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STRACT

This report is the first of a series which present
e results of a systems analysis of the problem of providing science
d engineering buildings at the university level conducted by the
ademic Building Systems (ABS) program. The document includes (1) a
er survey (data and conclusions from a series of studies involving
spectrum of individuals, disciplines, and space types, and
ncerning activity patterns in, and reactions to, existing
cilities); and (2) background studies of academic methods made to
certain the ways academic buildings may have to meet the needs of
ture users. Appendixes and a 126-item bibliography are included.
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environmental study ABS

1 science and engineering buildings

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PREFACE

The changing character of the sciences is now an accepted phenomenon. Yet there is remarkably little documentation about the nature of changes taking place or those that may be expected. What are the influences acting as agents of change? What will be their impact on future building design and construction? These are significant questions requiring answers if the nature of adaptability needed in science and engineering buildings is to be clearly determined.

Certainly, a major academic building—during its useful life of a half century or more—will need to accommodate many different activities and their environmental requirements. And, during this half century, technology, teaching methods and subject emphasis, as well as university size and organization, will be continually changing. Obviously, there is need for academic buildings that can be easily modified or altered to accommodate changing requirements.

Thus, a fundmental objective of ABS research has been to determine the degree of adaptability needed. Buildings for sciences and engineering were especially appropriate for study because these disciplines are complex, require relatively high rates of change, and involve space types (offices, classrooms and laboratories) common to many other academic disciplines. The ABS research involved four main lines of enquiry: User Requirements, Performance Standards, Cost Base, and Subsystems Options.

This document presents data and conclusions resulting from a series of user studies, involving a spectrum of individuals, disciplines and space types, concerning activity patterns in, and reactions to, existing facilities. Additionally, background studies of academic methods were made to ascertain the range of ways academic buildings may have to meet the needs of future users. These studies also provided insight into the attributes and functions of the university as a complex social system of aims, values and personal relationships.

Environmental requirements are thus reviewed in the context of the user's experience. The major intent has been to establish the range of activities and environmental conditions that the ABS system must accommodate. It is believed that this information will stimulate new creative thinking in the programming and the designing of academic facilities, and will set a pattern for extending such studies.

TABLE OF CONTENTS

USER SURVEY

BACKGROUND

Building user requirements are those requirements originating in the needs of the various users that must be met by the programming, design, construction, and operation of a building. Whereas in programming a building, specific requirements for a particular group of users must be stated within an academic context, this study is concerned with only "general requirements of academic buildings"—those requirements that are basic to the nature of learning, teaching and research activities.

The main thesis is that future academic buildings must be seen as structures capable of accommodating a changing variety of space types and departments. Departments must become accustomed to being tenants rather than owners of buildings. The single function of the single department building for classrooms or for a single discipline is no longer appropriate to the pace of change on the campus.

This study presents a general picture of three aspects of university academic buildings. These aspects are:

1. The various kinds of users of academic facilities.
2. The typical activities of the users: teaching, learning and research.
3. The environment and characteristics of academic buildings in which the users perform these activities.

Throughout the study, emphasis is on activities and corollary requirements rather than on building types. The principal focus is on the common attributes of users and their environmental requirements whether they be students, staff or faculty in engineering, the sciences, or other disciplines. Differences are also noted as appropriate.

Assumptions. The user study has been performed against the background of certain underlying assumptions about the nature of academic buildings and building users. In general, these assumptions have proven valid. The assumptions are as follows:

1. Similar basic activities impose similar requirements on the physical environment, regardless of administrative or geographic location. For example, reading, writing, typing, or conducting a seminar require similar physical conditions on different campuses regardless of geographical location.

2. Similar basic activities impose similar environmental requirements regardless of the specific disciplines involved. For example, a professor of bio-chemistry, a graduate student in civil engineering, and an assistant professor in psychology will require similar environmental conditions for reading, writing, or conducting a seminar.

3. Certain common characteristics exist in the required environment regardless of geographic or administrative location or discipline. In addition, specialized conditions are required by different activities, geographical locations, individuals.

4. An academic building during its useful life—of more than half a century—should be able to accommodate the environmental needs of many activities. In view of present and future resources, treating every requirement with a customized solution is neither necessary, desirable nor feasible.

Method of Investigation. A major intent of the ABS program is to develop a means whereby universities can begin to construct areas of generic space, with indeterminate programs, but with confidence, because of the ABS system, that their program needs will be accommodated. To this end, data collection for the user study relates to a spectrum of space types and disciplines. The method of data collection has been as follows:

1. Preliminary pilot surveys of faculty reactions to existing academic buildings by University of California staff for building systems projects.

2. A two-day conference attended by 25 faculty representatives from nine University of California campuses seeking reactions to existing academic building environments and ideas for future planning.

3. A series of background studies exploring academic methods for future trends that indicate a different emphasis in the way buildings may have to meet the needs of users.

4. Individual interviews with academicians and administrators (see listing, Appendix B) to provide testimony on current trends in teaching and research and corresponding facilities requirements.

5. Interviews, by project teams, of users of academic buildings on Indiana and California campuses. Six buildings were selected for study as representative of the building types likely to be designated as ABS demonstration projects by the two universities. These types were biological sciences buildings in California and engineering buildings in Indiana. Detailed cost/performance studies of the same six buildings are summarized in the ABS publication: *Cost/Performance Study: Six Sciences and Engineering Buildings*. These buildings are as follows:

   a. Biological Sciences Unit 3 (Storer Hall), University of California, Davis, California.
   b. Natural Sciences Unit 1, University of California, Irvine, California.
   c. Biological Sciences Unit 2, University of California, Santa Barbara, California.
   d. Jordan Hall, Indiana University, Bloomington, Indiana.
   e. Krannert Hall, Indiana University and Purdue University, Indianapolis, Indiana.
   f. Civil Engineering Building, Purdue University, Lafayette, Indiana.

Some 150 persons from the six sample buildings—staff, students and faculty—were interviewed in groups of six for three-hour periods. To start the interview sessions, the consultant provided a form whereon participants were asked to indicate the space types most commonly used for their activities. Thereafter, the discussions were free-ranging with interviewers attempting to let points of emphasis emerge from the groups. That sought from the interviews was information on user activities, and the user's estimate of the extent to which present buildings supported these activities.

This section summarizes the interview notes of the consultant. The attitudes expressed, and quotations, where used, have been selected because they were typical.

THE USERS

Users of academic buildings can be broadly classified in two groups—direct and indirect. The direct users are those persons occupying or regularly using space in a building. They include faculty, students, laboratory technicians and administrative non-academic staff. Indirect users are persons who by virtue of their responsibility must make decisions ultimately affecting building design, operation or maintenance. The indirect users include university programmers, architects, building committees, building managers, custodians, and physical plant personnel.

Perhaps one of the greatest barriers to effective planning is that these two groups have somewhat conflicting interests in a building. The direct user is primarily concerned with obtaining enough space and equipment to support his activities in a comfortable environment. The indirect user is responsible for buildings being constructed and maintained within the constraints of cost and time as often imposed by funding agencies and others. These values conflict to the extent that the direct and indirect users do not understand one another's problems.

An architect, in developing his design, must reconcile the conflicting values of the indirect and direct users. At the same time, he introduces a third set of values deriving from legitimate concerns such as his professional integrity and the objective application of accepted logic and aesthetics. He may also have a personal need for self-expression. Communication and an honest expression of differences between the users (direct and indirect) and the architect is paramount to understanding user requirements.

Translation of user requirements into building requirements traditionally occurs during the programming stages of a project. One faculty member interviewed described the programming process as a "balancing act." He felt that those involved should refer back to the users more often, pointing out that compromises are often negative and that either of two extremes may be better than a compromise which satisfies no one.

A statement of user requirements is initially unrelated to constraints of cost or time, but an architect must inevitably work within these constraints. In doing so, his solutions may involve compromises that disappoint the users. Each user, by clarifying his priorities, can assist the architect. Similarly, the architect can help the user enormously to establish these priorities if he explains the alternatives available within the relative constraints of cost or other factors that apply to these choices.

Chart 1

USER'S CHART

USERS	DIRECT	INDIRECT
Campus Administration		President, Chancellor, business office.
Faculty	Department heads Professors Associate Professors Assistant Professors	May be involved in building and space allocation committees at campus or departmental level.
Faculty-Students	Teaching assistants Research assistants	
Students	Graduate Upper division Lower division	
Staff	Departmental secretaries Faculty secretaries Laboratory technicians	Maintenance personnel (departmental, building) buildings and grounds, personnel (campus).
Others	Visitors	

ACTIVITIES

To gain insight into activity patterns and space use in academic buildings, interviews with students, staff and faculty were conducted in terms of *what individuals do*—not in terms of what they want. Thus, a portion of all interview sessions was devoted to brief reports of each person's activities. The activity reports were further amplified by in depth group discussions of space use, and individual and group needs for teaching, learning and research activities. Those activities typically performed are outlined herein. Subjective reactions to the existing environments and implications for space design are discussed in subsequent sections.

The direct users of an academic building are typically engaged in four categories of activity as follows:

1. Activities involved in the formal *teaching and learning* process.
2. Activities related to *research*.
3. Activities of the *community* within a building, comprising a mixture of academic, social, formal and informal functions.
4. Various activities of *individuals* in and around a building.

Although these must necessarily be overlapping (i.e., individual activities also belong in each of the other categories), such broad categorization assists in providing an overview of activities performed in academic buildings, in relation to both group and individual space needs and environmental requirements.

TEACHING AND LEARNING ACTIVITIES

In recent years, universities have tended to emphasize upper division and graduate instruction and the research inherent in these levels. Concomitant changes in curricula have not, however, altered the basic forms of teaching and learning. Despite change, the classroom remains the principal place for disseminating information and exchanging problems and solutions. And, the fundamental tools for teaching and learning continue to be the textbook for study and a teacher demonstrating lab processes or lecturing to a group of students.

Traditionally, lower division courses in a university are introductory courses designed for large numbers of first and second year students. Such courses are usually taught by a professor lecturing from a podium (equipped with demonstration bench and sliding chalkboards) to a class of several hundred students for approximately an hour. The lecture hall is often equipped with TV monitors, strategically located, to convey the details of demonstrations throughout the hall. Slides or films may also be projected onto these monitors.

Despite criticism of the impersonal nature of undergraduate instruction, classroom size generally remains a function of cost and the large lecture session persists. Universities are increasingly being forced to expand the size of lower division classes in which unilateral information is delivered, while attempting to hold down the size of graduate courses involving bilateral problem solving. Overall costs and shrinking budgets are dictating higher student to faculty ratios, increased use of technology to stretch instructional talent and use of parafaculty or graduate student teaching assistants.

Thus, although an undergraduate student may visit a professor in his office, consult with his advisor, or in some cases arrange for individual or group study under the supervision of a faculty member, his contacts with the faculty are extremely limited. In contrast, graduate level courses are commonly organized as seminars or small discussion groups meeting for approximately two-hour periods. A graduate student, because he performs his research in the laboratory of the professor in charge of his studies, has more opportunity for faculty contact than an undergraduate student.

Innovative programs replacing traditional lecture and laboratory methods have proven successful, both in improving educational quality and in alleviating shortages of money and space. Successful innovative programs include taped television lectures played and audio-tutorial programs. Tests indicate that TV lectures are an effective means of instruction, although some students prefer a more personal live lecture presentation of material. Audio-tutorial programs appear to be superior to conventional lectures, as they allow a student to repeat a week's course, if necessary, to ensure that information is completely assimilated.

The photograph below shows audio-tutorial facilities in Jordan Hall at Indiana University. These arrangements were designed and built by the building staff.

Originally the room was a teaching laboratory designed for forty-two stations. Now, thirty audio-tutorial booths have been arranged on the existing laboratory benches with the other twelve spaces forming a demonstration area. If necessary, the booths can be removed and the space reverted to conventional laboratory use.

Facilities requirements and space use vary significantly among disciplines and by student level. Characteristically, in the Humanities, a student performs much of his research in the library; in the Sciences, individual exploration takes place in the laboratory. Mathematics courses are seldom laboratory courses but often require the use of computer facilities. The percentage of time spent in a facility varies with the academic level of a student. Most students in the sciences are involved in at least one laboratory per day; however, a lower division student may spend 10% of his time in the lab; an upper division student 50% and a graduate student 90%.

No scientist or educator today questions the value of laboratory experience in the sciences, at both undergraduate and graduate levels, but there is debate concerning the content and conduct of undergraduate lab courses. Traditional laboratory exercises performed by undergraduate students are not really experiments because the outcomes are known. Many educators feel that once a student has learned lab processes, even undergraduate laboratory experience should be truly experimental. At the same time, some professors question the competence of graduate teaching assistants to supervise the traditional undergraduate laboratory, and therefore prefer a TV demonstration as a surrogate laboratory.

The availability of laboratory space, equipment and supervisory talent all have an important bearing on the modus operandi. Use of the laboratory as an educational tool may range from pure observation to the physical manipulation of sophisticated equipment. Some laboratories are moving away from the use of actual equipment, converting to simulators requiring less space. Or, to meet industrial requirements, some departments have substituted small elements for heavy thermo-dynamics equipment.

Innovation and uses of technology in teaching will undoubtedly have important implications for the allocation of space and equipment in future academic buildings. The large lecture theater, also useful for audio-tutorial teaching, continues to be an important facility. But, as "fact" becomes transitory, courses are becoming more discussion-oriented and less lecture-oriented. Student participation with teachers acting as discussion leaders is becoming the form. Interviews with faculty during the ABS user study indicated that all disciplines would prefer small seminars and discussion groups to large lecture classes.

RESEARCH ACTIVITIES

Research activities are as varied as the number of individuals and disciplines involved. Despite this multiplicity, it is possible to distinguish three groups of activity resulting in the need for particular kinds of environment. These groups are:

1. Research activity consisting primarily of mental activity.
2. Research activities requiring relatively traditional laboratory space and services.
3. Research activities requiring very specialized space, equipment and services.

Much pure research—the search for new concepts or posing of questions—is most dependent on the human intellect and least dependent on equipment. For example, projects in mathematics are predominantly intellectual, requiring only an office for reading and writing, a blackboard and possibly a computer terminal. Pure mathematicians, as opposed to number theorists, do not even use computers.

Similarly, much research in psychology requires no more than the ability to gather small groups of people together and to utilize a paper, pencil and possibly a slide projector and tape recorder.

The majority of scientific research requires relatively traditional laboratory spaces and services. Such activities are normally performed in conventionally sized spaces—large or small laboratories—offering a variety of conventional services. The requirements for services, however, vary enormously among disciplines and individual researchers. Hence, it is indeed futile to attempt to predict all the needs. Instead, the need is for expandable or divisible spaces to which a variety of services can be readily supplied.

Research activities requiring traditional laboratory space characteristically involve the use of instrumentation. Both the natural and the physical sciences disciplines now use electronic equipment. In biology, for example, electronic means are used to study animal behavior patterns. The type of instrumentation used affects the spatial and environmental requirements. Two examples of different kinds of experimentation requiring instrumentation are as follows:

1. Psychologists studying memory and verbal learning need spaces with connecting wiring between rooms to link people with equipment. Controlled environments, such as sound-proof and light-proof rooms, may also be required. Computer-run experiments may require special electrical shielding and controlled environment for the computers. However, research in psychology seldom requires unusually large spaces or spaces with high floor-loading capacities.

2. Experimentation in the natural sciences requires readily available multiple services and precisely controlled conditions. Low electrical voltages or temperature controls with small tolerances are often necessary. With the exception of specialized equipment, such as electron microscopes, almost all activities require relatively small spaces and items of equipment.

Research activities generating the need for very specialized space, equipment and services are most typical of the engineering and physical sciences. Radiation hazards are often high. In high energy physics, high voltages and large amounts of power are essential. High energy accelerators require a cavernous space more than one story high, whereas laser research requires long, narrow, dark chambers.

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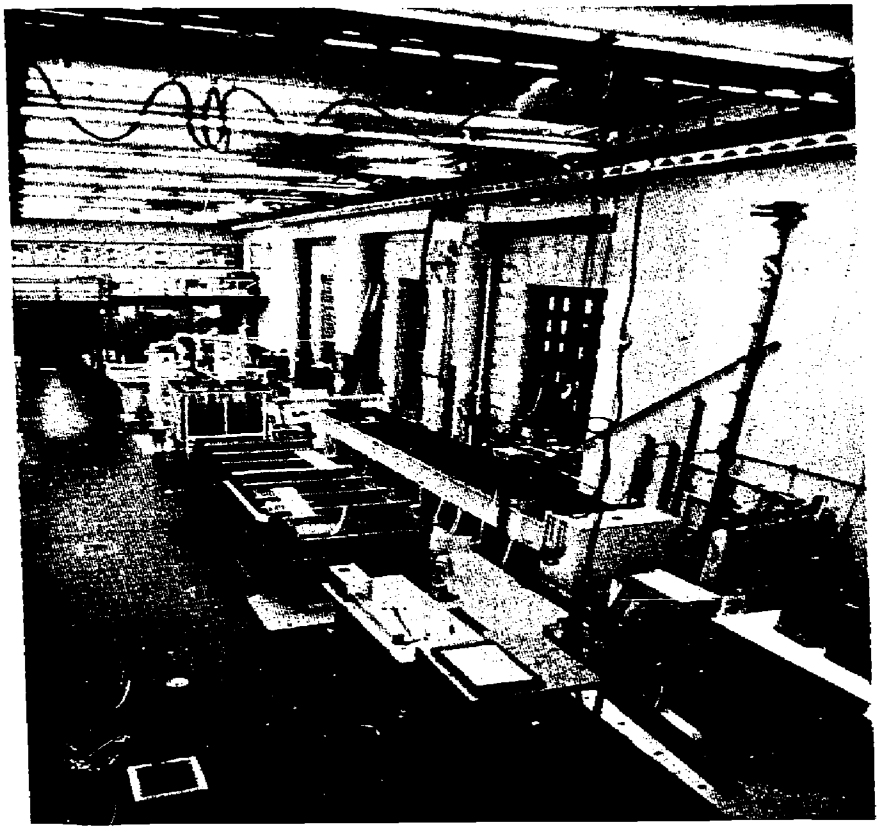
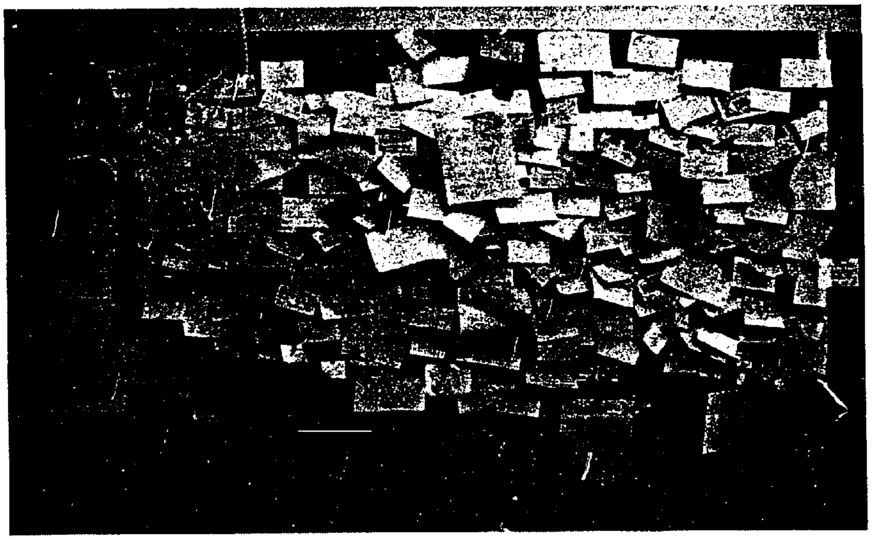


COMMUNITY ACTIVITIES

Direct users, in addition to structured teaching, learning and research activities, perform a multitude of activities within a community. The community is, first, the department and, second, the building, perhaps housing several departments. Although interaction among disciplines is becoming increasingly important, building design often isolates members of the academic community, making interaction difficult. In the buildings examined, the desired support for communication among the building community was universally lacking. Even departmental notice boards are often too small for the number of messages the community wishes to exchange.



