storage shelves. Each lab has two double benches in the center of the room and benches, storage cabinets and fume hoods around the outside wall. Specially designed portable fume cabinets can be used by each team and stored under the laboratory bench when not in use; this has proven to be an innovative and economical design.

Offices for faculty and teaching assistants, a small conference room and café are on the fourth floor. A mezzanine "bridge" functions as an observation gallery onto laboratories and classrooms. Vision glass is an important element of the design, creating a physically and psychologically open environment, promoting awareness and interaction, and supporting recruiting functions.

Organic chemistry and inorganic structures and analysis laboratories and two smaller computer rooms are on the level below. Instrumentation rooms with sophisticated instrumentation such as nuclear magnetic resonance, Fourier-transform infrared, thermogravimetric analysis—often found only in graduate or research laboratories—are also on this level.



The next level down houses the stockroom and a biochemistry laboratory, which has a built-in cold room. The rest of the floor is devoted to mechanical equipment and an instrument repair facility.

New east and west towers provide a prominent entrance structure and house HVAC equipment. As part of the renovation project, designed by architects from Harza Northeast, the building's windows and copper-clad roof were replaced, exterior walls were insulated for energy efficiency and electrical and ventilation systems were upgraded to meet current standards. The renovation of the Walker Laboratory Building and its preservation of the green-roofed campus at RPI received the "1996 Historic Educational Building Award" from the Preservation League of New York State.

Washington & Lee University Science Center

Lexington, Virginia

Architect: Payette Associates Inc., Boston, MA

Lab Design: Payette Associates Inc., Boston, MA

Size:

New Construction:	83,000 GSF
Renovation:	93,000 GSF

Construction Cost: 18,600,000

Delivery Method: Construction Manager

Net Square Feet:

Biology	16,840
Chemistry	15,460
Common Space	2,300
Computer Science	2,200
Geology	10,275
Physics & Engineering	11,275
Psychology	8,175
Science Library	10,200
Shared Instruments	9,000
University Classrooms	9,460
Animal	1,510
Total	88,595

Net/Gross Ratio: 50%

Completion Dates:

Phase I	June 1996
Phase II	April 1997
Phase III	August 1997

Building Population: 500

Washington and Lee University, a liberal arts institution with under 2,000 students, intended to strengthen its undergraduate science program by making major improvements to their two existing science buildings as well as constructing an addition to create a single Science Center complex. The new center contains the Chemistry, Geology, Biology, Physics and Engineering, Psychology, and Computer Science Departments. Additionally the six independent departmental libraries, located in separate buildings, were combined into one unified library as a focal point within the new Science Center.

The new portico creates a single symbolic entry for the Science Center which reflects the architectural context of the campus.

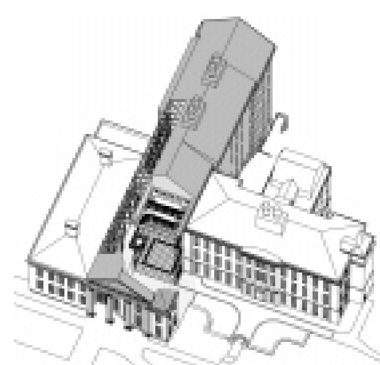
The traditional classical revival architecture of the campus presented a familiar challenge to the architect and campus planners. The facility needed to be harmonious with the existing character of the campus while still managing to create a technologically advanced Science Center that embraces the future.

Budget and flexibility requirements required a modular approach to the design of the teaching labs.

Design Principles

Working with a program document prepared for the university by Dober, Lidsky, Craig and Associates, Inc., the architect, Payette Associates, developed a three-stage phasing strategy that eliminates double moves and renovation around occupied space. The addition contains the hood-intensive chemistry department on the upper two floors and geology below. After these two departments moved into the addition, Howe Hall was totally renovated. After, biology and physics moved into Howe.

