Session 3266

Development of a Multidisciplinary Engineering Learning Center

Stephen Batill, Natalie Gedde
University of Notre Dame

Abstract

The College of Engineering at the University of Notre Dame has recently opened an Engineering Learning Center. The Learning Center is a classroom, a laboratory, and a meeting place. It is a facility designed for experiential learning, communicating ideas and developing new methods for teaching and learning. The Center was developed through collaborative planning and coordination with all the departments in the College of Engineering. The Center was designed to provide a dynamic, flexible, collaborative learning environment to support a wide spectrum of educational activities. This 4000 square foot facility, developed at a cost of over $1M, began operation for the fall 2000 semester and it is currently supporting the project-intensive, first year course with an enrollment of 300-400 students each semester. Besides its involvement with the first year program, the Center supports a variety of learning activities across the College in the specific departments and degree programs. The Center includes flexible project-team work areas with networked computer support, multiple screen audio/visual capabilities that support a variety of multi-media sources and space for students to fabricate and store projects. This paper describes the planning, design, and operation of this multidisciplinary teaching and learning facility.

I. Introduction

In 1998 the College of Engineering at the University of Notre Dame embarked on an intensive self-study of its undergraduate engineering programs. This was done in response to the challenges and opportunities related to changes in the engineering profession and in engineering education. This self-assessment led to a strategic plan that identified those areas in which the College of Engineering should invest time and resources. It emphasized the importance of moving from an education process that was faculty and lecture centered to one that contains significant elements that are student-centered. A student-centered activity is one that actively engages the student in the learning process, enhancing their understanding and ability to use the knowledge gained. This student-centered emphasis better prepares students to be effective engineers, life-long learners and leaders in new technology developments by stressing the importance of student participation through the discovery of knowledge. Particular importance was also placed upon increasing interdisciplinary breath in all fields of study to complement the existing emphasis on disciplinary depth. The overarching goal was to better prepare students to be effective engineers and life-long learners.

To this end, the College of Engineering began efforts to integrate the student-center activities in those parts of the curriculum where they could provide the greatest benefit. The first major effort was to restructure the First Year curriculum for all engineering intents. This included the development and introduction of a new two-course sequence entitled "Introduction to Engineering Systems" for all students who intend to enter the College of Engineering in their second year. These truly multidisciplinary courses introduce engineering students to the role of engineers in society, and illustrate how engineers design systems and solve problems in the context of how these systems influence, and are influenced, by the world around them. They introduce basic engineering skills including how to identify, formulate and solve problems, how to verify and communicate results, and how to use computers to aid in this process. The goal is to actively engage the students in applying engineering analysis and design methods to solve practical problems. This involves a team approach to plan, design, analyze, implement, evaluate and report engineering activities.

Beyond the first year, the study stressed the need for increased focus on team-learning, self-discovery of knowledge, closer interaction between student and faculty and increased opportunity for multidisciplinary projects. It emphasized the need for upperclass students to be given a greater opportunity to develop skills in problem formulation, problem solving, and contextual presentation of engineering topics. These changes are intended to better prepare students for the environment that they will experience following graduation, whether that be professional practice, graduate studies, or other opportunities.

One specific recommendation developed as part of this strategic plan was:

> *"Design and build a new Learning Center to support innovative teaching and learning activities."*

To foster and support the adoption of a student-centered learning environment, a major initiative was the development of a Learning Center, where students would have the opportunity to learn through experience, to develop interdisciplinary projects, and to interact with students and faculty from other disciplines and other class ranks. This would be a "space" dedicated to supporting these learning objectives. It should be noted that the term "learning center" is sometimes used to describe organizations or other entities that typically involve tutoring or other similar educational enhancement activities. The concept of "learning center" as presented in this paper is a dedicated facility and supporting organization and the primary emphasis is the facility itself. It was felt that it would be necessary to first develop the "infrastructure" before the faculty would be able to embark upon new teaching and learning activities.

