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Facilities and Quality of the Environment

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The facilities and the surrounding environment of a college or university are often overlooked as an element of the quality of an institution. This paper attempts to provide some general, minimal guidelines for space, equipment and pedagogical needs of a modern college of engineering.

INTRODUCTION

The *quality* of the college or university facilities and the environment is often first judged on the physical appearance and the state of maintenance of the buildings, laboratories and laboratory equipment, the beauty and serenity of the surrounding grounds, and the size of the library. This paper describes the space requirements, the equipment needs and pedagogical guidelines for a modern college of engineering.

SPACE

Often the impression that a college or university makes on individuals not associated with the university is due to the physical appearance of the buildings and the grounds surrounding the university. For example, even though both Oxford and Cambridge Universities are located in the centre of their corresponding cities, both are often described as beautifully situated, with cloistered buildings creating a powerful university visual image. Such images are important for university image and loyalty. It is important that adequate funding be available and protected for the maintenance of facilities and the upkeep of the grounds.

General space needs may be categorised by those needing support: student needs, both undergraduate and graduate; faculty needs; laboratory needs; administrative needs; research needs; and other needs.

Students

Students are often overlooked with respect to space needs. Usually the only space requirements that are deemed important for students are the obvious: housing, if the university is a residential campus; and classroom facilities and laboratories. However, both study space and social space should be a high priority for colleges of engineering. Often students are required to sit in crowded hallways waiting for classes to begin. Such environments are not conducive to student growth. The planning of facilities should include sufficient space for student study groups and socialising. Lounges for students should be provided, just as office space is a necessity for faculty. Most campuses attempt to get by using unused classrooms for study areas, but these should not be viewed as meeting student needs. Rather, empty or unused classrooms should be treated as overflow space or special purpose study space. A goal should be to provide, as a minimum, 0.25 square meters/full-time student of dedicated student activity space. Thus, a college of 1000 full-time students should have at least 250 square meters of student study and social space for exclusive use by the students. A ratio of half this should be used for part-time students to ensure even part-time students will have dedicated space for study and social times.

Classroom space is dictated by the size and number of offerings, but all space, in today's world, should be as multi-functional as possible. As well, dedicated laboratory space that is used on an infrequent basis throughout the academic year is not cost effective. Laboratory space should include instructional space and should be as highly scheduled as makes sense. Classrooms should be constructed as today's convention facilities are, with the ability to change shape and accommodate various audience sizes. A building with twenty 40-person classrooms is not as useful as a building with the ability to be reconfigured to contain five 160-person rooms, or any other combination or multiple of the base unit. Over time, many universities have found that the fixed classroom size has become inappropriate. As programmes grow in popularity, buildings built for a previous small cohort of students may become useless. Buildings with small classrooms become no longer useful and renovation costs are usually prohibitively expensive. Then faculty must use other facilities in order to accommodate the larger numbers of students in a classroom. If fixed size classrooms are to be built, it is probably best to err on the side of having classrooms that are larger than necessary rather than cramped, over crowded rooms.

Each classroom should be equipped with appropriate instructional aids, such as blackboards, or today's white boards with dustless drawing pens, overhead projectors and screens, and perhaps even television monitors for video-tape playback or computer demonstrations. If the classroom is large, overhead projectors should be used extensively rather than writing boards because viewing and legibility may become significant issues with the students.

Graduate students

Graduate students should be provided with their own office and work-space. Again, flexibility should be the major goal. Large rooms may be subdivided by using partitions; this works very effectively. A graduate teaching assistant should have, as a minimum, 2.5 to 3 square meters of individual space. Research assistants should also have an equivalent amount of space, but the space might be co-located in the research laboratory. Each student should be supplied with a desk, chair and book storage space, and teaching assistants who interact with undergraduate students should have adequate space for meeting with undergraduate students individually, or in small groups.