Parmly Hall, the final phase, began total renovation for psychology and computer science. The scheduling of the construction around the academic calendar with summer moves allowed for minimal interruption of ongoing classes. This phasing strategy allows for more new space and less disruption by not wasting time and money on double moves and difficult scheduling around ongoing occupancy in existing buildings.



The new addition is inserted between two existing building.

The Great Hall provides a major interaction space for the Center.

The Great Hall looking towards the library.

The planning principles for the departments called for a strong adjacency of teaching lab to research lab to faculty office. In the new addition the chemistry and geology teaching labs and support spaces were located on one side of a double-loaded corridor with research labs and offices located on the other side. The central core of the addition contained the ADA accessible elevators and toilet rooms. The 1925 Howe Hall accepted a certain amount of modular renovation for biology and physics, but the 1962 Parmly hall was less flexible and lent itself to the less modular psychology and computer science programs.

Science Center Organization

The new Science Center is organized by a central circulation spine and a Great Hall from which students can access the six departments. The library is in a “Head House” at the main entry and is the symbolic and literal focus of the Center and Great hall. Additionally the library’s location encourages non science majors to visit the Center. Along with these communal spaces there are centrally located shared-instrument rooms, university classrooms, and computer labs. They are all accessible to each of the six departments and the general student population in order to facilitate interdisciplinary studies within the sciences and the university at large.

The architect developed a three-stage phasing strategy that eliminates double moves and renovation around occupied spaces.

Interaction

The Great Hall was designed as the major interaction space in the Center; the “Front Door” to all the departments are off this space. The library, which overlooks the Great Hall, was programmed to facilitate learning for various sized groups, single study carrels, double study carrels, round tables for four, and several small meeting/study rooms. Additionally, corridors were designed throughout the Center. Many of these areas have blackboards and seating to facilitate impromptu discussions.

Typical physics lab with power grid located above.

Summary

The COV recognized the potential opportunity for new spaces to catalyze campus-wide discussions about the power of new technologies and pedagogical approaches. The importance of science and technology in a quality educational program for the 21st century was also made clear through the COV visits–from the experience of campuses where this happened and on those campuses where it did not.

The COV found the most benefit when:

- there is widespread and accurate communication within and beyond the institution about the intent of the project in regard to student learning
- the importance of the project to the institutional future is emphasized
- the involvement of building users–including students, faculty, support and technical staff, alumni, and others–has been extensive
- planning has taken place in context, relating to other disciplines, and buildings; environmental and community concerns have been considered.

Carleton College

Northfield, Minnesota

Center for Mathematics and Computing
42,000 GSF
Project Cost: $6.5 million
Completed: September 1993

Hulings Hall for Biological Sciences
73,000 GSF
Project Cost: $15 million
Completed: October 1995

Carleton College, a residential, coeducational, liberal arts college founded in 1866, has a distinguished reputation for the intellectual rigor of its academic program, the distinction of its faculty and the selectivity of its 1,850 students. In 1996, 34.33% of its seniors graduated as science majors.

Project Description. These two facilities are the culmination of a 10 year plan that also includes renovation of Mudd Hall of Science and Olin Hall. The Center for Mathematics and Computing (CMC) was competed in 1993. The four-story building houses the Department of Mathematics and Computer Science as well as the Mathematics Skills Center and Library, eight computing laboratories, Academic Computing and Networking, and Administrative Computing. In 1995 (phase two), Hulings Hall was completed for the Biology Department and a portion (neuroscience) of the Psychology Department. Phase three involves renovation to Olin and Mudd Halls.

Impact. A significant impact of the new Center for Mathematics and Computing (CMC) and Hulings Hall has been empowerment to use technology to the highest degree in both buildings for teaching and scientific research. One impact of the widespread use of the latest computer technology has been a spillover into other non-science disciplines, particularly in the popularity of computer classrooms and in the encouragement of innovative teaching and learning with computer-enhanced technology. Another impact has been an increase in communication among departments as a result of bringing them together in CMC. Space for informal student use in CMC works so well that students use it day and night. While the sciences have always been strong at Carleton, CMC and Hulings have fortified this position.