It was obvious that it would be impossible to achieve the active participation, collaboration and interaction desired without the appropriate investment in space and facilities. In parallel with the academic program review, the College was also conducting a preliminary building planning study for an additional engineering building. This new building will be a multidisciplinary teaching and research facility and should become a reality in the next 5 to 7 years. As currently planned, over 15,000 sq.ft. of this new 50,000 sq.ft. building will be dedicated to undergraduate learning. Understanding how to use this new space in the most effective manner to enhance the undergraduate programs across the College was set forth as a important goal.

The remainder of this paper describes steps taken during the past two years to begin to realize these goals. The paper presents issues related to the planning, design and initial implementation for a college learning center. As more universities begin to consider the development of this type of facility, it is hoped that this paper may provide useful information based upon the experiences gained at Notre Dame.

II. Design of the Engineering Learning Center

To achieve the goals set forth for the Learning Center, the Dean of the College appointed a Steering Committee with members from each of the College's departments and chaired by the Associate Dean for Educational Programs. This group was tasked with the development of the new first year courses and the Learning Center concept. These were parallel and complementary projects as one of the primary initial roles of the Learning Center was to support the new First Year curriculum initiatives. At the same time, the Dean of the College worked with the University administration to secure space and financial support for these efforts.

It was determined that academic program needs and available resources would necessitate the development of the College of Engineering Learning Center in three phases. This effort began in April 1999.

I. Project Space for prototype First Year courses for '99-'00 Academic Year
   (required completion date: August 1999)
II. Prototype College Learning Center - Existing Space Renovation
   (required completion date: August 2000)
III. College Learning Center - New Engineering Building
   (required completion date: TBD)

The primary purpose of this paper is to describe a number of issues related to the design, development and initial operation of Phase II, Prototype Learning Center

In the first phase, a section of an existing laboratory was modified to support the prototype offering of the new two-semester First Year engineering courses. The initial offering of these courses involved only 25 students each semester, thus a limited space was required. A 25ft x 40ft space was dedicated to this role and equipped with individual student desks (for presentations and recitation sessions), storage cabinets, tables and chairs for group project work and computers and limited support equipment. The room had computer access and five PC computers were placed in the room. There were five small areas in which "worktables," chairs, and a computer were placed. The small collaborative learning teams (5 students each) used these areas for discussion and working on the "hands-on" projects that were part of these courses. The students had 24-hour access to this space. It was particularly important to have this space available during the earliest stages of this project as it provided the opportunity to test the suitability of various pieces of equipment that were eventually integrated into the Phase II Center.

In order to be prepared to present the new First Year curriculum to the entire First Year class of over 380 students for the Fall 2000 semester, major commitments of space and resources were required. Somewhat ironically, the space identified by the University for renovation to provide the Phase II, prototype Learning Center (herein referred from now on as the Learning Center) was a large auditorium in the College building complex. This 4000 sq.ft. auditorium was actually the second largest auditorium on the campus and its conversion from a space where "faculty lecture and students listen" to a space where the students are actively and collaboratively engaged in learning is an indication of trends in engineering education.

Learning Center Design

In order to proceed with the first two phases in the development of the Learning Center, it was important to emphasize the purpose of the Center. Fundamentally, it is intended to provide a facility and necessary support infrastructure that will encourage the development of innovative teaching and learning activities within the College of Engineering.

One of the first steps was to identify similar facilities at other institutions. That survey indicated that though various institutions had facilities entitled "learning centers," few included the multidisciplinary attributes and supported learning activities across the curriculum in all departments. The term learning center is used in many different ways to describe everything from organizations that provide tutorial support and foster improved teaching methods to discipline specific facilities that provide specific technology support to student learning. The list below highlights some of these categories and indicates a number of schools (and when available, links to web sites) that have developed entities referred to as learning centers. This list is not all-inclusive and any omissions do not indicate a lack of importance or significance of any other institution's efforts in these areas.

<u>Teaching and Learning Centers:</u>

These focus on providing resources to improve teaching and learning primarily through organizational structures.