The concept of a departmental community implies activity extending outward into the public community as well as internal interaction. Increased university involvement in public concerns is producing a need for greater unity among the various academic, social, and cultural communities. Just as advances in the state of knowledge are removing the barriers among academic disciplines, attempts to personalize the university environment are breaking down barriers among administration, faculty, and students. These movements are also closely related to new concepts of teaching and learning.

As yet, the idea that teaching, learning and research effectively occur in areas other than offices, classrooms and laboratories is relatively unrecognized in building programming and budgeting. Thus, informal, comfortable spaces for meeting in small groups are seldom obtainable except by programming subterfuge. The resulting lack of space for small group and community interaction within academic buildings was substantially noted by both faculty and students during the survey.

INDIVIDUAL ACTIVITIES

The following activity reports by faculty, students and staff represent typical days in the lives of the users interviewed.

Professor A (Indiana University). His major field is soil mechanics.

8:30 a.m.	Arrived at his office; prepared a lecture.
10:30	Taught a class in the same building.
11:30	Lunch
12:30 p.m.	Taught another lecture class in the same building.
1:20	Conferred with individual students in his office.
2:30	Had a research conference in his office with two other people.
3:30	Attended a function in the senior high school.
8:30	After dinner, returned to his office until around midnight.

Professor B (University of California). He teaches half-time in the College of Creative Studies and half-time in the College of Letters and Sciences. His major field is population environmental biology. He reported on the previous day which was his "free day."

6:30-11:00 a.m.	Answered several letters; prepared a class schedule and worked on a lecture for the next day; was interrupted by prescheduled meeting with a graduate student.
11:00	Met with the department business officer.
12:00 p.m.	Went to the beach to collect seawater samples, swim, and set traps in the lagoon.
	Returned to his office, worked on a research paper, continued his earlier discussion with the graduate student, checked on the progress of several projects; went to the Marine Laboratory, and again to the lagoon to check his traps.

Professor B — continued

	In the late afternoon he rushed home to entertain dinner guests. After dinner attended a community meeting, leaving early to return to the campus for a meeting on budget problems.
10:00	Went home.
	Professor B explained that much additional time and effort is expended defending his research. Because of its controversial nature, it has incurred angry responses from hundreds of people throughout the world.

Professor C (Indiana University). His major field is microbiology.

7:30 a.m.	Arrived at work; prepared a lecture.
9:00-10:15	Talked with two or three graduate students and a lab technician.
10:30-11:30	Lectured.
12:00 p.m.	Lunch.
12:30	Talked with students and read.
3:30-5:00	Taught and talked with two graduate students.
	Went home.

Professor D (Purdue University). His major field is Engineering Materials.

8:30-9:30 a.m.	Worked in his office, taking a coffee break before 9:30.
9:30-11:30	Still in his office, prepared for class and answered mail.
11:30-12:30 p.m.	Lectured
12:30-1:00	Lunch
1:30-2:30	Conferred with graduate students concerning registration.
2:30-3:30	Involved in class preparation.
3:30-4:30	Lectured
4:30	Went home. During the evening at home he worked on class preparations for the next day.

Graduate Student A (University of California). He is a biological sciences major.

9:00-10:00 a.m.	Worked in the laboratory.
10:00-11:00	Attended class
11:00-12:00 p.m.	Performed surgery in the lab.
12:00-12:30	Discussed his laboratory research with the department chairman.
12:30	Lunch

Graduate Student A — continued

Spent the entire afternoon working in the lab.

After dinner at home, returned to the lab until 4:30 a.m. He had worked until 3 a.m. the previous night. He spends 60 to 70 hours a week in lab work.

Graduate Student B (University of California). He is working for a doctor's degree in the Institute of Environmental Stress; has an office in a graduate space with 14 others.

His day began by writing on his doctoral dissertation, followed by a conference with the Director of the Institute. Except for two hours of work with two teaching assistants, the remainder of the day until 5 p.m. was spent writing.

After dinner at home, he returned to the building to work from 7 to 11 p.m. with the building engineer; from 11 to 12 p.m. was spent writing. He left the building at midnight.

Graduate Student B generally spends five nights a week in the building, reading and writing until 11 to 12 p.m.

Graduate Student C (Indiana University). He is majoring in engineering.

8:30 a.m.	Arrived in the Engineering Building, then went to the computer center.
9:30	Returned to the Engineering Building (shares office with two other graduate students). Talked with an undergraduate student.
10:00	Worked on a research project in his office.
11:30	After lunch in his office, returned to the computer center.
12:15 p.m.	Worked out in the gym for 45 minutes; returned to the computer center.
2:30	Returned to his office to work.
3:00	Attended a seminar.
4:30	Worked in his office for an hour; again went to the computer center, subsequently leaving for the day.

Undergraduate Student A (University of California). He is a sophomore in the Institute of Environmental Stress at Santa Barbara.

8:00-9:00 a.m.	Met with a graduate student whom he is assisting in a study.
9:00-12:00 p.m.	Attended classes.

Undergraduate Student A — continued

12:00-1:00	Studied.
1:00	Attended class and then returned to the Institute for an hour. Assisted the graduate student in rat surgery for two hours; then went home.
7:00	Returned to the Institute to work in the graduate study area.

He is usually in the building or in classes from 8 a.m. to 11 p.m. Most of his study activity involves reading and writing.

Undergraduate Student B (Indiana University). He is majoring in Biochemistry.

Arriving at 8:30 a.m., he spent the first hour checking the results of a research project and the placement of posters around the building. Then attended an hour and a half lecture in the large lecture theater. A two-hour lab class followed before a break for lunch.

In the afternoon he took two people through the greenhouse, attended a two-hour class on the history and philosophy of medicine (a small class of about 15). He then attended a two-hour class in biochemistry with a small group. Until 7 p.m. was spent in the laboratory. Much of the time was devoted to hunting for space with suitable equipment and utilities.

Teaching Assistant (Indiana University)

A typical day is from 7:30 or 8:00 a.m. to 5 p.m., followed by study at home.

One TA working for a physiology professor started work at 7:30 a.m. He supervises five or six hourly workers and the monitoring of constant temperature and pressure rooms. These rooms require monitoring until 10:30 or 11 p.m. He has only one class during the day; does most of his reading and calculating at home.

Lab Technician A (Indiana University)

Arrived at work at 8:25 a.m., answered two phone calls, met for an hour and a half with the Fire Inspector concerning a partition placement and removal of equipment from the corridor. Then checked the mail, discussed budgets and orders for materials, made two phone calls to the purchasing department and checked invoices of payments to faculty. Worked on preparation of the annual equipment order; was interrupted for 30 minutes to scrutinize a bid for another department.

She then talked with two students about technical details, costs and availability of microscopes; wrote supporting statements for academic equipment; and made some emergency requests for research equipment. During all of these activities, she kept track of Buildings and Grounds staff who were moving partitions in one laboratory and resurfacing lab tops in another.

During her lunch hour she walked downtown to pick up her car.

After lunch, she met with a faculty member; spent about 45 minutes working on a hardware problem, about 15 minutes repairing a microscope and 10 minutes interviewing a salesman, leaving the building at 6:45 p.m. Typically, she sees about 40 salesmen a month—mostly at unscheduled times.

Lab Assistant B (University of California)

Lab Assistant B supervises eight work-study students, and is in charge of all divisional equipment, the aquaria, labs, budgets, and petty cash. She describes her job as a "rat race."

Her work day usually runs from 7:15 a.m. until 6 p.m, occasionally beginning at 2 a.m., and sometimes working until 7 or 8 p.m. When classes are in session she must be in the building at 7 a.m. to check equipment and confer with teaching assistants.

On the previous day, she checked her labs at 7:15 a.m. and met with a professor to plan a lab setup. Next she had a discussion with a work-study student; attempted to locate

Lab Assistant B — continued

her lost frogs and ordered some mice. On an errand to the bank she met the department chairman; a discussion of his problems followed.

During lunch in her office she gave directions to a work-study student, checked his work, and ran upstairs "because the elevators are always out" to replace a microscope lamp. She also made several new lab setups for students and classes; removed used lab setups.

Typist A (University of California). She reports to a supervisor.

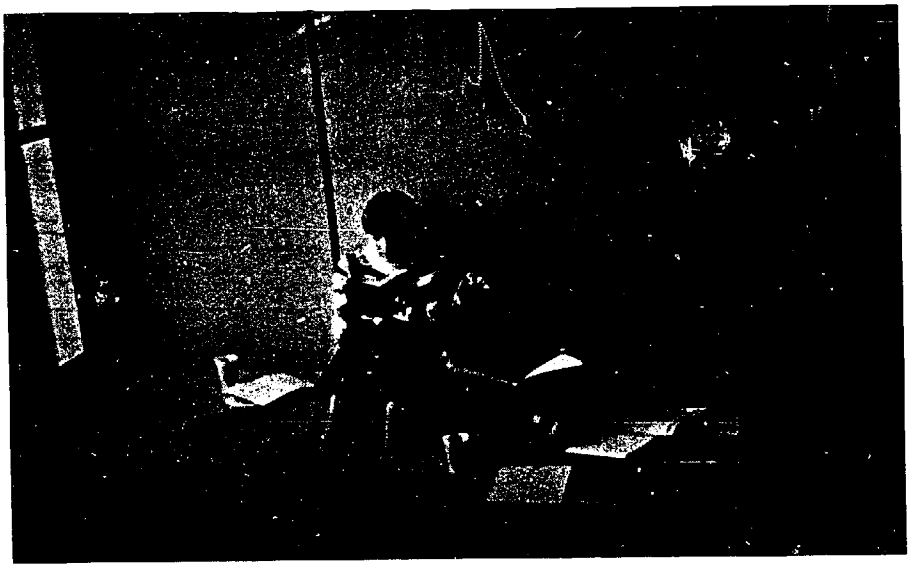
8:00-12:00 p.m.	Typed correspondence for the department chairman; typed a manuscript; ran errands to the Administration Building and made several Xerox copies.
12:00-1:00	During the lunch hour she cut out a dress.
1:00-5:00	Prepared a publication list for the faculty; typed several letters, and prepared a packet for a scientific society.

Typist A rarely works after five in the afternoon.

Department Secretary (Indiana University)

7:35 a.m.	Arrived at work, made coffee and started work on the department payroll.
8:00-12:00 p.m.	Wrote letters, answered incoming phone calls and made about 10 outgoing calls.
12:00-1:00	Took a nap on three chairs in the office—there is no lounge in the building. Had a bag lunch in the office.
1:00	Wrote several letters; made some phone calls; talked briefly with a number of people and finished the payroll.
4:10	Went downtown on an errand and then home.

In addition to reporting on a typical day, those interviewed filled in charts indicating the space types predominantly used for their activities. The pattern responses, as shown in the three charts following, indicate that the activities of the groups are quite different. For example, Chart 2, shows that a typist performs fewer activities—all within an office space—than a faculty member (Chart 3) who performs a great number of tasks in a variety of spaces. Graduate students (Chart 4) also perform a variety of activities in a number of spaces, sometimes using corridors for reading and writing.



The survey indicated that both faculty and students lead highly pressured, and physically and mentally exhausting lives.

Chart 2

USER ACTIVITIES

STAFF TYPIST

SPACE

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ACTIVITY	RESEARCH LABORATORY	INSTRUCTIONAL LABORATORY	OFFICE	CLASSROOM	SEMINAR	LIBRARY/MUSEUM	CORRIDOR	CONFERENCE ROOM	OTHER
STUDY - independent									
- group									
WRITING			▓						
READING			░						
RESEARCH - independent									
- group									
LECTURE or LAB. - prepare									
- attend									
- conduct									
SEMINAR									
LABORATORY RESEARCH - open									
- bench									
LABORATORY INSTRUCTION - open									
- bench									
COUNSELLING - professional									
- student			▓						
MATERIALS - selection			▓						
- creating or improving			░						
- display preparation			░						
STUDENT WORK REVIEW									
TESTING									
MEETINGS			▓						
ADMINISTRATION/PLANNING									
INFORMAL DISCUSSIONS			▓						
SOCIALIZING			▓						
FILING/TYPING			░						
SOUND/VISUAL RECORDING									
MAINTAINING			▓						
TELEPHONING			▓						
EQUIPMENT OPERATION			░						

Chart 3

USER ACTIVITIES

FACULTY MEMBER

frequent ░
occasional ▓

		SPACE
ACTIVITY		RESEARCH LABORATORY
STUDY	– independent	▓
	– group	░
WRITING		▓
READING		▓
RESEARCH	– independent	░
	– group	░
LECTURE or LAB.	– prepare	▓
	– attend	▓
	– conduct	▓
SEMINAR		▓
LABORATORY RESEARCH	– open	░
	– bench	░
LABORATORY INSTRUCTION	– open	░
	– bench	░
COUNSELLING	– professional	▓
	– student	░
MATERIALS	– selection	▓
	– creating or improving	▓
	– display preparation	▓
STUDENT WORK REVIEW		▓
TESTING		▓
MEETINGS		▓
ADMINISTRATION/PLANNING		▓
INFORMAL DISCUSSIONS		░
SOCIALIZING		▓
FILING/TYPING		▓
SOUND/VISUAL RECORDING		▓
MAINTAINING		▓
TELEPHONING		▓
EQUIPMENT OPERATION		░

Chart 4

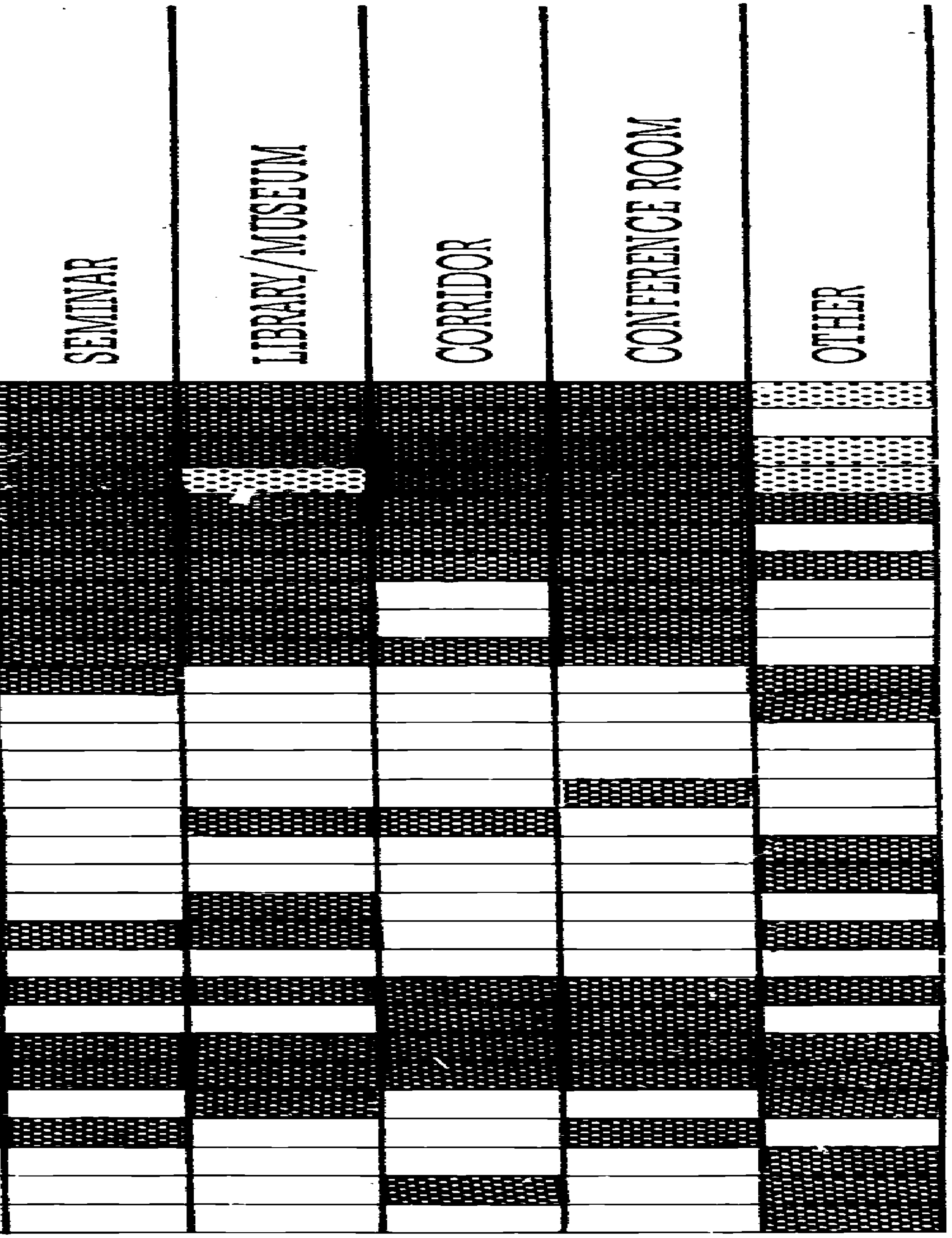
USER ACTIVITIES

STUDENT

frequent ░
occasional ▓

ACTIVITY	SPACE: RESEARCH LABORATORY
STUDY – independent	░
– group	
WRITING	░
READING	░
RESEARCH – independent	░
– group	░
LECTURE or LAB. – prepare	▓
– attend	▓
– conduct	▓
SEMINAR	▓
LABORATORY RESEARCH – open	░
– bench	░
LABORATORY INSTRUCTION – open	▓
– bench	▓
COUNSELLING – professional	▓
– student	▓
MATERIALS – selection	▓
– creating or improving	░
– display preparation	▓
STUDENT WORK REVIEW	
TESTING	▓
MEETINGS	▓
ADMINISTRATION/PLANNING	▓
INFORMAL DISCUSSIONS	▓
SOCIALIZING	▓
FILING/TYPING	▓
SOUND/VISUAL RECORDING	▓
MAINTAINING	▓
TELEPHONING	▓
EQUIPMENT OPERATION	░

USER REQUIREMENTS



ACTIVITY PATTERNS AND SPACE REQUIREMENTS

CIRCULATION

Because of highly pressured lives, faculty and students showed marked sensitivity to building circulation. To people moving constantly around a building, inconveniently located staircases and corridors are constant sources of irritation. Complete, convenient and easily understood circulation systems are important, especially if labs and offices are located on separate floors. In the buildings examined, circulation problems were attributed to a lack of uniformity in signs, inadequate elevator service and racetrack corridor plans. One user commented, "People always seem to be chasing around the corridors looking for the right rooms. Visitors tend to get lost." The photograph below, taken in one of the buildings studied, exemplifies an incomplete and unclear circulation system.