Claremont McKenna, Pitzer and Scripps Colleges

Claremont, California

W. M. Keck Science Center

81,193 GSF
Construction Cost:
$12.1 million
Completed: November 1991

The W. M. Keck Science Center is home to the Joint Sciences Department of Claremont McKenna, Pitzer and Scripps Colleges (total enrollment: 2,400), three of the five independent, undergraduate colleges in Claremont (the others are Pomona and Harvey Mudd). This interdisciplinary science department was established in the 1960s to provide physics, chemistry, and biology courses at a time when science was not emphasized in the educational missions of the colleges. Since then, the program has grown with strengthened science requirements and increasing science enrollments. In the mid-1980s, faculty and administrators began planning for a new facility, strategically located at the intersection of the three colleges, to replace the existing, aging science buildings.

Project Description. The Keck Science Center is a handsome three-level structure in two wings that enclose a central courtyard. Its floor plan encourages interaction among students and faculty; informal seating areas are located on each level facing the central courtyard. Laboratories are organized as open, structure-free spaces. Utilities are housed in vertical shafts in adjacent corridors.

Impact. The greatest impact of the Center has been strengthening the role of the sciences at the three colleges and adding to the prestige of the program. The location of the Keck Science Center at the intersection of the three campuses enhances the presence of science, and the building's appearance and functionality attract students. Science enrollments, particularly in biology, have increased dramatically since the Center opened in January 1992. The building, deliberately designed to encourage faculty and student interaction, has also contributed significantly to improving faculty morale.

Grand Valley State University

Allendale, Michigan

The Seymour and Esther Padnos Hall of Science

159,282 NSF
Total Project: 293,195 GSF
Total Construction Cost: $41 million
Completed: January 1996

Grand Valley State University was established in 1960 as a public undergraduate institution committed to serving the needs of the residents of West Michigan. The dual mission for the University is to provide programs needed for the professional and personal advancement of the people of the region and to provide and maintain a high quality of undergraduate education. The current student population is 16,000.

Project Description. The Padnos Hall of Science, the final building of a construction project designed to meet burgeoning enrollments, opened in 1996. The other members of the large three unit "Science Complex" are Henry Hall and the Student Services Building, both of which opened in 1995. An inviting building, three-story Padnos Hall is committed to undergraduate science education including chemistry, biology, anatomy, health science, geology and physics. In addition to research and instructional laboratories, and faculty offices, Padnos Hall houses the Water Resources Institute, a Math and Science Center and The Learning Center.

Impact. Padnos Hall of Science has increased classroom and laboratory space for growing enrollments, increased research and office space for faculty, and improved access to sophisticated technological/ computer systems for teaching and research. The facility has enhanced informal student and faculty interaction; and affirmed the importance of science at Grand Valley. It is a modern, exciting and inviting building and faculty are enthusiastic about working in it. Padnos Hall has four features that deserve special mention: The Learning Center, run by and for students; research facilities and significant research opportunities for students and faculty; the Water Resources Institute, a source of outreach and student research; and an abundance of glass and art throughout the building.

Kennesaw State University

Marietta, Georgia

The Science Building

103,911 GSF
Construction Cost: $15 million
Completed: January 1996

Located 30 miles northwest of downtown Atlanta and serving students in its vicinity and northwest Georgia, Kennesaw State University is one of the fastest growing institutions in the university system of Georgia. All students reside off campus and commute to Kennesaw. Responding to the need for accessible undergraduate, graduate, and public-service programs, Kennesaw offers day, evening, and weekend classes. The University's diverse student body includes many older adults. Over 40% of Kennesaw's 13,094 students pursue their academic goals on a part-time basis.