University of Wisconsin – Madison - http://www.engr.wisc.edu/services/elc/
University of Kansas - http://eagle.cc.ukans.edu/~cte/resources/websites/unitedstates.html
Georgia Institute of Technology - http://www.cetl.gatech.edu/
Massachusetts Institute of Technology - http://web.mit.edu/tll/
University of Michigan - http://www.crlt.umich.edu/
North Carolina State University - http://www.ncsu.edu/fctl/
University of Washington - http://depts.washington.edu/cidrweb/index.html

<u>Discipline Specific Learning Centers:</u>

These focus on providing resources primarily through instructional technology or specialized facilities and are elements of programs that are discipline specific.

University of Pittsburgh - Frank Mosier Learning Center for Chemical Engineering, http://www.engrng.pitt.edu/~chewww/FMLC
Virginia Tech - Goodson Learning Center for Mechanical Engineering
Stony Brook State University of New York, Technology Learning Center - <u>http://www.tlc.ceas.sunysb.edu/index.html</u>

<u>Student Assistance Learning Centers:</u>

These focus on providing support to students primarily through tutorial assistance.

Virginia Tech, Chemistry Learning Center -http://learn.chem.vt.edu/
University of California – Riverside - http://www.learningcenter.ucr.edu/
University of Arizona - http://w3.arizona.edu/~masa/MSLC.htm

Learning Factories:

The Manufacturing Engineering Education Partnership (MEEP) is a multi-institution partnership that has resulted in the development of specialized learning factories that support manufacturing engineering curriculum integrated through laboratory facilities and industry collaboration.
Pennsylvannia State University - http://www.lf.psu.edu/
University of Washington - http://www.me.washington.edu/~ilf/
University of Puerto Rico-Mayaguez - http://www.uprm.edu/winin/mfg_lab.htm

One learning center concept that was particularly useful in the development of the current facility was the ITLL, Integrated Teaching and Learning Laboratory (http://ITLL.colorado.edu), at the University of Colorado, Boulder which opened in 1997. This is a facility of significant size (a three-story building with 34,000 sq.ft. of dedicated space) so though some of the objectives for the facility may have been similar, the size and scope were not. On two occasions during the planning and design process, visits were made to the ITLL facility and the ITLL represents a benchmark against which developments in this area should be measured.

Other sources of information that proved useful in the design of the Center included experiences gained in the development of the Design Studio in the Aerospace and Mechanical Engineering Department at Notre Dame. This facility contained elements that were considered for the Learning Center, as did a number of laboratories and facilities in selected local high schools. It is of interest to note that the concept of a highly adaptive and flexible learning environments is something that has become part of many new high school facilities. This appears to coincide with the fact that high school science programs have expanded from the traditional biology, chemistry and physics to include topics often more closely aligned with engineering such as robotics, electronics and design projects.

The development of the Center took place on a very compressed time schedule. The curriculum revisions were approved in the late spring 1999 and the resources committed and available space identified by August 1999. Since the Center had to be open and operating within a year, approximately four months (Sept. - Dec. 1999) were available to design the facility as the facility modification would need to begin by January 2000 at the latest. The project itself was coordinated by the University's Facilities department and managed by a local architectural firm. The Dean's Office in the College of Engineering participated in the planning and design during all stages of the project. Meetings with the architects and project managers occurred weekly throughout the project. The primary role of the College's representatives was to define usage expectations and facility requirements for this unique learning space.

One of the first steps in this process was to define usage requirements. First a set of qualitative requirements were identified. This actually began by describing what the Learning Center was not intended to be:

- a traditional, "fixed bench," discipline focused laboratory.
- just a room - it must have a staff to support its operation, project development, project maintenance and a continuously updated infrastructure.

- the responsibility of a single department. It must be able to support activities from all degree programs in the College.