The layout of buildings should be such that traffic congestion and distances traveled are minimal. In one building, scattered locations for libraries and computer terminals produced excessive traffic and inconvenience to both students and faculty. Traffic congestion in buildings also resulted because of two sets of doors at the top of stairs, and the location of heavy-use classrooms on upper floors. Many users noted that the central core was a barrier to circulation and asked whether it was possible for the core to be cut so that circulation could pass through it.

In science and engineering buildings, movement of equipment and heavy awkward materials to and from laboratories poses a major problem. Separate freight elevators with access to the ground level and loading docks, as well as to all floors, are needed. Shipping and receiving areas should be carefully sized, with good truck and elevator access.

Because of unsatisfactory elevator service in his building, one professor said that his students had made a nose-count on usage. They found that maintenance personnel, in moving materials in and out of the elevator, frequently propped the doors open, thus banning its use to others. Rather than a single central location, several participants suggested that elevator locations be determined according to transportation needs to offices, classrooms and laboratories.

FACULTY ACTIVITIES AND SPACES

Faculty members stressed that the average faculty office space is less than adequate for the great number of activities they perform. The following quotation from a professor in a humanities department illustrates this forcibly:

"Let me be specific by telling you, for the record, what *I try* to do in my 130-square-foot office.

1. As a teacher the following duties must all take place in that office:
    a. prepare classes, make up examinations, and grade papers (which demands quiet, privacy, lack of interruptions, concentration);
    b. individual conferences with students in one's classes;
    c. maintenance of a 'working library,' course files, etc.;
    d. teach directed study courses, direction of dissertations;
    e. teach small graduate seminars or study groups (virtually impossible in 130 square feet);
    f. conduct oral examinations (MA and Ph.D.).

2. As a researcher:
   a. maintenance of a better 'working library' than mentioned above;
   b. extensive reading, writing, rewriting and revising, correcting proofs, doing book reviews, etc.;
   c. conferences with research assistants; occasionally sharing the office with a research assistant with whom one is working closely on a research project;
   d. open-stack system in the library plus a dearth of lockable carrels (in the library and the department) make 'research' of the above sorts impossible in our library.

3. As a faculy adviser:
   a. counsel students on their programs of study;
   b. counsel graduate students;
   c. general student counseling on a variety of academic and non-academic curriculuar and personal problems.

4. As an academic Senate Member:
   a. maintenance of extensive committee files and records;
   b. meetings of small committees, both Senate and administrative;
   c. constant telephone business on the above matters.

5. As a department member:
   a. committee meetings;
   b. consultation with colleagues on department business;
   c. typing, dictation, endless letter writing, telephoning, preparation of reports.

6. As a building committee member and chairman:
   a. meeting of committee;
   b. preparation of Preliminary Planning Guide and other documents;
   c. consultation with other departments and department chairmen;
   d. study and storage of building schematics and plans;
   e. consultation with Architects and Engineers office.

I don't think I've exhausted all the duties yet, but the myriad other little things don't come readily to mind."

The types of activities in a faculty office vary with the man. To quote one professor: "If he teaches lower division courses, he will be involved with more students. If he is involved with a subject—such as conservation, currently of interest to the public—he will have considerable contact with the press and public. If he is involved with pure research, he may only see his graduate students and an occasional colleague. If he is involved with department administration, he is lost."

Insight into the nature of student contacts and the place of a particular discipline within its professional or public category is an important factor in office design and building layout. At the same time, tailoring of a building to a detailed consideration of such issues is doomed to failure because of the inevitable change in occupancy during the long-term life of a building.

Distances between faculty or student offices and laboratories, and, to a lesser extent, the department administrative offices, are critical to the productivity of the users. Both faculty and graduate students generally preferred having their office spaces in close proximity to laboratory facilities. However, opinions and work patterns seemed too varied to establish specific relationships between these spaces. For example, Professor A said: "I get 20 percent more work done now that my office and laboratory are together." Professor B responded: "There are two points of view. I get 20 percent more work done now that my office is separated from the lab and I don't have graduate students underfoot." Many preferred having offices and laboratories at least on the same floor.

Faculty responses to the multiple-choice question: "Which of the following best describes the type of adaptation you are presently making to your physical environment"? indicated: (1) most were able to adapt and accomplish their aims and objectives without any amount of undue strain; (2) some were adapting but felt that they were paying a high price in terms of inconvenience, strain, and inefficiency, and (3) a few thought it impossible to achieve their academic aims and objectives because of the shortcomings of the physical environment.

As one professor put it: "We're adaptable because we're clever and we have some money to work with, but the building doesn't help." Several faculty members complained that their activities are dominated by frequent interruptions. One estimated that the maximum period without interruptions is 20 to 30 minutes, with an average period of about seven minutes. The number of contacts faculty now have is considerably greater than even two to three years ago. Those interrupting, besides students, staff and colleagues, include typewriter repairmen, salesmen, reporters, and others. Professors do not object to seeing students or others during certain set time periods. However, opportunities for undisturbed creative work are cherished.

Professor Y commented: "I must do creative work at home. Although I teach and must have contact with others, I am paid and promoted on the basis of my creative work which I can't do in the building since there is no control over interruptions. Either the building should be designed to provide "filtering" or two office spaces should be provided for a faculty member."

Professor Z said: "Not all of us have the same problem. As an experimental biologist I must work in the building—not at home."

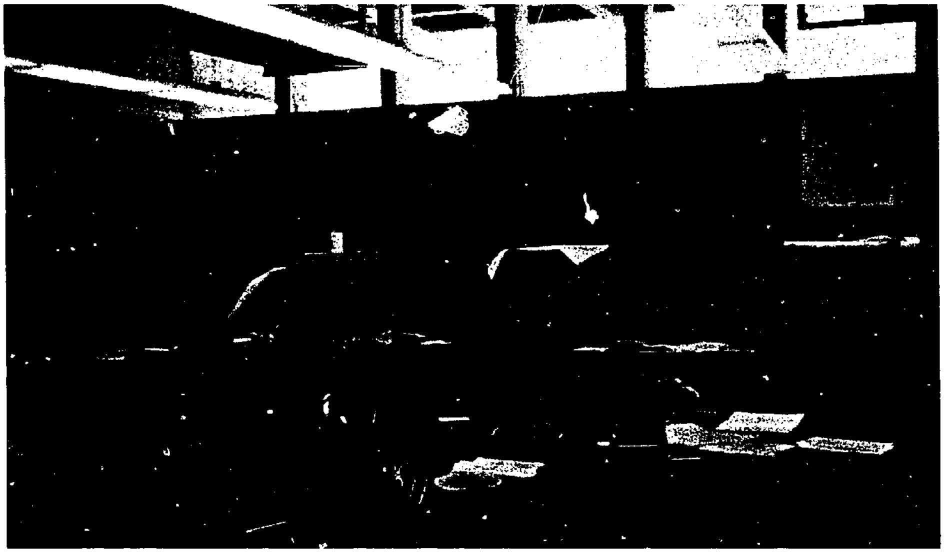
Although much of this is an administrative problem involving patterns of organization within a department and departmental relationships to outside parties, the message conveyed is a plea for building design providing more opportunity for privacy. The traditional layout of faculty offices opening directly onto a public corridor affords little opportunity for screening callers. A large proportion of those interviewed preferred offices along a private corridor or in suites, with a secretarial area for receiving callers.

Design experimentation is needed to devise better ways of allocating the limited space available to a faculty member. Design tradition often determines the form for facilities, resulting in uniform basic arrangements inappropriate to new types of activity. As an example, offices are increasingly used in the sciences and engineering for research, sometimes involving computer terminals or other facilities. The typical faculty office, from 100 to 140 square feet in area, opening directly onto a public corridor, is probably the worst physical pattern for such activity. As an alternative, landscaped offices with isolated rooms for discussing special confidential matters would seem to be a more appropriate design approach.

In addition to requirements for faculty space generated by academic programs, it is important to consider those features of office environments that influence a person's subjective reaction to his place of work. The faculty office is a personal space wherein a faculty member spends a great deal of time. Even though a faculty member is only a temporary tenant of an institution, he should still have the opportunity for individualization within his personal space.

GRADUATE STUDENT ACTIVITIES AND SPACES

Additional design criteria emerge from a study of the graduate science student's needs. His study activities may be adequately accommodated either within the laboratory, or in a room apart from the laboratory with the added advantage of permitting more group interaction. In one of the sample buildings, programming of such a room was in direct response to student request. The room had an open space in the center for group activities and a simple bench arrangement around the walls. Movable file cabinets delineated territory. Although extremely simple, the graduate students interviewed seemed very appreciative and pleased with this arrangement.



Others expressed the need for similiar but somewhat more sophisticated facilities, that is, non-structured departmental spaces partitioned into study carrels or offices for graduate students and teaching assistants, including a receiving area for students waiting to talk with teaching assistants.

Individual activity patterns indicate that graduate students spend an immense amount of time reading and writing. For science students and teaching assistants whose work involves a great deal of monitoring and recording of experiments, an office situation is often needed within or near the laboratory. Graduate students

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research. A department chairman interviewed conjectured that present budget restrictions on Federal funds could significantly abate this trend, but in time the research escalation would continue. However, a somewhat lower amount of research activity is anticipated in the next years.

During the interviews, the comment that interaction is important in research activity elicited responses to the effect that the crowded laboratory is the secret of success. Expanding on this point, one participant referred to a university where he thought laboratories were sterile in feeling because they were "chopped up" and assigned to individuals. Another cited a case where seven researchers had worked very congenially and effectively in a small room, but in moving to a new building became isolated and thereby less productive. Whereas this professor suggested three people per research space, another thought that five to seven per space was a critical mass for intellectual purposes but, in terms of use, did not know what the figure was. Still another participant felt that mixing students from different levels of instruction within a space is desirable.

Although detailed studies would be necessary to make specific determinations, the functional relationship of different space types most certainly affects the activity patterns of users. Of greatest importance is a plan configuration permitting the maximum variety of functional space relationships. Although the central service core plan permits some degree of later modiciation, it is limited in its possibilities. Greater opportunities for interaction among users, coupled with a wide range of configuration change possibilities, is afforded by large open areas with the service core placed to the side.

Effective use over the years dictates that buildings be adaptable to a diversity of academic functions and planned for maximum use of special facilities. In view of the continually escalating cost of scientific equipment, faculty and staff seem well aware of the serious need to consider shared facilities solutions. But, if centralized spaces for sharing equipment or other facilities are designed, they should be planned in full communication with the direct users in order to develop a solution with overall management and control of operations. Centralized space appearing to have economic advantages may produce conflicts in activities. Examples of issues implicit in the planning of centralized versus decentralized facilities are:

1. Centralized animal facilities for biological research would seem to make economic and administrative sense; better facilities can be provided for less money. But, for many research experiments and from the researcher's point of view, small animal holding rooms are needed in the laboratory areas in conjunction with a centralized vivarium.

2. Departments must share expensive equipment and laboratories. Users felt that multi-use of laboratories and equipment by different departments is difficult, especially if storage space is insufficient. It was suggested that storage for multi-use areas be provided on a departmental basis, with adequate provision for storing items such as oil drums, solvents, work benches and other furniture and equipment.

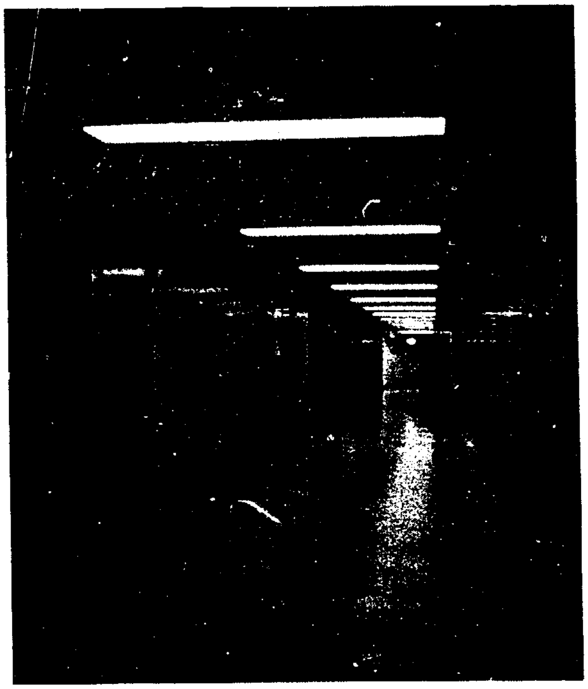
An impelling characteristic of research activity is that the people involved are quite adaptable, but requirements for the experimental processes are mandatory. People can tolerate, however unwillingly, cramped quarters or quite large variations in temperature, acoustics and lighting. But experiments may be ruined by the lack of quality control in a distilled water system, or too great a variation in voltage. Even the environmental needs of animals used for scientific experimentation are much more precise than those of their human investigators. Consequently, many buildings are largely designed for the needs of the discipline with little emphasis on the human environment. Although provisions for research requirements are essential, equal consideration should be given the environmental needs of people.

REACTIONS TO THE BUILT-ENVIRONMENT

SUBJECTIVE AND SOCIAL ASPECTS

The design aim for academic buildings must be to provide the best functional, atmospheric and aesthetic environment to support the user's activities. Even though scientists and engineers depend to a great extent on their buildings and equipment and are, therefore, especially aware of the functional aspects of design, discussions with building occupants revealed a parallel concern for interior and exterior aesthetics, color, texture and form of materials. Objecting to the "institutional" quality of the environments, faculty and staff chose words such as "drab," "dull," "stark," and "sterile" to describe a lack of color and imaginative use of form in their buildings.

In general, users feel a sense of resignation towards the institutional environment. Presumably, the environment is provided for the user. Yet he rarely participates in its creation, nor is his meddling with it sanctioned. The use of low-maintenance surfaces and furnishings necessarily contributes to institutional tedium, but monotony is further perpetuated by restrictions on individual decorations and the lack of variety in interior layouts.

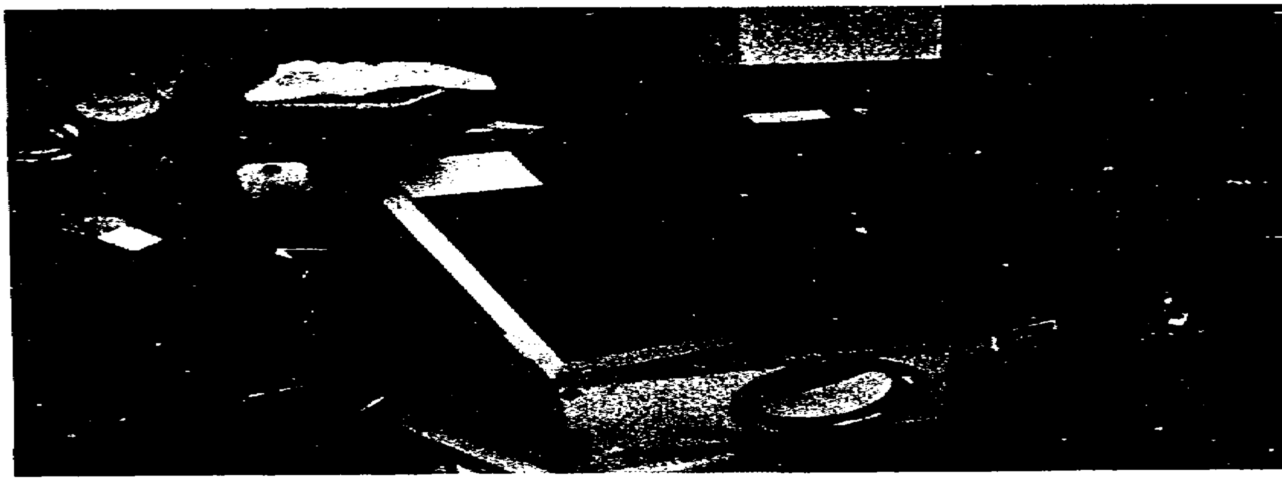


One professor comments: "The personality of the scientist is the opposite of the popular image. He should be asssessed as an artist. This would become apparent if we were allowed more individuality in furnishing our offices." The attitudes generally expressed, denoted the need to study ways in which the institutional environment can be designed to permit more individualization by the tenant user.

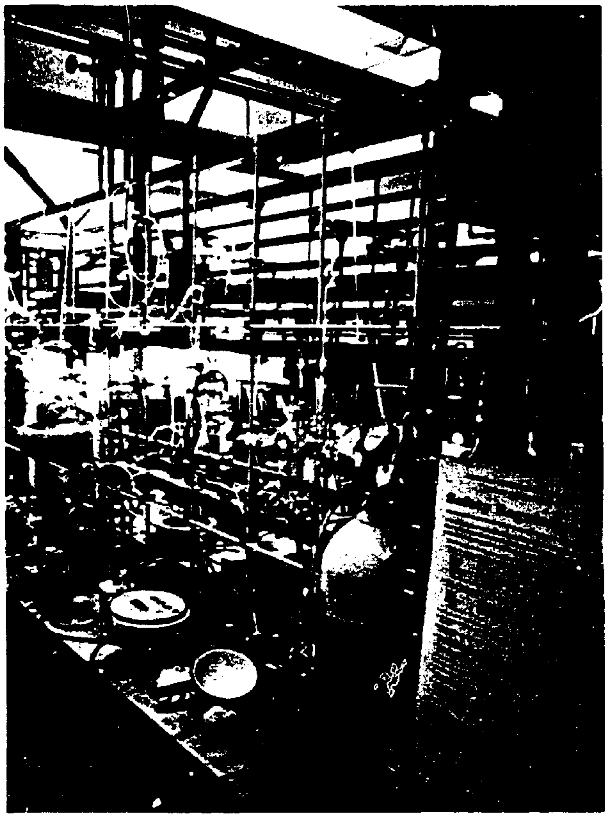
Typically, academic buildings lack spaces for social and informal academic interaction. Much discussion time was devoted to the need for informal general-purpose spaces. People in the sciences must spend long hours in their offices and laboratories. Too much time in the building made one participant "want to climb the walls." On the other hand, many complained of valuable work time wasted in having to cross the campus for a "break," and indicated that they preferred having spaces within their buildings for coffee, snacks, and bag lunches. Recreation and lounge areas were also requested to rest or to relax in. The idea that a scientist lives and works in his office, and is therefore different from his fellowmen in his needs for an environment conducive to professional and social interaction, was felt to be erroneous and must be dispelled.

THE LABORATORY

Whereas scientists and engineers participating in the survey showed perception and concern for the subjective aspects of their total building environments, their orientation toward the laboratory was singularly functional. From the discussions, it was evident that change is fundamental in the life of a scientist. Not only are the set-ups for experiments constantly changing, but also approaches to teaching and research and the personnel involved. Characteristically, the laboratory environment is complex, specific and transitory—a concept having several implications for the designer.