Project Description. The Science Building has provided critical expansion space for classrooms and laboratory facilities, created space for student-faculty projects and directed research, and is setting a campus-wide example for the use of computer and audiovisual technology in teaching. Science departments are housed together for the first time (previously, several had been in trailers) in the building's 64 teaching faculty offices, four classrooms, and 19 instructional laboratories. The building's 1,600 Internet data outlets doubled the number of campus connections. Every laboratory station has an outlet and the classrooms have floor boxes for data, power, and Internet connections.

Impact. This building is a clear example of the highly positive impact of a well-planned and constructed facility on teaching and learning. The infrastructure for computer and audiovisual technology is excellent. Dedicated space for student research allows robust implementation of the College's mission to train students in applied sciences. The generic design of rooms, emphasized throughout, allows flexibility and multifunctional use. Attractive spaces, particularly the atrium, have led to an increase of interaction among faculty and students. Faculty and student morale is high.

Rensselaer Polytechnic Institute

Troy, New York

Walker Laboratory (renovation):
50,000 GSF
Cost: $11 million for renovation; $2.5 million for equipment
Completed: 1996

Established in 1824 in Troy, New York, Rensselaer Polytechnic Institute is an independent, non-sectarian, coeducational university recognized internationally for its technological, engineering and science programs. Approximately 4,500 undergraduates and 1,500 graduate students are enrolled in five degree-granting schools. The renovation of Walker Laboratory was designed to implement Rensselaer's innovative approach to teaching science.

Project Description. Built in 1906 as one of the original campus buildings, Walker Laboratory had become inadequate for teaching chemistry by the 1980s. During the two-year renovation (1994–1996), the interior of Walker Laboratory was gutted and totally rebuilt to accommodate flexible high technology in support of interactive learning, with only modest alterations to the exterior. Some laboratories are adjacent to computer classrooms. Research grade equipment and multimedia computers complement spaces designed for "studio teaching," a pedagogy that replaces lecture time with student-faculty and student group discussions and problem-solving. The floors have a modular design with removable panels to allow changes in electrical connections if space and furniture are reconfigured. Because of space limitations in historic Walker, there is no room for faculty offices in the renovated building; faculty offices and laboratories for junior and senior students are in another building across campus.

Impact. With its highly sophisticated implementation of educational technologies and purposeful flexibility in laboratory and classroom design, Walker Laboratory enables Rensselaer to expand its successful program of "studio" teaching in chemistry. Tangible support from the dean and a system of faculty rewards for innovative course design encourages curriculum reform. Faculty, administrators and students are enthusiastic about studio learning. The renovated building also reinforces the historic core of the campus.

The University of Oregon

Eugene, Oregon

The Science Complex
(5 renovated and 4 new buildings)
250,000 GSF (new) and
150,000 GSF (existing space)
Cost: $45.6 million
Completed: 1990

The University of Oregon at Eugene, with 17,138 enrolled students in 1995, is the Oregon state system's flagship institution for the arts, basic natural sciences, social sciences and humanities, with a rich heritage in campus planning policy, begun by Ellis F. Lawrence, campus architect from 1914–1940. Lawrence's plans were ignored during a mini-building boom at the University in the '60s and '70s when five science buildings were added with unfortunate results. Planning for the Science Complex in the mid-1980s resurrected Lawrence's guidelines and the resulting nine-building Science Complex harmonizes very well with the rest of the campus while providing improved, attractive, expanded spaces for science education and research.

Project Description. This ambitious project is the result of a participatory planning process that successfully incorporated the ideas of faculty and administrators. A central feature of the organization of the science units is the integration of the University's interdisciplinary institutes (e.g., molecular biology, chemical physics) with science departments. Departments are located in individual but connecting buildings (vertical integration) and institutes are located on the same floor of each building that houses a related department (horizontal integration). The new and renovated structures are handsomely embellished with interior and exterior artwork and provide ample social space.

Impact. The project updated and expanded the University's science facilities, recaptured the essence of an innovative original campus plan, and transformed a portion of the campus. It has reinforced the interdisciplinary linkages between departments and research institutes, and added important public and social spaces, thereby contributing to the prominence of the sciences. The new facilities have had their greatest impact on research; some undergraduate curricular innovations have also resulted.