Faculty

Each faculty member needs an office, although offices may be shared if sufficiently large so as not to be over crowded. Offices should not be too large. A goal might be 8 to 12 square meters per individual. Each office should have a desk, chair, book storage, and boards (white or black) for writing or diagrams. There should also be space for faculty to interact with students individually or in small groups. Each faculty member should have his or her own telephone and computer. If possible a printer should be attached to the computer and appropriate networking should be available through a campus network or a modem. If a printer is not directly attached, one should be available within a short walking distance. Group printers and fax machines are usually adequate unless one individual has unusual requirements. All offices should be similar. Again, divided space using partitions may be used very effectively, allowing greater flexibility in room organisation. However, arrangements of this type do require extensive sound deadening in order not to disturb those working in other cubicles. A good rule to remember is that buildings seldom remain the province of one group or organisation over their entire lifetime, so fixed layouts seldom serve different uses over time. Classrooms may become computer laboratories, or other types of laboratories, etc.

Administration

Careful planning of administration space is very important for the successful operation of a college of engineering. All administrators should be in close proximity to the faculty and college facilities. A department's faculty should be clustered around the chairperson's office because that will become the focal point of the department. The departmental staff will be located there and provide secretarial services, photocopy services, mail and facsimile services, perhaps small conferences and meetings, etc. Such facilities should be pleasant and provide a place for waiting guests and visitors as well as students scheduling advising appointments or meetings with faculty.

At the college level, the departments should be clustered around the chief academic officer of the college, often a dean. Support services for the dean should be centred on the college activities, such as finances, public relations, development, research contracts and grants, etc. This area will be the first point of contact for many guests and visitors and should present a good first impression. Office space should be matched to the work requirements. Space should exist for waiting guests and for small meetings and conferences. If possible, there should be space for exhibiting local developments or student work in order to showcase the college's activities. However, this space should not be so large and luxurious that it inspires a faculty member to want to become an administrator for the wrong reason.

Laboratories

In a similar manner to the design of classrooms and offices, laboratories should be designed to be as flexible, re-configurable and efficiently scheduled as possible. As much as it makes sense, laboratories should not become the province of faculty, but should be thought of as the province of students. Today, two types of laboratories are possible. These may be referred to as those with large fixed equipment requirements and those that are based on changeable, more portable equipment needs. Among the former are machine shops, material properties laboratories, process laboratories that require venting hoods, wind tunnels, etc. Among the second are electronic circuit laboratories; controls and computing laboratories; design centres, etc. A new trend for universities constructing new buildings is to make the mechanical and electrical systems in the buildings themselves into laboratory experiments. Incorporation of sensing systems, and control systems at the time of construction may provide very useful systems for students to monitor and experiment with at a very little increase in the building cost.

Obviously, all teaching laboratory needs should be carefully planned and implemented. Teaching laboratories should always be considered student facilities, never research facilities. Laboratories should have faculty supervision, but not faculty ownership. Laboratories should be the highest priority of engineering faculty because engineering is a practical occupation and requires good hands-on learning experiences as part of the educational process. The individual equipment needs must be balanced with the college's budget and be maintained as up to date as is possible. Even though computing and computer simulations are feasible today in ways that were undreamed of just a few years ago, students should have as much physical involvement as possible. Skimping on laboratory expenses will turn out to be not cost effective in the long run. Engineering students must construct and destroy real world objects as a necessary part of their education.