The most direct form of change in the laboratory—continual modification of experimental conditions—is generally well understood by designers, but means for providing optimal building adaptability are only beginning to evolve. Recent experimental approaches make more use of complex equipment, electronic monitoring devices and instrumentation. Experimentation in the sciences is moving away from the traditional bench, sink, microscope and a few basic services. Requirements for experiments are very often quite unpredictable with unexpected dimensional problems or requirements for additional pieces of equipment. Obviously, a designer cannot anticipate all the support needs of all of the users in any one incremental dimensional system. order can be, and indeed often are, inhibiting



What this suggests, then, is not a design approach ignoring order and rationality, but one which does not attempt to force formal kinds of order where inappropriate. During the interviews, problems of change most frequently cited related to having enough space for necessary equipment, and to changes in setups involving plumbing access and the availability of electrical and environmental services. For most research, the best environment appears to be a subdividable open space with a selection of conventional services available. Benches, tables, equipment, support devices and racks should be movable and in smaller units. Such accommodations are not easily envisioned, but a good beginning is to design for a degree of indeterminancy in buildings rather than using a static position as the basis for design.

An indeterminate approach to building design, coupled with a comprehensive catalogue of standardized parts and furnishings of broad enough range to accommodate reasonably even the star scientist, would contribute substantially to solution of the long-term problems inherent in changing occupanices and research requirements.

SPECIAL ENVIRONMENTS

In addition, provision for specialized environments should be considered. Special requirements for equipment or experiment environments may be categorized as follows:

1. Requirements for increased height, breadth or length of spaces.
2. Requirements for heavy equipment requiring high floor loading capacities.
3. Requirements for special atmospheric or other environmental conditions.
4. Requirements for a degree of services unique in quantity, quality, or location.

In an indeterminate building with maximum adaptability, including removable partitions, requirements for long horizontal spaces can be fairly easily met. The need for increased vertical space is also not too difficult to satisfy in a simple building structure, if it is initially programmed. Requirements for high floor loading, however, are much more difficult to meet economically. This raises the question: should high floor loading be provided for throughout a building if the need and location for it are unpredictable?

Equipment and activities having special requirements beyond the reasonable capacity of a building should be housed in special, perhaps even temporary, facilities. Examples are: rapidly superseded facilities, hazardous facilities such as used for fire-testing, "dirty or smelly" facilities such as sludge tanks used in sanitary engineering, large facilities such as towing tanks used in naval architecture, and facilities requiring professional rather than student assistance.

On many campuses specialized equipment is located in remote, highly adaptable and expensive structures. Also, colleges engaged in modern research are finding that acquisition of test facilities is often beyond their means. Even in this highly selective review of user requirements, in many instances custom designed buildings were found to be housing obsolescent specialized equipment.

In general, it is questionable whether the university should attempt to provide highly specialized spaces within academic facilities. Spaces requiring special environments—rather than special size, shape, and loading—can best be met either by compartmentalized, prefabricated, portable units, or by the ability to separate and zone different parts of a lab. Some special environments are:

Electronically isolated areas are used most often in conjunction with neurological instrumentation requiring extremely high amplifications. Such electrical isolation is needed to prevent radio noise from fluorescent lights or other sources from affecting delicate electrical circuits.

Chromatography and electrophoresis techniques for separating biological materials were first tried about 20 years ago and have been in major use during the past decade. Special instruments and/or "compartments" for using these techniques are available. The compartments for electrophoresis are, commonly, desk-top size but may be as large as 8 feet long, 4 feet high and 4 feet deep; both sizes can be located within a regular laboratory. Chromatography cabinets are often no more than about three-foot cubed, but because the solvents for this process can be lethal and nauseating, special rooms with air control and fume hoods are often necessary.

Sterile transfer rooms are used in microbiology and bacteriology departments for the culture and transfer of bacteria. This environment requires special air handling, washable interior finishes, and sealed joints between components. Sterile conditions may also be provided by a "glove box" or other prefabricated portable compartment.

Constant temperature rooms can be found anywhere in a biological sciences facility. Any situation requiring the maintenance of animal material necessitates a constant temperature, to be determined by the type of experiments or specimens used. Although techniques such as electrophoresis or chromatography are best performed in a constant temperature room, often only rooms with controlled heating or cooling are needed if the air conditioning system is sufficiently sophisticated and responsive. Controlled temperature rooms—cold, warm or variable—can be prefabricated, sectional "roomettes" (available in sizes from "portable" to large walk-in units) or built-in rooms, operated independently of the building mechanical system.

Isotope areas vary in requirements depending on the quantity of radio-isotopes used. Although tracer work usually involves only small amounts and can be done in the typical laboratory, special storage and preparation facilities are required where the level of radiation may be high.

Plant growth rooms, usually interior spaces with controlled lighting, temperature and humidity conditions, may be part of a laboratory layout or a separate central facility. If a separate facility is used, plant life is maintained by a technical staff with delivery service to the research and teaching laboratories as required.

Clean rooms are a fairly new research requirement for either the exclusion of unwanted atmosphere or the containment of contaminants, and require positive air pressure and special filters to keep dust out. They may also be required for fabricating or assembling very precise or delicate parts or measurements, or for experiments using hazardous or expensive material. If used for solid state fabrication facilities, clean rooms are usually in a suite of about 3,000 square feet. Prefabricated clean rooms have washable walls and ceilings.

Screen rooms are used for experiments requiring radio-frequency shielding. Copper wire and/or screening is used to provide isolation for experiments. The copper installation details vary substantially and must be verified prior to, and during, construction.

Anechoic chambers, rarely required, are spaces for studying sound vibrations and require uniquely insulated walls.

THE CLASSROOM

The university classroom is still quite traditional in that it is conceived as a single space, acoustically and visually separated from adjoining spaces and under the control of a lecturer or teacher. However, seminar and discussion groups are becoming more prevalent and are replacing lecture classes. Typically, this type of class is smaller in size. Those remaining lecture classes are, in turn, growing larger or moving towards an audio-tutorial approach.

As traditional classroom organization in universities changes to encourage interaction between students and teachers, the physical nature of the setting must also change. At present, classrooms tend to be programmed and built as fixed spaces, often with concrete block or solid concrete walls between them. A general problem in space management is dealing with classrooms built many years ago which do not tightly fit the current patterns of class size. To have both a high room usage and a high station occupancy, there must be good correspondence between the spectrum of classroom sizes and that of class sizes. Adaptable spaces which can be changed as enrollments and teaching approaches change could have a significant impact on space management.

Informal approaches to classroom teaching, now prevalent in the open classroom at the elementary and even high school levels, are relatively untried at the university level. Work in new high schools has shown that relatively open classroom areas without doors, opening onto places where circulation and individual study can be combined, can be effective. This approach, combined with new lighting methods and detail developments such as demountable walls and movable partitions, presents possibilities for improved environment and space utilization in university facilities as well.

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Specific areas of environmental concern
reactions to environmental conditions in p
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SAFETY

Danger is inherent in much of scientific and engineering research. Research involves working with volatile substances, contagious bacteria, high radiation and voltages and a great number of electrical devices. Experience with accidents or near accidents seemed to be fairly commonplace among those interviewed, with electrical accidents appearing to be most frequent and dangerous. In expressing concern for the safety and reassurance provided by building design, users mentioned clarity of circulation, i.e., exit routes and the availability and location of stair cases; the location and number of emergency showers (too few and poorly located); and the number of bulky, awkward items lining corridors due to lack of storage space.

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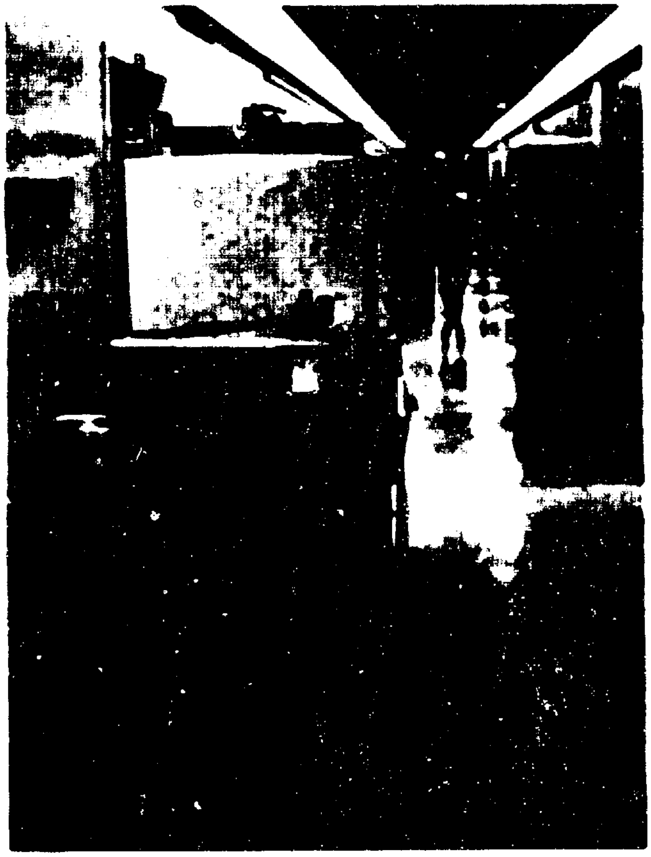

An architect, from a thorough knowledge of user activities, should strive for a building design wherein safety is synonymous with convenience. Safety then becomes much more than a code problem to be surmounted with the minimum expense and liability to the design.

SECURITY

In the buildings examined, theft presented a growing security problem. Losses included typewriters, microscopes, calculators, books, purses, security name plates and toilet paper holders. Losses from vandalism were relatively low, but damage to equipment from curious meddlers and knob twirlers was a problem. Security separation in partitions and walls is needed for preventing loss of equipment and protecting experiments from meddlers. Opaque doors were requested by some users to prevent potential thieves from surveying enticing pieces of equipment. Others felt that security was a problem because laboratory doors were kept open much of the time and users were careless. Suggestions from those interviewed ranged from extreme precautionary measures such as closed circuit TV monitoring of corridors to simply keeping purses and other items locked in desk drawers.

ODOR

Odor is an aspect of the environment perhaps more critical in laboratory buildings, particularly bioscience buildings, than in any other building type. Use of animals for experimentation increases the possibility of undesirable odors. Yet in an ideal research situation, animals for examination should be maintained in the laboratory building rather than in a separate facility. Odor thus requires a design response that carefully considers its treatment. A lack of coordination in the location and ventilation of facilities can easily result in design errors such as described in the following comment:

"The incinerator is only big enough for a 35-pound dog. Anything bigger requires shoving, pushing, and chopping. By law, certain things such as monkey droppings must be burned. Once the incinerator is overworked it automatically shuts off, but it then smoulders for five or six hours before anything can be done. The air intakes in the roof are next to the incinerator stack. If the wind is in a certain direction, half the sixth floor and all of the fifth floor get the results."

Odors and/or fumes are also a problem in engineering facilities. Fumes from asphalt testing had necessitated evacuation of one entire building. Users in another building, reported that sanitary engineering laboratories requirs a higher level of ventilation for many experiments than is presently available.

ACOUSTICS

Of all environmental problems, acoustical problems are possibly the most recurring and difficult to solve. During interviews, students and faculty stressed the need to be able to concentrate. Intermittent human speech or intermittent mechanical noise is extremely annoying when trying to concentrate quietly and intensely for prolonged periods of time.

Many complaints concerning acoustics can be related to what users *expect*. For example, faculty in their private offices do not expect to hear conversations in adjacent offices, nor do teachers in a classroom or teaching laboratory expect to hear conversations or teaching in an adjoining room; but, they do expect to be able to be heard within the space they are occuyping

The treatment of sound within a space is as important as sound transmission between adjacent spaces. Users' complaints of excessively high noise levels in labs were largely attributed to loud air handling systems and mechanical noise. In some cases, sound bouncing off concrete walls added to the noise level to the extent that teaching or other verbal communication was difficult.

In large open spaces, improving the Sound Transmission Coefficient (STC) rating of partitions or ceiling is only part of a solution to the noise problem. In addition to the STC rating of the wall panels, other factors such as the joints at the ceiling, the floor, the door to its frame, and the STC rating of the door must be considered. A general low level of background noise, such as that from an air conditioning system, is not objectionable until it begins to assume such prominence as to create communication problems. Consideration of all factors plus a thoughtful balance between background noise and openness of space and the availability of acoustically private spaces would seem to provide the most viable environment.

A common complaint in academic buildings is the lack of opportunity for interaction among the occupants. Interaction generally is incompatible with acoustical privacy. This suggests that present space arrangements providing both limited interaction and poor acoustical privacy should be subject to scrutiny. Designing for more interaction and vitality in the environment, with a few places where real acoustical privacy can be obtained, is desirable. Acoustical standards for the reasonably private environment are, however, quite well known and, when specified, can be adhered to realistically.

WINDOW-EXPOSURE

Daylight and a view to the outside from laboratories and offices was of primary concern to almost all of the users interviewd. Many described a claustrophobic reaction to enclosed spaces and expressed a fundamentally human need to have a sense of what is happening outside—to know whether the sun is shining or rain is falling. Long tedious hours in a laboratory building are more tolerable with an outside view. One professor commented: "Typical activities involve a lot of pressure. Distraction is good, and windows are necessary for diversion." A wall of glass is not necessary to meet this requirement, but it does call for enough glass to permit a worker to look up from his bench or desk to an outside view.

Although users generally preferred having windows in most spaces, a view from classrooms or seminar rooms does not seem so important because a faculty member is not in the same classroom for prolonged periods of time. In any event, a view should be provided in the circulation areas so that students may look outside as they move between classes. Lounges should have windows wherever possible.

Window-exposure can be very annoying if solar control is not provided. Where solar control has been minimized in present buildings for cost reasons, conducting experiments or teaching is difficult—if not impossible—at certain times of the day. Windows are not detrimental, even in laboratories where experiments require complete artificial lighting, if capability for temporary darkening is provided. Careful studies are needed to achieve control of sunlight, glare, sky and solar heat gain.

It is not essential that windows be openable if the HVAC system is adequate. In laboratory buildings, where dust is objectionable, most users preferred adequate HVAC and fixed windows. In two of the buildings studied, pivoted and gasketed windows, openable for washing by removable cranks, have been used with great success.

EXTERIOR WALLS

The general impression gained from the interviews was that most users seem satisfied with the exterior appearance of their buildings. Most considered exterior appearance important. A few commented on the brick monotony and institutional appearance of buildings. Others felt that a building should give some indication of its purpose—that is, a civil engineering building should look like a civil engineering building. Some were of the opinion that a disproportionate amount of money is allocated toward building exterior at the expense of function. Roof screens were felt to be particularly desirable on science buildings to conceal mechanical equipment on the roof.

STRUCTURE

In general, structure appeared to be the most adequate of the subsystems investigated although there were two areas of frequent criticism. Both related to floors: (1) building vibration, usually caused by heavy mechanical equipment such as compressors, fans or pumps, can seriously affect the use of sensitive instrumentation and electron microscopes; (2) proper drainage is frequently a problem in laboratories because of the lack of drains under emergency showers, floors not properly sloped toward drains, and unsealed cracks or penetrations in the floors allowing spillage or flooding on upper floors to seep down as many as three floors, ruining experiments on the way.

Appearance and comfort of floor finishes were also the subject of considerable discussion among the California users. Carpets were suggested even for laboratories, but a more frequent response was a desire for colorful, durable, cleanable, and impervious flooring materials.

CEILING

Acoustical ceilings are desired in virtually all locations: corridors and noisy activity areas to lessen noise transmission to adjacent areas; classrooms and teaching laboratories to facilitate communication; offices to provide privacy and quiet. Ceilings were also desired in research laboratories, otherwise dust collecting on exposed piping, ductwork and lighting fixtures can fall into and ruin experiments.

Although in one building corridor ceilings were considered too low, users generally seemed unconcerned about ceiling height, except for those few locations where specialized equipment required unusual height from floor to ceiling. Some users, bothered by shadows at their work stations because of lighting placement, suggested that consideration be given to a ceiling with movable lighting panels. The concept of movable lighting panels in a ceiling coordinated with movable partitions generated considerable interest.

ARTIFICIAL LIGHTING

Artificial lighting should assist in providing a pleasant and attractive environment as well as providing functional support for user activities. Although no great emphasis was placed by the users on aspects of artificial lighting in academic buildings, a general point was made—that artificial lighting tends to be too "bright." More specific comments were that ceiling lighting often produces unwanted shadows around tall equipment setups, and office lighting is generally higher in intensity than necessary.

Users tend to confuse lighting intensity with brightness, and the discomfort sensed may be due to the latter rather than the former. Nevertheless, the basic comment that lighting is too "bright" does raise questions about the basic approach to lighting in laboratories and offices. Typical modern lighting systems try to provide an overall high intensity of lighting suitable for almost all activities. A design approach utilizing a lower overall intensity of lighting, with localized high intensity lighting precisely at the points where needed, may result in a more economical, functionally effective, interesting and attractive quality of lighting.

INTERIOR PARTITIONS

The color, texture, finish, and functional uses of a partition have a complex effect on the environment, and largely define and characterize the user's relationship to his space. In the buildings examined, individual spaces appeared to be more representative of the institution than of the occupants. The general reaction of users to academic buildings was that they are environmentally "institutional," lacking in stimulating and inspiring colors, and affording no opportunity for individual expression.

In contrast, a partition in a primary or high school, in addition to delineating space, contributes to the general attractiveness of a room through its color, texture and design. Although this partition is likely to be covered with pictures and cut-out materials, color and texture are read and are significant to the environmental tone of the space. This should be equally true in the university. The partition in a laboratory or even an office may support many functional items: shelving, equipment, piping, conduit. Although the wall color and texture may be almost completely obscured, its nature should be such as to enhance the visual interest occasioned by strange and often ad hoc provisions that are otherwise the sole compensation for lack of environmental charm.

The ability of partitions to support equipment was of great importance to the users interviewed. (A demountable partition in one of the buildings studied was deficient in this respect.) Users strongly favored partitions accommodating adjustable supporting devices to allow building occupants to make their own changes. However, opinions varied regarding movability of partitions. Many suggested, at least, semi-permanent walls to accommodate changing laboratory and classroom space needs. Others questioned how partitions might be moved without affecting their neighbors, believing that departmental "fights" are minimized by fixed walls. Most occupants could cite some experience, either with the inconveniences associated with prolonged building modifications or with curtailed activities because of fixed spaces. The preference was for adaptable partitions that would facilitate and expedite needed alterations.

In addition to adaptability, functional support and aesthetic contribution, users expressed their concern for the acoustical, visual and security separation provided by partitions. The main points made were:

1. Good acoustical separation is particularly needed in offices to minimize interruptions of concentration.
2. Although the visual separation provided by solid partitions is satisfactory in most spaces, less separation is desired in corridors to reduce the unfriendly and claustrophobic effect.
3. Security separation is essential for preventing loss of equipment and protecting experiments from meddlers.

CASEWORK

Fixed casework presents the greatest deterrent to adaptability in laboratory spaces. As laboratory equipment and instrumentation change frequently, users find it difficult to anticipate their total needs in an initial program statement. They would prefer a smaller initial complement of casework and a supply of relocatable items to create functional configurations as activities change. In unanimously requesting movable furnishings, users emphasized the ability: (1) to move whole units over relocating parts within cabinets; and (2) to coordinate work surfaces with equipment.