Washington and Lee University

Lexington, Virginia

Parmly, Howe and Great Halls

83,000 GSF new construction (Great Hall)
93,000 GSF renovation (Parmly and Howe Halls)
Total: 88,595 NSF
Project Cost: $23.2 million
Completed: August 1997

Located in Lexington, Virginia, Washington and Lee University is an independent, non-sectarian, and privately endowed liberal arts institution with just under 2,000 students. Founded in 1749, Washington and Lee emphasizes learning, service and personal honor and attracts top students nation-wide.

Project Description. In this project, Great Hall was built between two older science structures (Parmly and Howe Halls) integrating and connecting all three. The Science Center houses the Chemistry, Geology, Biology, Physics and Engineering, Psychology, and Computer Science departments. Six department libraries have been combined into a central science library in Great Hall and this serves as the focal point of the facility. An atrium serves as the Center's living room, providing social space for the entire campus as well as the sciences.

Impact. The ingenious design integrating Great Hall with the existing science buildings added improved space for science while preserving two classic campus structures. Science is now taught in expanded, safe facilities with the advantages of classroom and laboratory computing technologies and accessible instrumentation. Students now spend more course time in a laboratory setting, which has a positive impact on student learning. Faculty response to the Science Center has been extremely positive. Students are enthusiastic about the facility and use its informal social spaces in corridors and the atrium.

Xavier University of Louisiana

New Orleans, Louisiana

Norman C. Francis Science Center

85,000 GSF
Project Cost: $20.8 million
Completed: 1988. An addition to the Center of 100,000 GSF opened in June 1998.

Xavier University, which dates back to 1915, is an historically black, Catholic university, located in the inner city of New Orleans. Consistent with the school's original mission to provide higher education to blacks, 88.9% of its students are African-American. More than half of Xavier's 3,500 students major in the natural or health sciences, and Xavier has successfully placed more African-Americans in medical schools than any other U.S. college. Xavier's extraordinary commitment to its students is reflected in its emphasis on student mentoring, on quality, student-centered learning, and in its encouragement of student-faculty research and publications.

Project Description. The original occupants of the 1988 Francis Center included, in addition to science departments, the departments of Mathematics, Philosophy and Theology. To accommodate enrollment increases, these departments moved to other locations and a number of renovations to the reallocated space created laboratories and offices. Francis Center now houses the departments of Biology, Chemistry, Physics, Computer Science, and the Information Technology Center. The space added in 1998 includes a Mentoring Center and a computer laboratory.