It was important to differentiate the Center from the traditional engineering laboratory or a classroom with "computers" and to emphasize its multidisciplinary nature. With these ideas in mind, it allowed for the definition of important features or attributes that the Learning Center facility should contain:

- flexible and adaptable space
- space to support the activities of the First Year course sequence that would include up to 400 students per semester with section sizes of approximately 25 students each
- work areas and benches for project fabrication, test and assembly
- electrical and mechanical fabrication tools for hands-on student projects
- storage space for student projects
- ability to support the limited use of "learning modules" - movable, student-operated equipment for hands-on interactive learning activities in courses other than the new First Year courses and this would require: fume hoods and vents, compressed air, vacuum and natural gas, running water and drainage
- computer network access for both carry-in and permanently placed computers
- office/work space for a full-time manager
- storage space for equipment, instrument and tools
- project development and set-up area
- space for student helpers/facility monitors (undergraduate mentors and TA's)
- features that would allow student access for a significant part of the day/evening

State-of-the-art computing and audio/visual capabilities were considered as key elements of the Center. As the planning for the Center proceeded it became apparent that if the Learning Center were to provide a testbed for developing the new building facilities, it would have to be place where a variety of teaching and learning "experiments" would take place. These would include activities ranging from student presentations and demonstrations to real-time, virtual "field trips" so access to a variety of media sources and display technologies were desirable. The University's Office of Information Technology played an important role in providing guidance and support in this area.

The Learning Center was designed to complement the College's existing instructional computing resources. The existing College computer "cluster" had actually served one of the roles perceived for the Learning Center as it had become a location where students met outside of class to work collaboratively and many of the students "hands-on" activities now involve computing.

To support the group-based, small project activities planned for the new first year courses the Center would need small-group meeting/work areas that would be equipped with a computer, most likely a "PC class" machine for microprocessor programming and network access. The computers could also provide remote access to a large cluster of engineering workstations that allowed the students access to a wide range of engineering software applications. It was also desired that these spaces also allow for students to "carry-in" their own computers and have network access as it is anticipated that in the near future most students will have portable, personal computing resources. It was also required that there be adequate space to allow for 25-30 students to work on-line under an instructor's supervision for computer instruction.

These perceived needs were then converted into anticipated floor space requirements and a working schematic of the Learning Center developed. The schematic, shown in Figure 1, was used in planning and provided to the architectural firm. The 50 ft x 80 ft space indicated on the schematic was consistent with the space provided by the University for the renovation.