Laboratory furnishings are usually fixed and non-integrated with equipment, and so permit little change in arrangements. Because the time period required for local workmen to make modifications is often inordinately long, students, research assistants and faculty felt that if furnishings and utility services were so designed that users could make their own modifications, time and money could be saved. One participant, remarking that good movable modular furniture is available for hospitals, asked if it would be possible to have similiar furnishings for laboratories.

Adaptability within a room can be more important than the ability to move partitions. It was suggested that the laboratory initially be an unfurnished generalized space with only a fume hood and plumbing and electrical services provided. Departments could then warehouse assemblies of service outlets and movable furnishings in units small enough to be installed by the users.

Some standard cabinets do permit interchange of drawers and doors, but many weeks are required to obtain new parts. Wood cabinets are preferred to metal because they are durable and attractive, and are more easily modified. Users suggested that attractive wood laboratory tables and wall cabinets might be interchanged between offices and laboratories as needed.

Sit-down work stations are commonly preferred in the biosciences. In chemistry laboratories, stand-up stations appear to be more practical. Generally, tables are preferred to benches as they provide more leg room. Adjustable table heights are advantageous for different uses.

It was agreed that the top surface of the chemical bench presents a difficult problem. Wood tops tend to become pitted. Even though stains and corrosion are inevitable, lighter and more colorful countertops are preferred to those black tops usually selected for their greater chemical resistance. Some people reported good experience with light green laminated plastic, as well as with stone tops. The best all-around surface, however, was thought to be epoxy resin although black in color and quite expensive.

Other points made by users related to types of storage:

1. Wall shelving is now 12" deep and holds two half-litter bottles. If it were 15", it would hold three bottles. Wood shelving is preferred to steel, which corrodes.
2. Storage space is preferred over, rather than under, work surfaces. Many users suggested omitting under-bench cabinets entirely.
3. Wall storage space is insufficient. Glass front storage is necessary for viewing supply stock.
4. Particularly in cold climates, more coat and book storage space is needed in rooms, not in corridors, because of theft problems. Secretaries also requested coat closets.

SERVICES

In most cases, the service subsystems found in laboratories were reasonably logical, straightforward, efficient and economical. Each subsystem, when considered in isolation, is defensible as a static solution to a well-defined problem. If context and change are considered, however, most subsystems are lacking in both design and coordination with other subsystems.

Electrical power was notably deficient in the laboratory buildings, with inadequate provision for 220-volt circuits. In some instances, the electrical capacity was adequate but higher amperage (30 amp.) circuits were needed. Where separate circuits had not been provided in corridors, janitors buffing corridor floors had inadvertently overloaded laboratory circuits and ruined experiments. Where laboratories share control panels and circuits, electrical overloads in one laboratory often cause loss of experiments in another laboratory. Thus, each laboratory should have separate breakers and reserve power capacity. Power outages in laboratory buildings cause serious losses of experiments. The reasons for power failure or inadequate electrical support were numerous. Grounding of electrical circuitry frequently was reported as inadequate and hazardous.

Floor-mounted electrical outlets are generally undesirable and a source of annoyance to users. Pedestal-type floor outlets interfere with furniture and equipment arrangements. One user commented: "You get a short circuit if you kick them often enough." In the event of floods or spills, outlets flush with the floor are also unsafe.

Leakage between floors from floods and spills at penetrations or cracks was a common complaint and has accounted for costly equipment damage and loss of experiments. In many locations, floors are either inadequately sloped to permit drainage or the number of drains provided is insufficient. More floor drains and better drainage were specifically requested in preparation rooms, central chiller rooms, engineering laboratories and under emergency showers. As previously mentioned, emergency showers and eyewashes traditionally located in the corridors are unsatisfactory. Where floor drains are not provided underneath, activation of the showers (often by pranksters) causes flooding and slippery floors. Many users prefer a sink spray in each laboratory so that an accident victim can direct water immediately to where it is needed.

The restricting of distilled water taps to a few central locations in corridors is inconvenient and expensive in terms of manpower use. Distilled water should be supplied directly to bioscience laboratories, and should have automatic cut-off to prevent contamination when the stills malfunction. Breakdowns are not infrequent and replacement of parts takes time. For such emergencies, users requested extra standby stills.

A general distrust of existing subsystems to function well was partially attributable to the relative newness of some of the buildings examined. Although cognizant of this, many occupants expressed their frustration in waiting for local forces to make adjustment and repairs. Because research time is extremely precious, the majority of users interviewed, favored subsystems over which they had direct control—individual water stills, portable vacuum pumps and electrical voltage regulators.

Water temperature was satisfactory and the size of mains appeared to be adequate in the six sample buildings, but secondary distribution was sometimes poor and with excessive water hammer noise in one location. Because of electrolysis or salt deposits, the hot water line in one of the buildings will soon have to be completely replaced. Modifications will be difficult as utilities in this building run behind clay tile walls and in concrete chases. Because of difficult access to piping and wiring, services are often the greatest part of space alteration costs.

During the interviews, criticism of laboratories frequently pertained to the lack of adaptability in services—particularly in laboratories with floor utilities fixed by the location of benches. Users requested generalized space with utilities available. The most successful laboratory arrangements were those combining movable furnishings with utilities dropped from the ceiling. In general, those interviewed responded with approval and enthusiasm to ideas for standardized furnishings and adaptable patterns of services.

HEATING-VENTILATING-AIR CONDITIONING (HVAC)

Extreme demands are placed on the heating-ventilating-air conditioning subsystem in laboratory buildings. Needs vary from minimum requirements for offices to "controlled atmospheres" for laboratory experiments. Users were critical of existing HVAC systems, although aware of the complexities involved in providing both variety and precision in thermal conditions. They cited instances wherein experiments had been damanged or destroyed, or found impracticable to conduct, because a clean and regulated atmosphere could not be provided. The general impression was that HVAC designers had tried to accomplish too much within a limited budget.

Science buildings are different from most buildings in that the thermal environment must be more responsive to the nature of the work performed than to the requirements of the people. Not only are the requirements for adequate thermal environment difficult to satisfy in an initial installation but, also, adjustments in the installation are difficult to make when changes are required. One factor frequently underestimated in the initial HVAC design was the amount of equipment generating heat. For example, in an engineering building studied, the electronic laboratory equipment generated more heat than the ventilation system could properly handle. In the same building, too much air infiltrated into the offices. Some heat generating equipment requires cooling the year around.

Special environment rooms are typically found in engineering and science buildings. Controlled temperature rooms are required for all bioscience disciplines and "white" rooms for all engineering groups. Such rooms may be built into the structure or prefabricated. Sometimes served by the building HVAC system, they are often provided with their own separate HVAC system. Normally, the building HVAC system is inadequate to provide the degree of environmental control required for these specialized spaces. In some instances the building HVAC system was found inadequate even to provide suitable environmental conditions surrounding specialized spaces served by their own systems.

While adequate ventilation must be provided in laborato[illegible] a satisfactory thermal environment, the ventilation system should be [illegible] minimize air pollution. As stated previously, air supply and exhaust for animal rooms should not permit cross contamination. Dust and dirt are also a problem [illegible] connection with certain types of instrumentation and most chemical experiments. [illegible] a sample building many problems resulted from inadequate filtering in the HVAC system. Dust infiltration was particularly noticeable in those buildings adjacent to construction work. Especially in the biosciences, experiments must be free of particle [illegible] users noted that the problems with dust were magnified in laboratories without ceilings where dust collects on exposed piping, ductwork, and lighting fixtures.

[illegible] building HVAC system must be based not only on the capacity of the system [illegible] and ventilate but also on the capability for control. [illegible] was restricted to a trained operator [illegible] individual spaces and expressed [illegible] needed adjustments or changes [illegible] The frequency of adjustment and change [illegible] was a [illegible] balancing.

Many laboratories even with [illegible] AC system [illegible] fume hood exhaust was unsatisfactory. Fume hoods were criticized in some cases for providing insufficient air velocity for effective operation and in other cases for producing [illegible] drafts in work stations. Some users were of the opinion that laboratories were underhooded, requesting that fume hoods be made easier to [illegible] or add and suggesting a minimum of two hoods each per laboratory and per preparation room. Users also suggested that fume hoods be equipped with indicators to show when the exhaust fan is not working for any reason, such as belt breakage or power shut off.

[illegible] of the [illegible] buildings studied in detail users complained about the thermal environments. Some complaints related to their experiments and others to basic human comfort. Typical HVAC systems are unsatisfactory. The most probable cause is that not enough money is being spent to provide systems adequate for both comfort control and equipment operation.

GROWTH AND CHANGE

In the years between 1955 and 1965, many institutions, including the University of California, doubled their enrollment. Indiana University, in the decade from 1959 to 1969, experienced a 120% growth. This was accomplished during a period of great change in social, political, cultural and economical attitudes among the college population. These processes of change are largely influenced by the culture of which the university is but a part.

Such change affects methods of administration. The changing student society, for example, has a tremendous drive to become incorporated into academic and administrative policy making. Members of the faculty who support the idea of greater student responsibility agree that the campus culture is greatly affected by what occurs in the residence hall, the committee room, the corridor, as well as in the classroom.

Other changes are in traditional university areas such as is exemplified by the rise and fall of departments. It is not difficult to identify courses and disciplines that were literally non-existent only a decade and a half ago (less than one third the lifetime of an academic building): courses in information theory, feedback control, atomic and nuclear physics, computer science and computer technology, computer aided design, solid state physics, plasma physics, systems theory, in research, probability theory, and biomedical engineering. In addition, changes instituted by an administrator or academician or a new department head can create enormous demands on the adaptability of a facility.

Growth and change, whether caused by increased student population, the expansion of a discipline, or the splitting of a discipline into subdisciplines, produces a continuous game of musical chairs within academic facilities in a university. Technological developments relating to teaching or research, or changes in the methodology of teaching and research, also affect facilities use. Technological changes in the engineering facilities at Purdue University in the last two decades have had a profound effect on course configuration and supporting equipment. Early obsolescence of equipment and facilities was significant. As an example, the mechanical engineering internal combustion engine facilities have been converted to optics and laser research. In the face of such changes administrators are hard pressed to provide facilities that will keep departments happy, a substantial argument for adaptable facilities.

Improvement in equipment very rapidly affects research methods. The impact of electronics in all areas of science and engineering in the last decade is a clear instance. Because industries often have greater resources than universities, they have attracted researchers at the expense of the university. Thus, research projects traditionally pursued by the university are being developed, in many cases, by industry.

Computer facilities of various types are also becoming increasingly prevalent. In the future, more scientists will require large high speed computers of the type now serving whole campuses. Others finding central campus computer facilities inconvenient will prefer a smaller departmental computer requiring no programmer. Still others will require a desk top computer no more complex than a calculator. The problems of dealing with vast amounts of published academic literature and the need for academic people to have up to date information will require computer storage of information and corollary electronic information retrieval. Such facilities will be necessary not only in the engineering and natural and physical sciences but also in the social sciences where the processing of statistics, for example, lends itself ideally to computerization.

With the many factors influencing change, it is evident that new physical facilities may become prematurely obsolescent unless spaces are planned to accommodate both changes in function and in disciplines housed. The completion of a new building starts a series of "checkerboard" moves wherein spaces vacated by departments moving to the new building are occupied by other expanding departments. The latter bring with them the requirements of different disciplines and different space uses. For example, there may be need to convert offices or classrooms to laboratories.

Attempting to predict all of the requirements for change would be quite fruitless. The most effective way of responding to unpredictable change is to provide buildings capable of adapting to changing requirements irrespective of the causes. Thus use of an "indeterminate design approach" is suggested. In designing for indeterminacy, a building design must not only provide for specific initial requirements but also the ability to accommodate a wide range of future requirements common to one or more disciplines. Findings from this study indicate that in adapting science and engineering facilities to changing requirements, problems are largely concentrated in the areas of services: plumbing, electrical and atmospheric.

In appraisal of the future, as it relates to the built-environment and the nature and vitality of the university, a very real challenge is that of establishing clear, long-range goals to accommodate both growth and change. Indications are that growth, while predicted to continue into the 1980's, will then taper off, but that change will become an increasingly important factor in keeping the spirit of the university alive and vital. It therefore behooves those responsible for academic and physical planning to recognize and to plan for long term changes in the department, the discipline and the institution. On the basis of the requirements generally defined herein, providing efficient spaces usable for offices, classrooms and laboratories at different times would appear to be feasible. Although the ultimate cost saving lies in the long-term effective life of a facility, it is a goal of the ABS project to provide this degree of adaptability with minimum or no penalty in first cost.

SCIENCE AND ENGINEERING IN THE UNIVERSITY

THE NATURE OF SCIENCE

CHARACTERISTICS

"Science" is most commonly described as a body of knowledge enabling man to understand and control his environment. However, science is not only a product; it is a process. It is a process of enquiry—"a procedure for answering questions, solving problems, and developing procedures for answering questions and solving problems."[1]

The process of scientific enquiry is called "research," sometimes taken as identical with "experimentation." As conceived in the 19th century, experimentation involved physical manipulation of objects, events and their properties commonly taking place in a laboratory. This was assumed to be identical with controlled (i.e., scientific) enquiry. More recently, techniques replacing physical manipulation and utilizing mathematical procedures are used increasingly. These techniques are called "designed experimentation." However, most experimentation still involves some physical manipulation.

Almost all definitions of science refer to the primary role of experimentation. It has been called by some "the essence of science"[2] and by others the "ultimate criterion of scientific knowledge."[3] The tight interrelationship between theory and experimentation is one of the most marked characteristics of science.

The means for pursuing scientific research are referred to as the tools, techniques and methods. Tools are both physical and conceptual instruments including mathematical symbols, microscopes and cyclotrons. Techniques are ways of using scientific tools. Method is the way in which techniques are chosen, i.e., the rules of choice.

[1] Russell L. Ackoff, *Scientific Method: Optimizing Applied Research Decisions* (New York: John Wiley and Sons, 1962).

[2] [illegible] "Science Laboratories [illegible]," [illegible] *Science Education* [illegible] 196[illegible].

[3] [illegible]

Research (i.e., scientific enquiry) can be described at different levels. It is "pure" or "applied," depending upon its use. It can also be described as "fluid" or "stable," depending upon its point of departure. Fluid enquiry involves the search for new concepts, the posing of new questions. Stable enquiry "constructs an edifice on a plan devised by fluid enquiry";[4] it attempts to find answers to questions.

Traditionally, the phases of all research have been described as observation, generalization and experimentation. These phases often overlap, sometimes occur simultaneously, and are generally cyclic. The activities involved in these three phases can be further broken down as follows: observation made, hypothesis evaluated, conclusions reached, and new experiment designed. The cyclic nature (i.e., the revisionary character) of the acquisition of scientific knowledge makes it "an endless frontier with unlimited possibilities for continuing expansion."[5]

Unresolved debates and differences in concept and interpretation are the life blood of science. "Self-evident truths" are no longer fixed; assertions are treated as conceptual structures which can be revised as necessary. The conceptions are guiding principles of enquiry.[6]

CLASSIFICATION

There are seven major areas of science: mathematics, the social sciences, the biological sciences, the earth sciences, astronomy, chemistry, and physics. The last four are commonly termed the physical sciences. Each major area has many divisions. In 1964 one source[7] listed the number of science specialties recognized by the National Science Foundation as 620. Since then, the number has no doubt increased.

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[4] Joseph J. Schwab, The Teaching of Science as Enquiry (Cambridge: Harvard University Press, 1962).

[5] C. W. [illegible], Participant, Conference on "Science and the Future," sponsored by the British Association for the Advancement of Science and AAAS, Boulder, Colorado, Aug. 1965.

[6] Schwab, op. cit.

[7] Henry Margenau, David Bergamini and the Editors of Life, The Scientist (New York: Time Inc., 1964), Life Science Library Series.

The seven major areas of science, together with the humanities, constitute the liberal arts disciplines as opposed to the vocational or occupation disciplines.

The sciences are distinguished from the humanities by their "philosophy and methodology. All sciences have an experimental base."[8] What constitutes a "true" science, however, is not universally agreed upon. "Even among subjects unanimously acknowledged as scientific, some are considered 'less scientific' than others,"[9] and therefore lower on the hierarchical scale.

A hierarchy, often unspoken, exists at many levels in the world of science. There is a pecking order as among "descriptive," "theoretical," and "exact" sciences. There is a ranking between "pure" and "applied" research, and between the "hard" and "soft" sciences. "Hard," "exact" sciences and "pure" research rank at the tops of their respective heaps.[10] A physicist involved in "pure" research outranks a biologist involved in "pure" research, whereas the latter outranks a biologist involved in applied research.

As with disciplines themselves, there is an increased blurring of the boundaries among these various types of science and research. The differences between pure and applied research are not always discernible.[11] Mathematics are being utilized by more and more of the branches of science as can be seen from the diagram on the following page illustrating the proliferation of interdisciplinary specialties.

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[8] [illegible] Mayer, [illegible] Integrating Disciplines [illegible] American Biology Teacher [illegible]

[9] [illegible]

[10] [illegible]

[11] [illegible]

BLENDING OF THE SCIENCE DISCIPLINES

	MATH	PHYSICS	CHEMISTRY	ASTRONOMY	EARTH SCIENCES	LIFE SCIENCES	SOCIAL SCIENCES
MATH		mathematics used by all other sciences					
[illegible]		THERMODYNAMICS MECHANICS OPTICS MAGNETISM/ELECTRICITY CRYOGENICS STATISTICAL MECHANICS QUANTUM MECHANICS PARTICLE PHYSICS NUCLEAR PHYSICS PLASMA PHYSICS ATOMIC PHYSICS SOLID STATE PHYSICS RELATIVITY PHYSICS	MOLECULAR PHYSICS PHYSICAL CHEMISTRY NUCLEAR CHEMISTRY QUANTUM CHEMISTRY	ASTROPHYSICS PHYSICAL ASTRONOMY RADIO ASTRONOMY	GEOPHYSICS GEODESY HYDROLOGY OCEANOGRAPHY METEOROLOGY	BIOPHYSICS RADIOBIOLOGY MEDICINE	
[illegible]		MOLECULAR PHYSICS PHYSICAL CHEMISTRY NUCLEAR CHEMISTRY QUANTUM CHEMISTRY	INORGANIC CHEMISTRY ORGANIC CHEMISTRY POLYMER CHEMISTRY ANALYTIC CHEMISTRY		GEOCHEMISTRY	BIOCHEMISTRY PHYSIOLOGY MEDICINE PHARMACOLOGY MOLECULAR BIOLOGY	
[illegible]		ASTROPHYSICS PHYSICAL ASTRONOMY RADIO ASTRONOMY		[illegible] ASTRONOMY CELESTIAL MECHANICS COSMOLOGY ASTRONAUTICS			
[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
[illegible]					[illegible]	[illegible]	[illegible]

TRENDS

Perhaps the most significant trend is the blurring of the distinctions among the major areas of science. This has resulted from the rise in interdisciplinary endeavors, the proliferation of specialties, and the synthesis of scientific knowledge. "Today, all the physical sciences and some of the life sciences deal in related aspects of a very few basic ideas . . . Indeed, it may some day turn out that all the specialists of science have been working different shafts of the same atomic mine."[12] As a result, many similar tools, techniques and the methods of physics are employed increasingly.[13]

Another significant trend has been the increase in the quantity of basic research (i.e., fluid enquiry) and the drastic shortening of the revisionary cycle. "A recent poll of physicists put the life expectancy of a body of knowledge in small particle physics at no more than four years . . . the modal rate of revision (for all sciences) is probably of the order now of fifteen years. Thus some of the knowledge gained by a high school graduate of 1960 is likely to be obsolete by 1975."[14]

With the increasing shortage of funds, research probably will become more and more "outer directed," especially with a marked political trend demonstrating concern for social and environmental problems. Thus, the quantity of research in certain fields (i.e., physics) is likely to diminish as a greater proportion of the available funds is directed towards the biological and social sciences.