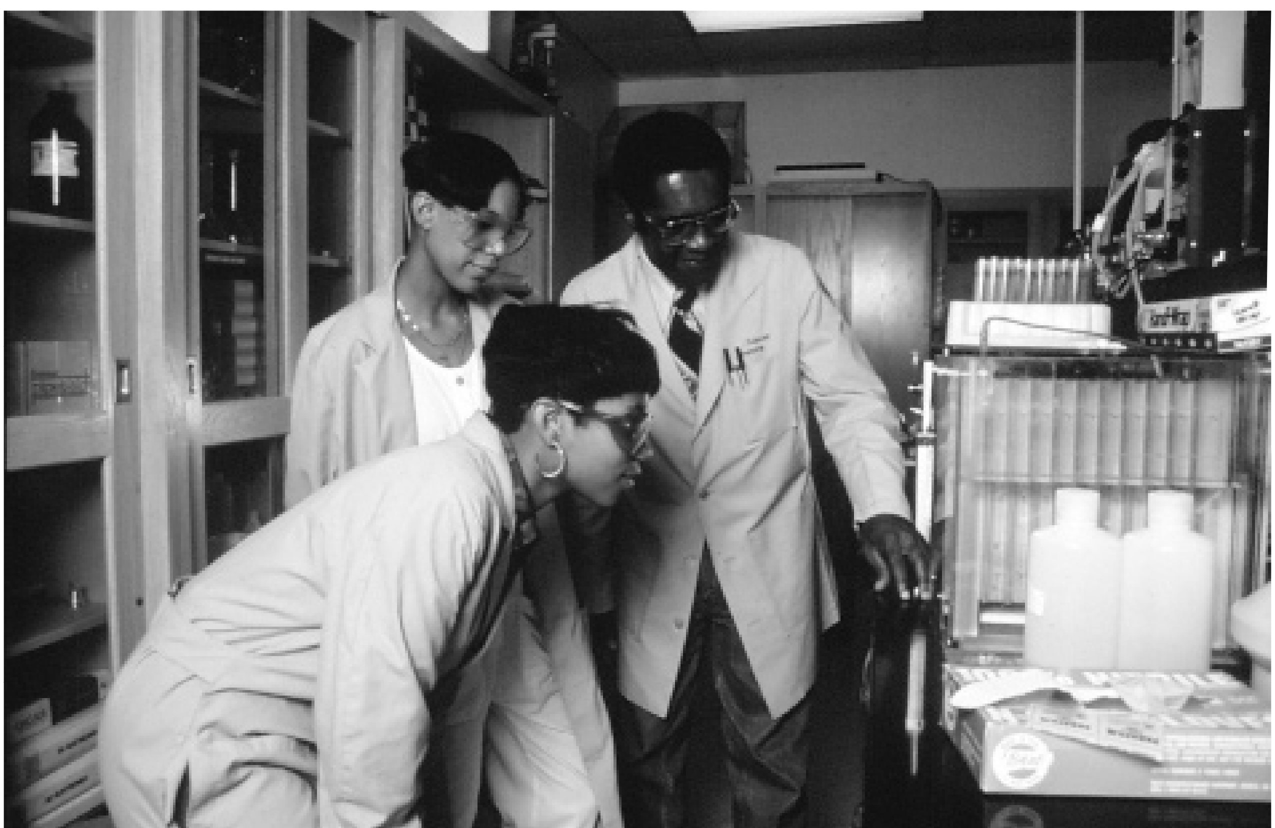
Impact. Because of the growth of Xavier's student body (80% between 1986 and 1994), space in the "old" Francis Center has been at a premium. Renovation of spaces vacated by non-science departments, and renovations funded by government and foundation grants, enabled science departments to continue student and faculty research programs and paved the way for raising funds for the new addition. The new spaces facilitate the implementation of Xavier's institutional policy of extraordinary commitment to its students.

ABOUT PROJECT KALEIDOSCOPE: FOCUSING ON FACILITIES

Project Kaleidoscope (PKAL) began Phase II (1992–1997) with a workshop on planning facilities, believing that one of the most formidable barriers to ensuring access for all students to research-rich learning communities was the inadequate physical environment for learning. In the past five years, with support from the National Science Foundation, PKAL has hosted sixteen facilities planning workshops, with over 300 colleges and universities sending teams to one or more of these events. A modest estimate is that renovation and new construction projects represented by participating institutions total over $2 billion.

PKAL Volume III: Structures for Science–A Handbook for Planning Facilities for Undergraduate Natural Science Communities, published in December 1995, captures the experience of these workshops.

The focus on facilities and the publication of *Structures for Science* was another critical step for PKAL, in at least two ways. First, in addressing a critical issue of common concern to colleges and universities of all sizes, with differing missions and student populations, it illustrated much could be gained as institutions learned from and worked together across the various sectors of higher education. Second, through a focus on the physical infrastructure, the need for kaleidoscopic reform became more tangible, as colleges and universities began to take more seriously questions about who their students were, about faculty roles and rewards, and about education in a changing world.



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As the Report was evolving, many people had the opportunity to comment on its direction, scope, and intent. Their critical comments helped to ensure that the final product would serve the undergraduate SME&T community most effectively. To these all we say thank you.

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