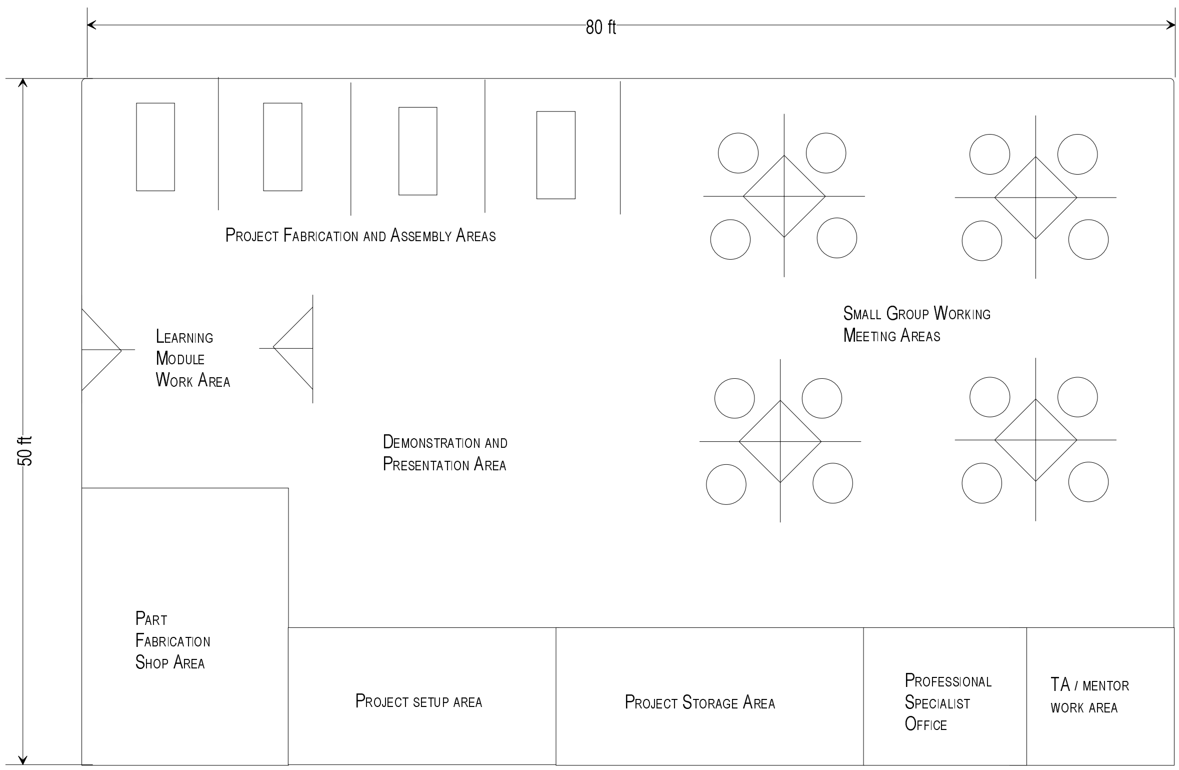

Figure 1. Original Learning Center Floor Plan

The corresponding initial floor space requirements were developed and are shown in Table 1. With the requirements and general space needs defined, the architects could begin the process of the detailed design of the facility.

Table 1. Proposed and Actual Space Allocations in the Learning Center

Space Type	Initial Space Request - ft^2	Space Allocated in Final Design - ft^2
Group Working/Meeting Areas (computers and network access)	1200	1200
Fabrication/Assembly work areas (with storage)	560	930
Learning Module work areas	400	250
Demonstration/ Presentation area	600	500
Manager’s office	120	120
Students aide office	100	
Equipment Storage and Issue	200	300
Project Preparation Area	200	300
Part Fabrication Shop	300	N/A
Total Space Requirement	3680	3600

Since this was not “traditional” academic space, there was a need for close coordination between the designer and the users and fortunately this was encouraged and facilitated by the University’s Facilities Engineering project manager. This coordination between the three groups allowed the final product to be developed on time, within budget and provided the required capabilities. One of the biggest challenges was maintaining flexibility in the facility so that new and unexpected uses of the space could be considered. Recall that this Learning Center was to be a testbed for teaching and learning innovation.

A couple of other specific issues that were unique to this facility development are worthy of mention. The first was the need to continuously involve members of all the academic units in various aspects of the planning. This was particularly true in the case of the Chemical Engineering department, as their requirements for specialized space was the most complex. Anticipating the specialized facilities to support hands-on activities for this degree program required the inclusion of special drainage for chemical disposal, controlled chemical storage, safety items such as shower and eyewash, vent hoods that allowed for demonstrations and access to vacuum, compressed air, natural gas and distilled water. It may have been easier and surely less expensive to not include this type of equipment, but the overriding desire to provide a truly multidisciplinary facility that would support teaching innovation across the College and allow for students to work across discipline boundaries required that these be included.

Another item to note was the need to develop special “furniture.” The limited overall space and the desire to provide space for small team meetings and project work necessitated the development of custom computer “islands.” Each island involves a central fixed desk and movable tables and chairs that can support up to three groups of five students each. The central islands each contain three computers, monitors, and keyboards. An survey of available furniture did not yield any adequate alternatives so it became necessary to design custom tables for the islands and this allowed for the integration of features such as under-table mounting of computers.

The last items to note dealt with issues related to student access to the facility, security, and safety. Though it was anticipated that the Learning Center would be open for at least 12 hours per day, issues related to access to equipment, equipment security, and student safety while operating equipment in the Center were considered in its design. Certain areas in the facility were designated as open access while others were restricted. It was decided to try to provide certain types of spaces that would allow the faculty the greatest flexibility as they attempted to integrate the student's use of the Center into their courses.

III. Engineering Learning Center – Description of the Facility

The new Engineering Learning Center is shown in Figure 2. The Learning Center is a 4000 ft^2 facility dedicated to hands-on multidisciplinary undergraduate engineering education.