The scientific community seems to be showing more concern and involvement with directing research to the solution of these problems. It seems eager to assume a greater degree of social responsibility than before. "No longer does it appear that science can move forward freely on the basis of bright ideas alone. No longer can the growing points of science develop in an uncontrolled way in the firm belief that the technological spinoff will in the long run be of benefit . . . Scientists have to accept a responsibility for influencing the uses to which new knowledge is put. Science, as a community, must act."[15]

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[12] Margenau, Bergamini and the Editors of "Life," op. cit.

[13] Werner Schramm, *Chemistry and Biology Laboratories*. London: Pergamon Press, 1965 (First English edition).

[14] Schramm, op. cit.

[15] A. F. [illegible], Participant, Conference on "Science and the Future," sponsored by the British Association for the Advancement of Science and the AAAS, Boulder, Colorado, April 1969.

[illegible]

[illegible]

Biology is the science [illegible] and microbiology. [illegible] the structure and function of [illegible] organisms [illegible] the interdependence of organisms, the [illegible] of all living things and their [illegible] with the [illegible]

Biology is now [illegible] requiring a grounding in chemistry [illegible] understand the mechanics of the body [illegible] genetics and in [illegible]. Biology is [illegible] of science [illegible][a] The training and background [illegible] what biology should or should not include. What are [illegible] that biology can no longer be considered a fragmented series of disciplines but must be considered as an integrated science.

The advances of biology have been spectacular in the past twenty years. An [illegible] that even more spectacular achievements are [illegible] the future [illegible] population, urban and environmental problems should increase the research activity in areas such as ecology, the development of marine resources and the behavioural aspects of biology. Interdisciplinary research is bound to increase as biologists focus on such issues as the basis of learning, the nature of growth, development, disease and aging, and the

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[a] [illegible]

[illegible]

[illegible]

The university is generally divided into a number of schools or colleges. [illegible] these are [illegible] either [illegible] departments [illegible] a number of divisions comprising a group of related departments. For instance, the University of California at Irvine has five divisions in the College of Arts, Letters and Science. One of these, the Division of Biological Sciences, is comprised of four departments: Organismic Biology, Population and Environmental Biology, Psychobiology, and Molecular and Cell Biology. The last may soon be split, adding a Department of Biochemistry and Biophysics.

The above example illustrates several characteristics and trends in the organization of departments. One is the fluid nature of organization over a long time period. Disciplines that are sometimes separate departments coalesce to form new departments, just as most of the old disciplines of zoology and botany are now integrated into the Department of Organismic Biology. Conversely, new disciplines emerge or old ones sometimes grow too large and therefore split off from their old departments to form new ones (as with Irvine's proposed Department of Biochemistry and Biophysics).

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[17] Robert H. Knapp, "Changing Functions of the College Professor," In Nevitt Sanford (ed.) *The American College*. New York: John Wiley and Sons, 1962.

SCIENTISTS

CHARACTERISTICS

The word "scientist" was first described as "a cultivator of science" in 1840, although others had been "cultivators" of particular sciences long before. Astronomers and mathematicians were labelled as such in the 14th century, the chemist in the 16th century, the zoologist and botanist in the 17th century, the geologist and physiologist in the 18th century. The term biologist encompassing both botanists and zoologists was coined in the 19th century. As the label "scientist" embraces all these specialties and many more, only gross generalizations can be applied to describe the characteristics of so large a group of people.[18]

Several characteristics are common to most scientists. One is an I.Q. half again higher than that for the ordinary citizen. Another is that the scientist's attitude towards his work is self-imposed. He regards his work both as a vocation and an avocation. Many scientists are nature-oriented for their work is based on a faith in the essential orderliness of nature. Since science is a cumulative effort, most scientists work cooperatively with others. But even though they may share research projects, tools or research results, they tend to prefer to operate individually in their own personal area of interest.

Not all scientists are research scientists, however. Some are teachers, others are laboratory assistants or technicians or engineers. Although the research scientists command the highest prestige, all echelons cooperate in the pursuit of scientific knowledge.

RELATIONSHIPS AND COMMUNICATION

Scientists have always pooled ideas and information. In order to do so, they have organized themselves into various formal associations dating back to the Royal Society in England founded in the 17th century. The "Society" is still the institutional form whereby scientists gather to share information. They cooperate in

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[18] Margenau, Bergamini and the Editors of "Life," *op. cit.*

[illegible] [illegible] the general public through [illegible]

There is also a considerable amount of international contact among scientists, although there are few formal mechanisms through which international cooperation can take place. Among these few are [illegible] and the European Physical Society. Since the fruits of scientific research are the basis of modern technology and of national power, [illegible] tend to guard the strategic resources and [illegible] international cooperation in restricted areas of science.

Scientists are concerned with better modes of information selection, storage, retrieval and dissemination, and are primary users developing in these areas in the decades ahead. Some are concerned with the negative aspects of innovative retrieval systems. Innovations in a retrieval system may discourage science. Science usually goes by the kind of word-of-mouth communication that comes about when a top expert takes a plane and talks to another top expert. It is the corridor talk rather than the formal papers at the scientific meeting that determines where things will go.[19]

Scientists predict that face to face communication will continue to be the principal mode of communication. Mobility of scientists, already considerable, will increase at a national and international level. The cosmopolitan aspects of the scientific community, never parochial, will intensify. The cohesion of the local community has always had less significance for the scientist than the international community of his colleagues.

FUNCTIONS OF SCIENTISTS IN UNIVERSITIES

The diverse and often conflicting functions of the university, and consequently of its faculty, have been indicated. University faculties are expected to teach, to be recognized scholars in their field advancing knowledge through research, to provide

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[19] Hugo Thiemann, Participant, Conference on "Science and the Future," sponsored by the British Association for the Advancement of Science and the AAAS, Boulder, Colorado, April 1969.

[illegible] than the regular 40 hour week. A recent study [illegible] than the average [illegible] 60 hour a week [illegible] as follows:

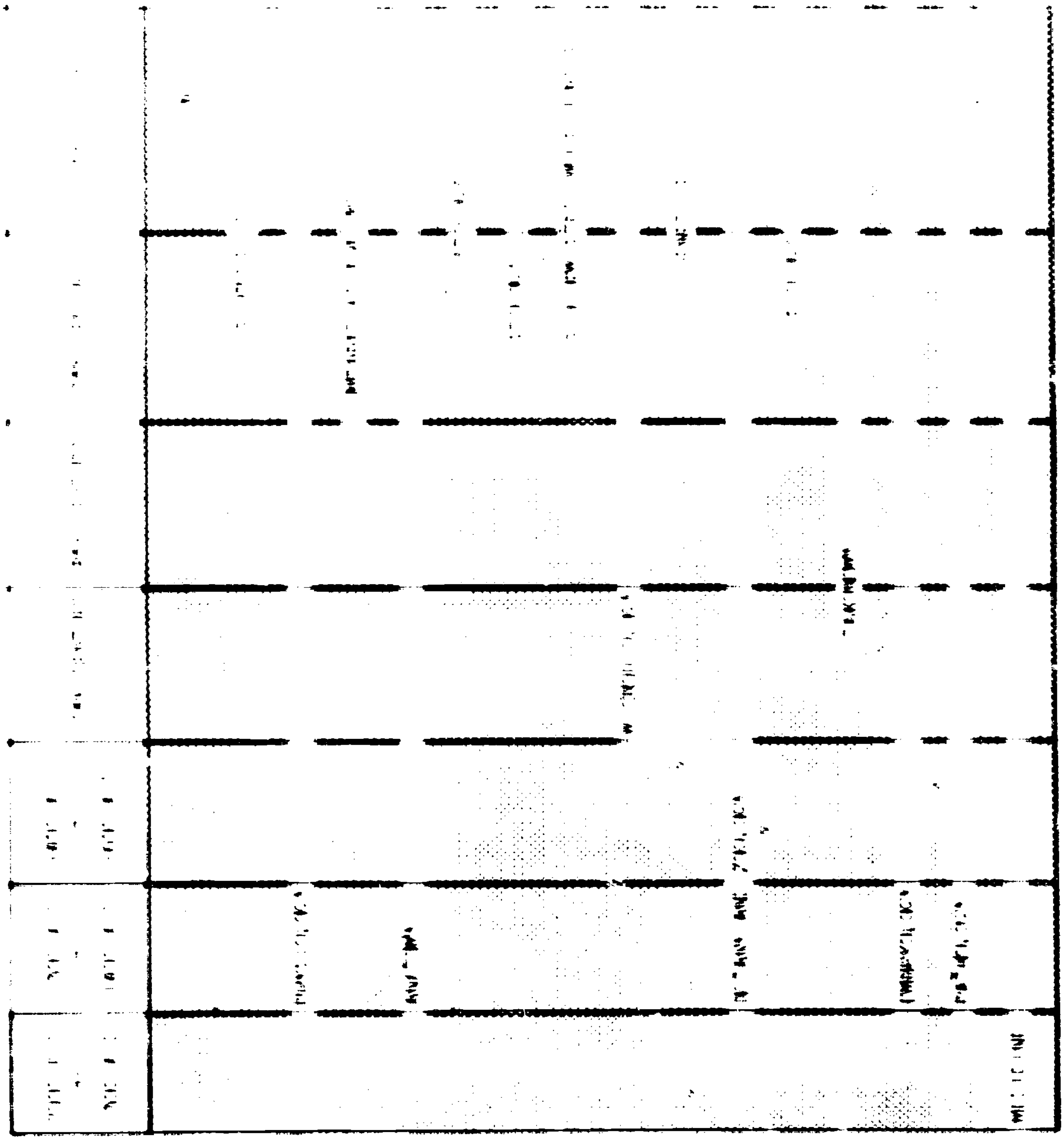
Regular courses including [illegible] and evaluation of students and supervision of student teaching assignments and office hours [illegible]	[illegible] hours/week
Supervision of independent studies including thesis and non-thesis research supervision, special readings [illegible] special arrangements and post-doctoral supervision	3 hours/week
Student Affairs	3 hours/week
Administration including both budgeted and non-budgeted activities related to administration. The [illegible] department faculty [illegible] and special [illegible] assignments is not a part of faculty Senate activity	7 hours/week
Public Service including professional society activities	1 hour/week
Research	19 hours/week

In this study, 42% of the time allocated to faculty research was considered to result in the creation of new knowledge whereas over 40% was considered to be related to the instruction of students. Of course all faculty within one department do not spend the same amount of time in these various activities. In general the younger tenured faculty spend more time teaching and less time in administration and research.

[illegible]

[illegible]

DEVELOPMENT OF THE LIFE SCIENCES



THE NATURE OF ENGINEERING

CHARACTERISTICS

[illegible] [21]

[illegible] [22]

[illegible] [23] [illegible] [24]

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[21] [illegible]

[22] [illegible]

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CLASSIFICATION

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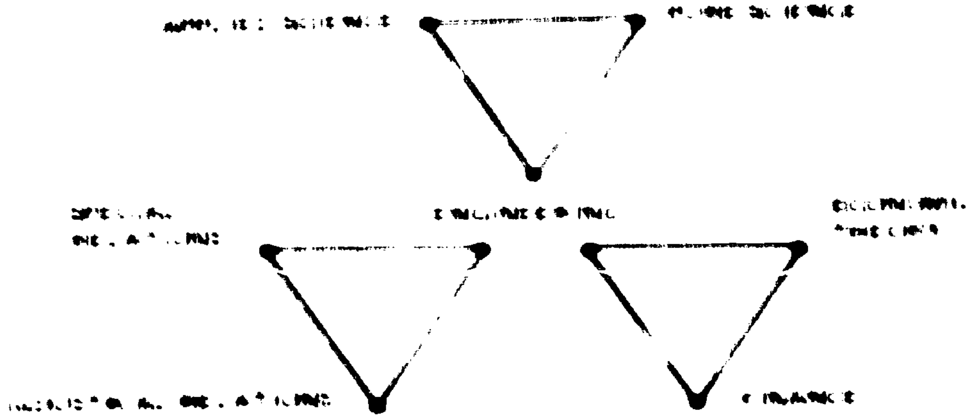

[illegible] given by the [illegible] headings of the book *The World of Engineering* edited by John R. Whinnery. These headings are energy, [illegible] materials, [illegible] information, transportation, [illegible] large structures, large systems, space and bioengineering.

[illegible]

[illegible]

[illegible]

[illegible] engineering.

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

Ibid.

[illegible]

ENGINEERS

CHARACTERISTICS

The scope of engineering is so vast and functions of engineers so varied that the most diverse types of people practice as engineers, from the most theoretically oriented to the most [illegible] minded.[22] It is [illegible] difficult to evoke a clear image of the modern engineer. The image held by the general public of the modern engineer is [illegible] [illegible] limited.

[illegible] Brown, Dean of Engineering at MIT, has categorized four very different types of engineers. The first, who have a great talent for abstract thinking and can relate seemingly unrelated concepts in novel, purposeful ways, he calls the conceptualizers. The second group are engineers, inventors or innovators. Their work is also highly intellectual and creative but their major purpose is to devise, design, and build things that work. The third and largest group are called the custodians of modern technology. They are responsible for assembling, operating, and maintaining complicated machines and engineering works. Finally, there are the interpreters who [illegible] technology to interface areas with such fields as industrial management, political science, or the life sciences.

Although the engineering profession embraces many different personality types with diverse activities and talents, certain characteristics are shared by a great majority. One of these is a practical approach. [illegible] is first of all a practical man, a pragmatist who shoulders the immediate problems of civilization and solves them. [illegible] Paradoxically, this practical man may be a visionary who dreams of a better way to do the job, who uses his creative ingenuity to establish a totally new system or applies an old method in a new and imaginative way.[23]

The description above certainly applies to the top echelon of engineers and probably to many recent graduates from the better engineering schools. Gorham's study[24] of a large number of practicing engineers indicated that even though the engineer is

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[22] [illegible] and Whitmore, op. cit.

[23] *Ibid.*

[24] [illegible] Gorham, "Engineering Characteristics and Management Careers," *Journal of Engineering Education*, April 1965.

often working in the forefront of technology, he tends to be conservative, to fear originality, to distrust deviations from tradition and to seek consensus for his authority. This conservativism and conventional behavior applied in engineers' personal lives, their work, politics, religion, fraternal affiliations, dress, and manners.

The author of the above study makes several pertinent comments about the characteristics of engineers. Most significantly, he believes that these characteristics of conservativism enhance rather than hinder an engineer's occupational adjustment, since engineering circles value these traits.[35]

RELATIONSHIPS AND COMMUNICATION

Engineering is a profession, the practice of which is controlled by each State. In order to use the title "professional engineer" or "consulting engineer," an engineer must register with the State. This requirement for formal recognition requires formal channels for an engineer's dealings with his colleagues and with regulating agencies. These channels exist in the form of several national organizations—called "Institutes," or "Societies"—each of which represents a particular branch of engineering.

There are two national federations of engineering societies. One is the Engineers' Council for Professional Development (ECPD) which acts as a coordinating agency, especially in education and training of engineers. The other is the Engineers' Joint Council (EJC) which coordinates matters of national or international significance and maintains the Engineering Manpower Commission. Another organization—The National Academy of Engineering—was formed in 1964 to advise the government on matters of engineering policy.

On the international scene, engineers, like scientists, tend to discourse with their colleagues of other nations, often at international conferences such as the 1955 Conference of Engineering Societies of Western Europe and the United States. American engineers are also involved in a consulting capacity, e.g., the NATO, or in assistance programs to underdeveloped nations; they often travel overseas on behalf of the government or philanthropic organizations.

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[35] *Ibid.*

Assistance programs to other nations are likely to increase in the future and the contributions of the engineering profession will no doubt increase markedly as attempts are made to improve the standards of living through technology. "In today's world a large corps of educated engineers is clearly a powerful instrument for enhancing human activity in every nation."[36]

FUNCTIONS OF ENGINEERS IN THE UNIVERSITY

The functions of university faculty have been indicated previously. Engineering faculty members have much the same duties as those of other disciplines, i.e., teaching and student guidance, "creative activity" including research, administration and public service. The proportions of time spent on each depend both on the individual faculty member and on the engineering school.

Research is only one of several "creative activities." Also included are engineering practice (during summers, leaves, or through guidance of engineering internships and work study programs), organization of knowledge for use by engineers, and development of educational materials and methods for use in the university's programs and elsewhere.[37] A proportion of engineering faculty also does consulting work for industry.[38]

The teaching function, together with student guidance, occupies the bulk of most professors' time. It includes not only undergraduate and graduate programs, but in some cases, continuing education programs as well. Continuing education for professional engineers is of major concern to the engineering profession.

Other faculty functions include continuing self-improvement: "One of the most crucial problems facing administrators of engineering colleges and universities is to discover efficient ways to keep their faculties not only abreast of changing technology but to give them the facilities, the environment, and the purposefulness that will make them generators of new technology."[39]

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[36] Gordon S. Brown. "Modern Education in Science and Engineering—Pace Setter of Industrial Technology." A presentation delivered at the 1964 Long Range Planning Conference at the Stanford Research Institute, Palo Alto, California.

[37] University of California Engineering Master Plan, 1965.

[38] Dean Maslach of the University of California at Berkeley says "the proportion of faculty involved in consulting is very small—in the order of one in a hundred."

[39] Brown, *op. cit.*

Research and development "directed toward urgent public needs" is also labelled as a public service activity. This function is especially important in state schools. Another public service function of growing importance is consulting work for the government and participation in foreign assistance programs. This often involves considerable travel time. "The engineering professors of today are members of the 'jet-set,' commuting to Washington to serve as advisors to the government, commuting to confer with their research sponsors and their consulting clients, travelling to their visiting lecture assignments, and going overseas to advise and contribute expert knowledge to international assistance programs."[40]

Engineering faculty do not move as often as scientists do from one university to another. Their mobility is rather between the university and industry, many forming their own companies on the basis of their research achievements.

Of all the functions a faculty member is expected to perform, only the research function is truly rewarded. "The faculty members whose creative work is not in the area recognized as research are disadvantaged . . . And excellence of teaching is not weighted strongly enough. A result has been the evolution of a research-dominated education program, albeit one of high quality. Undergraduate and professional graduate instruction and continuing education have been handicapped."[41] Of course this is not true of all schools of engineering. "At Purdue, promotion requires excellent performance in teaching OR research OR service. Stanford has been able to appoint or promote a number of engineers on the basis of high-quality work in design and teaching."[42]

Many changes in university education are predicted for the future, among them changes in the type of engineering faculty. Dr. Gordon Brown has stated: "I believe that many academic changes must take place . . . a new kind of faculty must emerge. To bring this new faculty into being, many of today's professors must undertake much new learning, and many new men must be added; they will inevitably be younger."[43]

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[40] M. R. Lohmann (ASEE President). "In the Main Stream," *Journal of Engineering Education,* September 1967.