Research

The research needs of a college of engineering are difficult to anticipate without knowing the strengths of individual faculty. Two possible models may exist or even co-exist. In one case the college makes a decision as to its research directions. For example, the college may be located in a high seismic area and elect to pursue earthquake engineering as related to building structures, water systems, etc. This overriding direction may make support of research laboratories simpler in the long run. The other model allows each individual or small group of faculty to pursue their own research agenda. A mechanical engineering department might have a thermal sciences group, a design sciences group, a manufacturing research group, etc. This approach tends to be less synergistic than the former model. Regardless of which model or combination of models is used, laboratory space will always be a requirement. The laboratory space should not be carved out of the laboratory space used in the teaching programme. Dual use laboratories, while sounding good from an efficiency standpoint, are seldom successful because the demands are quite different. The instructional laboratory must be available at set points in time, whereas the research laboratory is usually operating nearly all the time and probably has postgraduate research students co-located within the laboratory. No rough rules of thumb may be specified for research laboratories because the needs differ so dramatically. A laboratory for hydraulic testing or a large-scale wind tunnel may dwarf the needs for a faculty member working on engineering design or analysis software. Even though the space needs may be much smaller for computer-based research, physical and experimental research will always have a place in engineering and some effort should be expended to support the physical researchers, if at all possible.

Other

Other space needs include storage locations for records or equipment that is no longer used and is waiting to be disposed of. Parking for both students and faculty may also be required and should be adequately planned.

EQUIPMENT

Equipment requirements usually fall into three categories: office equipment to support general administrative needs, teaching equipment to support the instructional programmes, and research equipment to support research activities.

Office equipment is primarily associated with the support of the teaching faculty and support staff. Each individual should be supported with a telephone, facsimile and photocopier access, and any necessary computing equipment, such as a personal computer with Internet access. All equipment should be distributed in such a way that it has convenient access. For example, it may not be necessary that every individual have a facsimile or photocopy machine; one each might be adequate for an entire departmental unit, or even a college unit if separation distances among users is relatively small. On the other hand, each office should have an installed and operating telephone. Computers should also be easily accessible, although perhaps shared among several users. However, as the cost of personal computers continues to decline, the goal should be one computer per individual because these machines will subsume a number of previously stand-alone activities, such as telephony; photo, image and text reproduction; television; facsimile transmission; and will do so less expensively than the original single-purpose equipment.

Instructional equipment needs depend on the disciplines offered. The only universal equipment needs have to do with computing support. Every undergraduate engineering student must have access to a computer and the access needs to be significant. Two models exist for this support: provide adequate computing as part of the instructional process or require each student to supply their own computing environment. As prices for personal computers continue to drop, most of the developed world is choosing the latter approach. Students may now be able to purchase a computer for less than US$800 and prices continue to drop and computing power continues to improve at a doubling every eighteen months as observed by Gordon Moore. Used computers, or non-current models may be purchased for even less, often for as little as US$300. These machines adequately support word processors, graphical presentation software, spreadsheet analysis, mathematical analysis, and even sophisticated engineering analysis, such as finite element modelling, fluid mechanics, thermodynamic analysis, circuit design and simulation, antenna design, trajectory analysis, etc.

If possible, all computers should have networking capability either through a locally supplied network or via telephone modem. A growing availability of data and information through the Internet and the World Wide Web make network access extremely important and growing in importance daily. So much information is available today and expected in the near future that the problem of textbook availability and affordability in much of the developing world may be circumvented.

Other peripherals are also required, such as printers and file servers for supporting electronic mail. There is also a need for local human support and an on-going budget for leasing or purchasing equipment, software and system maintenance. These budget requirements are not insignificant and careful planning is required. In the United States many colleges of engineering have passed the costs of computing directly to the students through a fee structure. Such decisions depend on the local economy and government funding structures and may or may not be possible.

Other instructional equipment needs are dictated by the disciplines offered. Mechanical and manufacturing engineering programmes demand that students have instruction in and experience with production technology. Mechanical shops, consisting of welding machines, drill presses, lathes, milling machines, etc, should be provided. The shops should also have a working supply of materials for the students to use, such as wood, aluminium, copper, plexiglass, etc. Budgets for supplies are an on-going cost and need to be funded adequately. Professional shop staff is also important for instructional purposes. Using this type of equipment can be dangerous if relevant instruction and supervision are not available. The professional staff may also be involved in the construction of special purpose equipment for the college's research activities and paid from research budgets.