[41] University of California Engineering Master Plan, 1965.

[42] *Ibid.*

[43] Brown, *op. cit.*

RESEARCH VERSUS TEACHING

As financial resources have dwindled, the university is examining its resource utilization more closely. A primary resource is the faculty, whose functions are not only educational but include the scholarly and professional functions of research and publication. "Their own professional standards set limits to institutional resource management. These standards govern the national market place in which every university must compete for manpower."[44]

Because of conflicting claims on faculty time, a system has evolved whereby faculty are freed as much as possible in order to pursue the research and teaching functions, leaving certain tasks to be fulfilled by the laboratory assistants and graduate students. The relationship between faculty and graduate students has become symbiotic; it seems impossible that the one could function without the other. Graduate students serve the faculty both as Teaching assistants (TA's) and Research Assistants (RA's). Generally, the services of the TA's are paid for by the department concerned, whereas the professor's research grant pays for the RA's time.

The graduate *research* assistant benefits from his very close contact with the professor. His thesis is developed from work pursued under the professor's guidance. From one to eight research assistants perform their research work in the professor's laboratory or one located close by. These assistants often serve as buffers for many potential interruptions that might otherwise disturb the professor.

The graduate student *teaching* assistant benefits financially more than academically since he may not have close contact with the professor. He supervises undergraduates in their laboratory sessions, conducts discussion groups with them, answers their questions at unscheduled hours and often grades the examinations.

In this way, the professor has been enabled to pursue his many duties at the university. His research serves as a model for his students, providing them with an indispensable part of their education.

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[44] From a report to The Regents entitled, "Faculty Effort and Output Study." Berkeley: Office of the President, Analytical Studies, University of California, January 6, 1969.

There are two major types of research laboratories found on university campuses One is the laboratory belonging to an "Institute" maintained by the university (such as the Institute of Environmental Stress at University of California, Santa Barbara); the other is the research space allocated to an individual faculty member and his graduate student research assistants.

Institute laboratories are a twentieth century creation, and require teams of workers and substantial budgets. Generally they are specially designed facilities not subject to the same pressure of need of adaptability and change as the individual scientist's own laboratory.

The individual's laboratory is unique since university scientists' careers take them from one institution to another, and each works in his own specialty, on his own particular project and with its own particular needs for manpower, equipment, space, utilities and controls. There is no way of generalizing about this type of research laboratory, other than each is required to be as adaptable as possible in all ways, and that obsolescence in both laboratories and equipment is rapid.

As long as the university seeks the well known scholars for its faculty, so long will research remain a dominant activity in departments of the university. This system is likely to endure even if changes should alter the priorities between research and teaching.

It is feasible, of course, that the university might divorce the functions of teaching and research and seek both scholars and interpreters—the latter hired to spend all their time teaching—as is the case with many faculty members at four-year colleges. But the trend over many years has been in the other direction, and the university is now "primarily a center of research, scholarship, and professional training; . . . the home of the expert, . . . the academic and conceptual distance between the expert and the (undergraduate) student is so great that it is only bridged with difficulty."[45] There has been, therefore, an increasing emphasis on graduate as opposed to undergraduate education, and a strong emphasis on advanced study research. "Maybe the pattern of Central Europe—the research institute on the one hand, and the university on the other—will emerge in this country, partly as a consequence of student pressure but also as a growing recognition of the built-in incompatibilities.[46]

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[45] Burton R. Clark and Martin Trow. Determinants of College Student Subculture. Unpublished paper. Mimeo. No date (approximate date 1962).

[46] *U.S. News and World Report,* January 12, 1970.

THE CURRICULUM

"There are six 'elemental' parts of the curricular-instructional system as it operates on any campus anywhere. These are:

1. The content of study.
2. The part by which groups of learners (with or without teachers) are brought together to pursue their studies.
3. The part by which the learner is officially evaluated, certified, and awarded titles of degrees, i.e., the system of formal incentives.
4. The relationships among learners and between learners and teachers during the "instructional" process.
5. The kinds of experiences the learner undergoes as part of his learning.
6. The total part of freedom-authority under which a learner pursues his studies."[47]

Joseph Axelrod has named these as: content, schedule, certification, group/person interaction, student experience, and freedom/control.[48] Each one interacts with each of the others, forming a dynamic system. Changes in one part cannot be made without repercussions throughout the entire system. This may explain why successful innovative programs are not yet accepted on any large scale.

The whole question of curricula design is being studied and debated. Since the late 1950's, science curricula have been the concern of the top scientists in each field—in itself a major innovation. The curricula in physics, mathematics, chemistry, the biological sciences and engineering are being examined by separate groups of experts.

RECENT DEVELOPMENTS IN CURRICULUM DESIGN

Axelrod[49] describes six major trends in innovative undergraduate programs responding to recognized weaknesses in the standard curriculum. These are:

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[47] Joseph Axelrod. *New Patterns in Undergraduate Education: Emerging Curriculum Models for the American College*. New Dimensions in Higher Education Series. Washington: U.S. Department of Health, Education, and Welfare, April 1967.

[48] Joseph Axelrod. "Curricular Change: A Mode for Analysis." *The Research Reporter*, Vol. III, No. 3, 1968. Published by The Center for Research and Development in Higher Education, Berkeley, California, pp. 1-4.

[49] *Ibid.*

Weaknesses of Standard Undergraduate Program	Innovative Program Response
Depersonalization in relations between faculty member and student and between student and student	Creation of relatively small primary groups consisting of faculty and students who by participating together in the learning process, comes to know, care about, and develop a sense of responsibility for one another
A program of fragmented and departmentalized courses within the same department but not to each other	A program of courses organized in such a way that their materials flow into one another
A curriculum that is isolated from the community and the world with "credit"—yielding experiences revolving mainly around books, lectures, written papers, and artificial laboratory exercises.	Classroom, library, laboratory work blended together with direct experience in the community and the world as part and parcel of the curricular structure.
Outdated and inaccurate notions about how human beings "learn"; teaching is mainly telling; learning is mainly receiving; the student is mainly an information-skills storage and retrieval unit.	Teaching and learning seen as process of cooperative enquiry; a "dialectic" as opposed to "didactic" approach.
Prevalence of notions of academic "success" which gives the highest grades to the best gamesman; emphasis on faculty member as "judge" at the expense of his function as teacher and critic.	Liberation from the value system which creates the "grade game" between student and faculty; emphasis on faculty member as teacher and critic, with role of "judge" relegated to some other person or agency.
A pattern of student freedoms and controls—authority and status—that works against growth in students toward independence of mind, creativity, and responsibility.	A pattern of student freedom and controls—authority and status—that reinforces the values professed by American colleges.

The second and fourth response listed in Axelrod's chart have been of particular concern in the sciences.

College curricula in biology are presently the concern of the Science Curriculum Improvement Study, supported by the National Science Foundation and of the Commission of Undergraduate Education in the Biological Sciences (CUEBS). Other groups working to change science curricula are the Federation of Unification of Science Education (FUSE), a loose federation of 75 projects, each working towards the new philosophy in science education that restructures the curriculum so it cuts across traditional course lines. The main objectives of these new science curricula are to place emphasis on the structure of the subject, on the basic concepts integrating the various disciplines, and on how information is obtained. It is felt that less attention should be paid to the accumulation of "facts," and "facts" themselves should no longer be presented as unalterable truths. In other words, it is believed that science should be taught as a laboratory-oriented process of enquiry, rather than a stable body of knowledge."[50] The enquiry approach, involving the student as an active participant in the education process, will become more and more prominent, and classrooms will be no longer lecture halls but sites of mutual discussion.[51]

Some of the changes that have already started to occur in the biology curriculum include the "breakdown of the organismally-oriented artificial disciplines of botany, zoology and microbiology" and the reorientation towards process centered topics such as genetics and metabolism.[52] Bently Glass is quoted as saying that "in many universities, the upper positions are still filled by men to whom biology means classification rather than experiment, morphology rather than biochemistry, organ physiology rather than cell biology."[53]

Since the end of World War II, "the words, 'changing curriculum' also have characterized engineering education. In one sense this is healthy, indicating a dynamic educational system; in another sense it is tragic, in that educators cannot agree on the foundation subjects that will prepare students to be engineers . . ."[54]

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[50] Schwab, *op. cit.*

[51] William V. Mayer, "Biology for the 21st Century," *American Biology Teacher*, May 1967. Author is Director of Biological Sciences Curriculum Study.

[52] *Ibid.*

[53] P. B. Siegel, "An Agricultural Scientist Looks at Modern Biology Teaching," *Science Education*, March 1967.

[54] M. E. Van Valkenburg, "The Changing Curriculum: Electrical Engineering," In *Industry's Stake in the Changing Engineering Curriculum* (see ASEE Report 1969).

Changes are the concern of the American Society for Engineering Education (ASEE). One of its recent reports, "Industry's Stake in the Changing Engineering Curriculum," reflects a predominant current concern of the profession that the engineering curriculum has become so science-oriented that graduates are not now sufficiently well equipped to deal with industry-related problems. Analysis is stressed at the expense of synthesis (i.e., design). The trend towards a more scientifically oriented curriculum in engineering is fairly recent.

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[55] This trend is discussed in "The Nature of Engineering," under the title, "Trends."

TRADITIONAL COURSE ORGANIZATION

At the university level courses of study are divided into three classes: lower division, upper division, and graduate.

Lower division courses are usually introductory courses, often designed for large numbers (usually in the hundreds) of first and second year students. Generally there are relatively few lower division courses at the university, perhaps three or four per discipline.[56]

Undergraduates generally have no contact with faculty other than at formally prescribed lecture periods.[57] They may, however, visit the professor during "office hours" if in need of advice or if the professor has been assigned as a student "advisor." Undergraduate individual study courses, under the direction of a faculty member, seem to be rather rare, a major reason is the problem of conducting and/or supervising individual laboratory work, especially where sophisticated equipment is required. Undergraduate student laboratories are conventionally supervised by graduate student Teaching Assistants (TA's). On some campuses the student sees only TA's for the first two years of his studies.[58]

Because of the increasing numbers of students, many upper division courses are organized in a manner similar to the lower division. Formal contact between faculty (or assistants) and students in any one course of study in the sciences or engineering may take place in one or more of the following modes: lecture, lecture demonstration, laboratory, discussion, seminar. Seminar-type courses, the least common, are limited sometimes to as few as eight students.

Specialization takes place only at the graduate level. Herein many courses are organized as weekly seminars, each lasting perhaps two hours. The graduate student receives most of his laboratory experience in the research laboratory of the professor in charge of his studies.

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[56] Albert H. Bowker. "City University Faces up to the Urban Realities." *New York Times*. January 12, 1970. Annual Education Review. He suggests one innovation feasibly emerging in the next decade is early specialization in courses directly related to an undergraduate's career choice. This would provide more academic motivation than the present system.

[57] Ideally, faculty would supervise discussion groups and laboratory sessions as well. This is rarely possible except in classes of less than about 30 students. Traditionally, laboratory sessions are conducted in a 24-student group (number varies between 18 and 36). Discussion groups are often smaller and are handled by TA's (i.e., graduate student teaching assistants) under the general supervision of the "head TA"—the only one likely to be in contact with the professor in charge.

[58] Bowker *op. cit.*

The major difference between engineering and science is that the former does not need to cater to large numbers of non-major students. Also, engineering class size tends not to be as large as for most science disciplines. Student faculty ratios in engineering are generally the same as in other university colleges.

The importance of laboratory experience to all students in science or engineering is constantly stressed by most progressive educators. They emphasize that science is a process of enquiry which can be understood only if the student is involved in this process. "We can no more conceive of a science course without laboratory than a music course without listening to music."[59] In some subjects it may be possible to obtain this involvement by observing a demonstration.

Laboratory work is expensive on a per student basis. This cost and the increasing pressures for space have resulted (in some universities) in the elimination of laboratory sections for all non-majors. In a few instances the shortage of laboratory space has led to innovative programs such as "take home labs" for experiments requiring unsophisticated equipment.

"There are several types of engineering teaching laboratories:

1. The *set laboratory* with specified experiments using detailed instructions and equipment. The experiments are repeated each semester with minor change.
2. The *take-home laboratory* wherein a significant part of the work is done by the student away from school, and the results of his work reported to the instructor.
3. The *problem laboratory* wherein a student is given a specific, well described task to undertake.
4. The *project laboratory* wherein the project to be undertaken may be somewhat general in description and may be of broad scope.

Each of the different types of laboratories is used for instruction in all of of the different aspects of experimental studies . . . the actual appearance any one laboratory takes is dictated by many factors: school, instructor, facilities, capital equipment available."[60]

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[59] James H. Mathewson. "Student Laboratories: An Underdeveloped Educational Resource." *Science Education*, March 1967.

[60] Commission on Engineering Education Report: "New Directions in Laboratory Instruction for Engineering Students." *Journal of Engineering Education*, November 1967.

INNOVATIVE PROGRAMS AND TRENDS

INNOVATIVE PROGRAMS

Several institutions have initiated experimental programs in an attempt to overcome several educational and logistic problems in the traditional curriculum and course organization. These innovations are briefly described below.

1. **Core Programs.** This is one of the most widely adopted innovations. It teaches the basic concepts common to several disciplines, in an effort to avoid duplication and to convey the structure of the subject to the student. Each discipline (or department) contributes resources to a series of courses planned as a unified continuum. In general, the mode of presentation of the learning material is no different than that for a conventional science course.[61]

   An example of the core curriculum in the biological sciences exists at Stanford University, and is projected for the University of California at Irvine. At the Case Institute of Technology, ten lectures from different specialties and twenty four instructors in charge of laboratories coordinate their efforts in a "core laboratory."[62]

2. **Instruction for Graduate Student Teaching Assistants.** All laboratory instructors attend workshops throughout the semester in order to maintain quality teaching, and are intermittently observed at work by the department chairman and his assistant. The lecturers–professors on the faculty–are also observed by the department chairman. Student workshops are conducted throughout the term to overcome difficulties and to maintain a high quality of education.

   An example is at Brooklyn College in New York City. A two-year integrated science course for 2,000 non-science majors is divided into 120 student groups for three hours of lectures per week and 20 student groups for two hours of laboratory. The laboratory sessions are supervised by TA's.

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[61] Even in conventional lower division courses, the laboratory has tended to become "interdisciplinary" in character with special equipment required for particular disciplines stored in a large prep room and brought into the laboratory when required. In this way, the same laboratory can be used by several disciplines.

[62] L. C. Dumholdt. "An Engineering Core Laboratory." *Journal of Engineering Education*, November 1967.

3. **Taped TV Lectures for Small Classes.** Lectures are taped and presented on TV to small groups of 24 students. These 45-minute lectures are followed by 30 minutes of discussion with a graduate student instructor. The instructors have previewed the taped lectures and are briefed by the lecturer. Laboratory sessions are longer and include a "high level of complexity and sophistication of both ideas and equipment" necessitating the services of an administrative assistant. TA's receive lab-preparation sessions and supervise the laboratory sessions.

   An example is at Rutgers University in New Jersey where the General Biology course has been reorganized.[63] This was to accommodate the increased enrollments and to improve the quality of instruction.

4. **Two-Way Television.** One example is now under way at City University of New York. It will extend the college classroom to the workplace of many New Yorkers. Using recently developed two-way television instruction system, employees at work will be able to participate in courses keeping them abreast of their technologies."[64]

   As another example, Southern Methodist University has rented videotapes of an outstanding seminar program on computer-aided design and is beaming them out between semesters to industry over its talk-back TV system. It "has been an enormously important interactive mode for the SMU Institute of Technology and North Texas Industry."[65]

5. **Programmed Laboratory Instruction on Tape Recorders.** Played on a tape recorder to the entire class, the instruction covers all the procedures to be followed—the background information and the theoretical aspects of the work to be performed. It is so prepared that students have time to carry out the procedures after instructions are given. Separate tapes covering instrument operation and procedures may be played at the individual student station.

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[63] Paul G. Pearson and William B. Foster. "Change in College Biology—A Case History." *American Biology Teacher,* March 1967.

[64] Bowker, *op. cit.*

[65] Thomas L. Martin, Jr. "Industry-Education Interaction: Synergistic Symbiosis." *Journal of Engineering Education,* May 1969.

One example is the chemistry laboratory at Hamline University, St. Paul, Minnesota.

6. Computer-Aided Instruction (CAI). Use of the computer in science research has increased rapidly. Apart from its obvious use in solving computational problems and analyzing data, and its use for laboratory quizzes, it is being explored as an aid to instruction in science at several universities. The computer is able to bring into play films, filmstrips, audio materials and printed text. Capable of the utmost patience and the ability to direct the student appropriately at the proper time, use of the computer in the future as an aid to instruction seems certain.

   A January 1968 report[66] says preliminary studies and development projects for computer-aided instruction have been started at the Universities of Michigan, Texas, Illinois, Pittsburgh, and California (Irvine and Santa Barbara). Projects are also under way at Stanford University, Pennsylvania and Florida State Universities. In November 1968, the CAI, CMI Newsletter (published by Enteleck, Inc., Newburyport, Mass.) noted that the National Science Foundation had awarded a grant to the University of California at Irvine to develop computer-based materials for teaching beginning level physics.

   Examples of programs now utilizing computer-aided instruction are:

   - McMasters in Hamilton, Ontario, has 35 to 40 undergraduate CAI courses in math and engineering.[67]

   - The University of California at Berkeley uses CAI for part of three courses in electrical engineering; CAI is used as a supplement to regular course work rather than a substitute.

   The use of electronic computers as learning aids in engineering is incidental as compared with its use as a tool. Increasingly, computer simulation is taking the place of physical simulation and testing. Computer graphics and computer-aided design are finding their way into the engineering curriculum. "It has been

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[66] Vincent S. Darnowski. "Computer-Aided Instruction: A Tool for Science Teaching in the Seventies." *Science Teacher,* January 1968.

[67] Entelek, Inc. *CAI-CMI Newsletter,* Vol. IV, No. 6, December 1969.

contended that no other single learning experience should be more common to the framework of engineering than familiarity with computers . . . . It is time to prepare for the new approach to education that this will entail."[68]

7. **Audiotutorial Laboratory.** This innovation will probably become the most widespread. The freshman botany course at Purdue University is the best example.[69] Begun in 1961, it is still in operation. Four basic activities involved are: the independent study session, the general assembly session, the small assembly session, and "other activities."

   The general and small assembly sessions are held weekly in two spaces—the one accommodating 420 students, and the other eight students plus an instructor. The general assembly session is useful for orientation activities at the beginning of the course, and ensures that students see the senior instructor whose voice is heard on tapes during the individual study session.

   The small assembly session is in the manner of a seminar, with students and instructor seated round a table. All students are expected to give a short lecture on the subject studied during the preceding week. The session is one of review, reinforcement and correction, plus feedback to the instructor.