Electrical and electronics engineering programmes need to be able to construct and make measurements of physical electronic circuits. Such measurements require multi-meters, oscilloscopes, or other electronic measuring devices, such as wave form generators. An electric motors laboratory should also be part of any electronics programme. Because mechanical engineering students also should have a background in mechatronics, all of this equipment serves two groups of students.

Civil engineering laboratories need to be equipped with measuring and destructive testing machines. Students should learn to make measurements of physical properties of materials, loads measurements, breaking tests, etc. Learning to work with concrete and other building materials is often overlooked, but is important for the student.

PEDAGOGY

The quality of any engineering school is known by its students, faculty, classroom and laboratory facilities, the buildings and surrounding grounds, and, of course, the library. It was the centralisation of books in the Middle Ages that was the first impetus for the creation of universities. Scholars assembled around the early book collections. Today, libraries are still a very important part of any university. In fact, in Great Britain and the United States, the library is usually the central building around which the others are clustered. However, libraries are rapidly changing too.

With the advent of on-line digital information, the position of the library has been somewhat diminished, although the availability of books on-line, because of copyright issues and/or access charges, will probably remain low for some time to come. Each year more on-line journals and reference material are becoming available. This means that libraries in the near future may be less important to a college of engineering than in the past. An engineering library should contain a set of equivalent, but not necessarily currently used, textbooks for students to use to get another presentation. Also, more advanced books should be available for students interested in pursuing some area of study in more depth than a current textbook or course.

To support research, a collection of relevant journals is important. The list, however, is probably not too long. Thirty to fifty journals are probably sufficient to cover most engineering advances in order for faculty to remain current. Here, the library staff should work closely with the engineering faculty to obtain the appropriate journals. Some faculty will probably subscribe to the most important journals in their fields and these should not be duplicated unless they have broad audiences because individual subscriptions are far less expensive than institutional ones.

In a few disciplines, conference proceedings are the relevant source of on-going research. Lag time for publication in a well known journal may be in excess of two years, which means that research results may be quite stale by the time the results are published. In very fast moving fields such as computer science, conference proceedings contain the most up-to-date information and research findings. Such proceedings are usually published by the appropriate technical professional society such as IFIP, IEEE and the ACM.

SUMMARY

This paper has attempted to identify key issues with respect to quality aspects of key physical facilities and the environment for a college of engineering. Obviously the degree to which the present suggestions can be followed will depend greatly on the budgeting and funding available, but the important aspect is that the facilities and environment are one of the four key elements in achieving a recognised quality programme: students, faculty, pedagogy, and facilities. A balance must be maintained among these four elements.

BIOGRAPHY

Dr Gearold R. Johnson is the Academic Vice- President of the National Technological University (NTU) in Fort Collins, Colorado. He holds a BS in aeronautical engineering, a MS in engineering, and a PhD in mechanical engineering from Purdue University. He joined NTU in July 1994. Dr Johnson spent 23 years on the faculty at Colorado State University (CSU) before joining NTU. In the ten years before his retirement from CSU in 1994, he held the George T. Abell Endowed Chair in Engineering, Colorado State University's first endowed chair. He was a NATO post-doctoral fellow at the von Karman Institute for Fluid Dynamics in Rhode-Saint-Genese, Belgium. He has been a visiting professor at the University of Kent in Canterbury, England, and the California Institute of Technology in Pasadena, California. Dr Johnson also spent a year as a visiting researcher at Shape Data Ltd in Cambridge, England. Dr Johnson is Co-Editor of *Computing: Archives for Computing Science* published by Springer-Verlag, and Assistant Editor of the *International Journal of Computing and Software Engineering* published by Ablex Publishing. Dr Johnson is a member of the International Committee on Engineering Education (ICEE) that advises Dr Federico Mayor, Director-General of UNESCO, Paris, France. His research interests over the years have focused on computing environments to assist engineering analysis and design, technology in support of engineering education and embedded control systems.

Proceedings of the 1st UICEE Annual Conference on Engineering Education

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