   The major innovation in this concept is the independent study sessions. These take place in the "learning center" of audiotutorial laboratory.[70] The learning center enables the student to study individually at his own convenience and progress at his own rate. The tape recorded learning material covers a week's work and is played on a tape recorder at the study carrel. The tape also directs the student's activities; he is told at which point to conduct an "experiment" at the central table, or when to read a short segment from his text. The student uses the tape in conjunction with a film projector and a mimeographed list of the "behavioral objectives of the week's work."

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[68] David L. Johnson. "Computers in the Engineering College Curriculum." *Journal of Engineering Education,* April 1968.

[69] S. N. Postlethwait, J. Novak and H. T. Murray, Jr. The Audio-Tutorial Approach to Learning: Through Independent Student and Integration Experiences. Minneapolis: Burgess Publishing Company, 2nd Edition, 1969.

[70] This space is furnished with study carrels for 32 students, a long central laboratory table for experiments and demonstrations, a small library, and equipment such as blackboards, tackboards and growth racks with flourescent lights (for growing plants over a long period of time). It is convenient to a slide projector area, and a preparation and storage room.

The "other activities" include a relatively major research project for students anticipating an "A" grade, plus a small research project for all students.

The major advantage of this concept is the possibility of "individualized instruction" without prohibitive costs—a combination sought with most innovations.

8. The **Project Approach**. One example, much larger in scope than might be expected, is the program of educational laboratories at MIT. These have been developed "hand-in-hand with the evolution of institute-wide research centers . . . in these project-oriented environments, sponsored projects in exacting the authentic development and design are undertaken in ways that permit student participation or suggest projects that students can conduct on their own."[71]

9. **Interdisciplinary Activities**. This is a variant of the project approach. "Several universities already have taken action to provide an educational framework to bridge the gaps among specialists and to provide opportunity for their collaboration on environmental problems."[72]

   An example is a series of courses at Purdue University dealing with "environmental engineering," and supported by the Departments of Mechanical Engineering, Geosciences, and Agronomy "because of their mutual interest in the air environment."[73] Funding of the program, including support for students, comes from the National Center for Air Pollution Control of the U.S. Department of Health, Education, and Welfare.

10. **Case Study Method**. Close in spirit to the project approach and a common method in law schools, the Case Study Method is new to engineering education. It presents engineering students with current, relevant problems in engineering practice. "In this method industrial firms outline design problems that either were great successes or great failures. The problems are a vicarious experience

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[71] Brown, *op. cit.*

[72] *Journal of Engineering Education,* October 1968, p. 108.

[73] J. F. McLaughlin. *Annual Report for the Year 1968-69.* School of Civil Engineering, Purdue University.

for students; they study a problem from the beginning, through identification and development stages, to its conclusion."[74] This method is used in the Department of Mechanical Engineering at the University of California at Berkeley.[75]

11. **Continuing Education Programs.** Designed for the continuing education, these programs aim to present learning material so as to interfere as little as possible with employment. For example, the Universities of Santa Clara and Southern California give engineering courses early in the morning or in the evening. The University of Wisconsin operates a program called Articulated Instructional Media (AIM) giving courses via telephone hookup so that the distance between industry and the university is no longer an obstacle.

    In the "Live-in Program" at MIT, practicing engineers spend a year at a special engineering center in an environment conducive to considerable individual attention and interchange between faculty and students.

12. **Innovative Methods of Organizing Laboratory Courses.** These innovations either reduce costs, or improve content by emphasizing the experimental rather than the cookbook type of laboratory experience. Examples of both exist at the University of Illinois,[76] where a programmed self-demonstration lab is used to cover certain non-experimental portions of the curriculum and an "Experimental Laboratory Program" permits students to use the laboratory at unscheduled times.

TRENDS

Relatively minor revolutions using electronic media for individualized instruction will probably be widespread by the year 2000 since these changes increase the "productivity" of the university, affecting student-faculty ratios and space utilization. "New technology will have profoundly affected education by the year

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[74] Arthur G. Hansen. "The Changing Curriculum: Mechanical Engineering." In *Industry's Stake in the Changing Engineering Curriculum* (see ASEE Report, 1969).

[75] Professor Steidel, primarily responsible for introducing the case study method, considers it necessary that traditional teaching spaces be altered to accommodate the freer discussion that occurs.

[76] J. O. Kopplin. "An Experimentation Laboratory." *Journal of Engineering Education,* November 1967.

2000 . . . . Education will have been freed from the constraints of location and stage of life . . . . little of this will have happened by 1980. Some of it will have happened by 2000."[77]

Other changes improving the university "productivity" will be: the four-quarter system, the increasing number of students completing two years at junior colleges, and increased utilization of teaching spaces such as laboratories by various devices (e.g., "take home labs," "lecture/experiment" tapes and computer terminals in the laboratory, reduction in number of hours per week per student).

The most significant trends applicable to engineering education are:

1. **Lengthening of Engineering Education.** "The time required for a first degree in engineering has traditionally been four years past high school, although a few schools have set a five-year curriculum. However, the ever-growing complexity of engineering education suggests that within a decade most engineering schools will allocate five years for a degree. . . . "[78]

2. **Continuing Education.** The accelerating expansion of scientific and technical knowledge has resulted in increasingly rapid obsolescence of specific and/or narrow training programs. The engineering curriculum needs to be constantly updated and practicing engineers are needing to constantly update their skills. Collaborative programs between industry and the university will become increasingly common in the future.

3. **Increased interdisciplinary Activity and Emergence of New Disciplines.** Interdisciplinary activity can be expected to increase markedly and will result in the emergence of new disciplines and curricula. New courses will be integrated into the program while others are shed. Kincaid lists: "Courses which are now accepted parts of today's program but which were literally non-existent only a decade and a half ago: information theory, feedback

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[77] Clark Kerr. "New Learning Looks Longer and Broader." *New York Times,* January 12, 1970, p. 49. Annual Education Review.

[78] John F. Kincaid. "Engineering Education for an Age of Change." *Journal of Engineering Education,* February 1968.

control, atomic and nuclear physics, computer science and computer technology, computer-aided design, solid state physics, plasma physics, systems theory and research, probability theory and biomedical engineering. Who would attempt to list the curriculum offerings of the year 1982?"[79]

4. **Changes in Tools, Techniques, Methods and Equipment Used in Education.** Education must be constantly updated because of increasing availability of these. For instance: "The computer will play an increasingly potent role in engineering education and in the practice of the engineering profession. Today it is used primarily as a computation tool; tomorrow it will be used for on-line processing of research data. But perhaps the greatest impact of the computer in the field of engineering will be in design. Today computers can translate numbers into visual models which can be manipulated; tomorrow many of the routine but complex problems of design—problems which now absorb vast quantities of man-hours—will be solved by the computer at a speed of millions of operations per second."[80]

   Other tools, such as systems analysis and operations research methods, enable the design of more complex systems.

5. **Development of a Four-Year Engineering Technology Curriculum.** The need for technicians and technologists is not presently met by the country's colleges and technical institutes. According to the University of California Engineering Master Plan, the ratio of technicians to engineers will need to be substantially increased in the future. It is presently one-to-one. It is likely that there will be a marked increase in the number of four-year engineering technology baccalaureate programs.

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[79] University of California Engineering Master Plan, 1965.

[80] Kincaid, *op. cit.*

APPENDICES

APPENDIX A

INDIANA SAMPLE BUILDINGS

Listing of Occupancies by Discipline for the 1969 Academic Year

Building Location	Building Type	Disciplines Housed
Jordan Hall Indiana University Bloomington	Biosciences	Biology Microbiology Botany Zoology
Krannert Hall Indiana University/Purdue University Indianapolis	Science & Engineering	Electrical Technology Chemistry Construction Technology Manufacturing Technology English Speech Industrial Technology Industrial Management History Engineering Management Physics Philosophy Education Mathematics Modern Languages Biosciences Nursing Technology Mechanical Engineering Technology Psychology Sociology Foods and Nutrition
Civil Engineering Building Purdue University Lafayette	Civil Engineering	Civil Engineering Bionuclear Engineering

CALIFORNIA SAMPLE BUILDINGS

Listing of Occupancies by Discipline for the 1969 Academic Year

Building Location	Disciplines Housed
Biological Sciences Unit 3 U.C. Davis	Biological Sciences (principally Zoology)
Natural Sciences Unit 1 U.C. Irvine	Physical Sciences Engineering Sciences Biological Sciences
Biological Sciences Unit 2 U.C. Santa Barbara	Biological Sciences Vivarium Institute of Environmental Stress

APPENDIX B

ADMINISTRATORS AND FACULTY INTERVIEWED

In addition to the group interviews with occupants of the six sample buildings, the following persons were individually interviewed regarding educational programs and space use in academic buildings.

Discipline	Person and Title	Date of Interview
General Education	Rankin, Allan President Indiana State College Terra Haute	4 April 1970
Audio Visual	Richardson, Edgar Director Audio Visual Center Indiana University Bloomington	26 March 1970
Geology	Patton, John B. Geology Department Dean Indiana University Bloomington	19 March 1970
Psychology	Saltzman, Irving J. Psychology Department Dean Indiana University Bloomington	19 March 1970
Astronomy	Edmondson, F. K. Professor of Astronomy Indiana University Bloomington	18 March 1970
Zoology	Torrey, Theo. Professor of Zoology Indiana University Bloomington	25 March 1970

Discipline	Person and Title	Date of Interview
General Education	Buhner, John C. Vice Chancellor I.U.P.U.I. Indianapolis	3 April 1970
General Education	Ryder, Jack Vice Chancellor I.U.P.U.I. Indianapolis	3 April 1970
General Education	Pruis, Jack D. President Ball State Muncie	4 April 1970
Chemical Engineering Metallurgy & Geology	Eckert, R. E. Assistant Head of School of Chemical Engineering Purdue University Lafayette	30 April 1970
Civil Engineering	McLaughlin, J. F. Head of the School of Civil Engineering Purdue University Lafayette	30 April 1970
Mechanical Engineering	McFadden, Peter W. Head of the School of Mechanical Engineering Purdue University Lafayette	29 April 1970
Electrical Engineering	Hancock, John C. Head of the School of Electrical Engineering Purdue University Lafayette	23 April 1970

Discipline	Person and Title	Date of Interview
Geology	Mursky, Arthur Professor of Geology I.U.P.U.I. Indianapolis	2 May 1970
Construction Technology	Davis, William Chairman, Construction Technology I.U.P.U.I. Indianapolis	2 May 1970
Physics	Meiere, F. T. Chairman, Physics Department I.U.P.U.I. Indianapolis	2 May 1970
General Engineering	Max, A. M. Chairman, Department of Engineering I.U.P.U.I. Indianapolis	3 May 1970
Computer Technology	Dalphin, John Chairman, Department of Computer Technology I.U.P.U.I. Indianapolis	3 May 1970
Manufacturing Technology	Peale, Robert A. Chairman, Department of Manufacturing Technology I.U.P.U.I. Indianapolis	3 May 1970
Electrical Engineering Technology	Sharp, Paul K. Chairman, Department of Electrical Technology I.U.P.U.I. Indianapolis	2 May 1970

Discipline	Person and Title	Date of Interview
Industrial Supervision Technology	Wisner, Howard L. Chairman, Department of Industrial Supervision I.U.P.U.I. Indianapolis	4 May 1970
Computer Technology	Kira, Nicholas J. Professor of Computer Technology I.U.P.U.I. Indianapolis	4 May 1970
Mathematics	Johnston, E. R. Chairman, Department of Mathematics I.U.P.U.I. Indianapolis	4 May 1970
Social Sciences	Boch Director of the Social Science Integrated Courses University of California Berkeley	5 August 1969
Zoology	Spieth, H. T. Chairman, Department of Zoology University of California Davis	8 December 1969
Biological Sciences	Thimann, Kenneth V. Provost Crown College Professor of Biological Sciences University of California Santa Cruz	10 August 1969
General Science & Continued Education	Dr. Cohen, Nathan W. Head, Letters and Science University Extension Berkeley	12 December 1969

Discipline	Person and Title	Date of Interview
Zoology	Dr. Deamer, David W. Assistant Professor of Zoology University of California Davis	16 January 1970
Biological Science	Dr. Goldstein, Norman Associate Professor of Biological Science California State College Hayward	8 January 1970
Zoology	Dr. Grey, Robert D. Assistant Professor of Zoology University of California Davis	16 January 1970
Biological Science	Dr. Gross, Phyllis Professor of Biological Sciences California State College Hayward	8 January 1970
Biology	Dr. Holm, Richard W. Director, Division of Systematic Biology Stanford University Stanford	20 January 1970
Pediatrics	Dr. Kretchmer, Norman Chairman & Professor of Pediatrics Stanford Medical Center Stanford	20 January 1970
Education	Dr. Lowery, Lawrence P. Assistant Professor of Education University of California Berkeley	6 January 1970
Biology	Mr. Ruth, Fred Assistant to the Director Lawrence Hall of Science University of California Berkeley	12 January 1970

Discipline	Person and Title	Date of Interview
Biology	Dr. Wake, Marvalee Lecturer in charge of Biology labs. University of California Berkeley	16 December 1970
Earth Sciences	Dr. Whitney, Robert Professor of Earth Sciences California State College Hayward	8 January 1970
Engineering	Bouwkamp, Jack G. Professor of Civil Engineering Vice Chairman, Division of Structural Engineering & Structural Mechanics University of California Davis Hall Berkeley	7 April 1970
Engineering	Hazlett, Tom Professor of Mechanical Engineering Head of Continuing Education in Engineering University Extension University of California Berkeley	2 March 1970
Engineering	Maslach, George J. Dean University of California Berkeley	1 April 1970
Engineering	Skalnik, John Chairman of Department of Electrical Engineering University of California Santa Barbara	26 March 1970
Engineering	Steidel, Robert F. Jr. Professor of Mechanical Engineering University of California Etcheverry Hall Berkeley	6 April 1970

Discipline	Person and Title	Date of Interview
Engineering	White, Richard Associate Professor of Electrical Engineering (involved with CAI Programs) University of California Cory Hall Berkeley	9 April 1970
Engineering and Computer Sciences	Zadeh, L.A. Professor, Department of Electrical Engineering & Computer Sciences University of California Cory Hall Berkeley	19 March 1970
Engineering Technology	Higdon, Archie Dean, School of Engineering and Technology California State Polytechnic College San Luis Obispo	26 March 1970
Engineering Technology	Smith, E. W. President Cogswell Polytechnical College San Francisco and TIAC Chairman – i.e., Technical Institutes Advisory Council	13 March 1970
Psychology	Nelson, Keith Professor of Psychology Stanford University Stanford	
Mathematics	Bremerman, Hans J. Professor of Mathematics and Medical Physics University of California Campbell Hall Berkeley	17 April 1970

Discipline	Person and Title
Physics	Kimley, William H. Business Manager Physics Department University of California LeConte Hall Berkeley
Physics	Portis, Alan M. Professor of Physics University of California Birge Hall Berkeley and Associate Director of Lawrence Hall of Science Berkeley

APPENDIX C

SYNOPSIS OF THE ABS PROJECT

THE PROBLEMS

Institutions of higher education are under increasingly severe pressures to provide adequate facilities for the many processes of education in the face of rapidly rising student enrollment, explosive growth in the body of knowledge, and constrained budgets. The cost of providing academic facilities has steadily risen because of escalating construction costs coupled with increasing sophistication in building requirements. The changing technology, teaching methods, and educational policies are creating early obsolescence in many existing buildings.

ABS RESPONSE

The Academic Building Systems (ABS) project was initiated in April 1968 as an experimental effort to respond to the need for academic buildings that would be more economical to program, construct, and operate, more efficient and effective in use, and far more adaptable to change. The building system approach was selected as the vehicle for effecting improvement over conventional methods.

A basic assumption was: an academic building during its useful life span of many decades needs to accommodate different activities and their environmental needs. Technology, teaching methods and subject emphasis, as well as university size, organization and administration are continually changing, producing need for buildings that can be easily modified or altered to respond to changing requirements.

METHODS

The ABS project is divided into three phases:

1. The ABS Research Phase provides the data base for the design of the building system. There are four main lines of enquiry:
    a. *User Requirements:* Define the general nature and range of the user requirements for the building types involved.
    b. *Performance Standards:* Establish specific standards of performance the ABS subsystems must meet.

   c. *Cost Base:* Establish cost targets and cost control mechanisms for the ABS subsystems.
   d. *Subsystems Options:* Conduct studies of building size and shape leading to a range of functional relationships, dimensional criteria, and the establishment of basic concepts feasible for the coordinated subsystems.

   Work concentrated on buildings for science, engineering, and technology. The emphasis was oriented to teaching and research laboratory, classroom, and office space types.

2. The ABS Subsystems Design Phase involves translating user needs into building subsystems. The subsystems selected for development are:

   a. Structure
   b. HVAC
   c. Interior Partitions
   d. Lighting/Ceiling
   e. Utilities Distribution

   In addition, the initial ABS demonstration building in Indiana will include exterior walls and casework subsystems.

   The ABS subsystems were designed and coordinated to utilize readily available building components. The subsystems can be bid prior to completion of working drawings.

3. The ABS Demonstration Phase will utilize the ABS subsystems in the design and construction of academic buildings. This phase will also demonstrate innovative programming, design and construction phasing, and management concepts. The initial building at Indianapolis, Indiana, will accommodate science, engineering, and technology disciplines.

SPONSORSHIP

The ABS project is conducted jointly by the University of California and Indiana University. Financial support comes from four sources:

1. The State Legislature of California
2. The State Legislature of Indiana
3. Office of Education, U.S. Department of Health, Education, & Welfare
4. Educational Facilities Laboratories, Inc.

Indiana University

Donald H. Clark, Assistant Vice President—Business
Ray W. Casati, University Architect
Howell H. Brooks, Director, Department of Physical Plant
Alfonso L. Messina, ABS Program Coordinator
Ruth Neil, Secretary

University of California

Robert J. Evans, Assistant Vice President—Physical Planning and Construction
R. Clayton Kantz, Director—Building Systems Projects and ABS Project Director
Richard H. Rohrbach, Assistant Director—Building Systems Projects
Marjorie A. Kingland, Administrative Analyst
Theresa Coombs, Administrative Assistant

ABS CONSULTANT

Building Systems Development, Inc.—San Francisco

Ezra Ehrenkrantz, President
Christopher Arnold, Vice President, Officer in Charge of ABS
William A. Kinst, ABS Project Manager

Consultants to Building Systems Development, Inc.

Forell/Elsesser Engineers, Inc.
G. L. Gendler and Associates, Inc.
David Bradwell and Associates
The Koch Company
Copenhagen and McLellan
James Associates

Indiana Demonstration Building

The Indiana University/Purdue University campus, Indianapolis, Indiana
In joint venture:
Building Systems Development, Inc.
James Associates
Fleck, Burkart, Shropshire, Boots, Reid & Associates

California Demonstration Building

To be designated at a later date

ABS PUBLICATIONS

ABS documents have been prepared by the ABS staff of the Office of the President, University of California. Except for a limited printing by the University of California Printing Department, the documents have been printed by Indiana University Publications, at the expense of Educational Facilities Laboratories, Inc. Copies are available from either of the two Universities.

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