Figure 2. Engineering Learning Center

As is shown in Figure 2, other than areas for an office (120 ft^2), two small support rooms (totaling 600 ft^2), and two mechanical rooms (totaling 200 ft^2), the Learning Center is one large open space. The office is for the Learning Center manager and the two rooms are the equipment storage and issue room and project preparation room. As can be seen in Table 1 when comparing the initial space request with the final design, some compromises were made. Due to the need to support the first year course activities, the size of the collaborative group work area was maintained as initially planned and most of the space that was eliminated had been intended to support a small student "shop" but the overall space limitations did not allow for this. Certain features initially planned for this space were then integrated into other parts of the facility.

The equipment storage and issue room contains large storage shelves that house electronic test equipment and components, fabrication hand tools, project supplies for the first year engineering courses, and special learning modules for other courses. Since this is a limited access room, the fixed-base, larger, powered fabrication equipment (i.e. drill press and saw) were located in this area. This equipment can only be used once a student has been properly trained and appropriate personnel are in the Learning Center to monitor them while they use the equipment. Students can checkout the equipment required for a project from this room. Much of the equipment in the Center is based on specific engineering course activities. As such, the Center's equipment will change with time to match student and faculty needs. The Learning Center offers a wide variety of equipment for portable and tabletop activities. The equipment checkout room also contains a desk and PC for use by the Learning Center student staff.

The project preparation room is used by the faculty and the Center manager for developing projects that are used in the Learning Center. This room contains electronic test equipment, electronic and mechanical components, and tools required to maintain the Learning Center equipment and to assemble new learning modules and projects. It has built in storage and an electronics workbench and allows for computer network access. The room also contains several storage cabinets for the various engineering departments to store specialized equipment that is used in the Learning Center.

The remainder of the Learning Center is an open area with groupings of specialized equipment to set apart the different open areas that make up the Learning Center. There are no walls or partitions in this main area. This promotes a collaborative learning environment and gives students ready access to other experiments, learning modules, and engineering disciplines. The open area promotes communication and invites questions from other students as a project is being constructed. The Learning Center provides an ideal location for students to work in groups.

The different spaces in the large open area are a group work area, a demonstration/presentation area with audio/visual support, a storage and fabrication area, and a learning module area. The size of each of these areas was detailed in Table 1. The group work area contains five specially designed, two-tiered, hexagonal computer "islands" mentioned earlier. The lower work area hexagonal surface has 36 inch edges. The top tier hexagonal surface has 22-inch edges. The support pedestal for the top tier contains electrical outlets and network access outlets. All the electrical and data wires to the island are provided from above through a central pillar. The tables each contain three PCs, one on every other side with the monitor on the top tier and the CPU sling-mounted under the bottom tier. Moveable worktables (36 inch by 60 inch) are normally aligned with the remaining three sides of the hexagonal tables. Moveable chairs are positioned around the perimeter of the tables. While the hexagonal tables are fixed to the floor, these worktables can be moved to accommodate specialized activities or experiments. This arrangement provides three work-group areas per island with seating for five students per group. This allows for a total of 75 students to use this area of the room at the same time.

The group work area gives students a place with access to a PC where they can easily work individually or in small (2 - 5 students) groups. This provides the ability for the students to spread their work out and for all group members to easily view the PC screen. This is different from the existing computer clusters in which the computers are all lined up and a work area is provided for only one person. A student can also bring a laptop to the Center and directly access the University network through the network access outlets that are set to "plug and play". There are 9 of these access jacks per island. The cluster of five islands appears to promote collaborative learning among the students. The walls in this area are lined with white-boards to assist in the sharing of ideas and communicating concepts and are used extensively by students and instructors.

The demonstration/presentation area is a very general-purpose open space. Movable tables and portable chairs are available for use in this area. Whether students use the area to test their automated bar code scanners developed during the first year course, to demonstrate their senior design projects, or to make a special video presentation to a class of 30 students, the area is flexible and can be configured to meet the current need.

The Learning Center has an integrated audio/visual system that supports a number of presentation media. The system supports information input from a island-based PC, guest laptop, a movable lectern (Sun Workstation, PC or MAC), a video recorder, or a DVD player all with audio capability. The room has three projectors and three screens for display. Two screens are located in the group work area and one in the demonstration/presentation area. The faculty, student, or guest speaker can run a computer presentation or a demonstration video on all screens simultaneously or use a single screen. The locations of the screens provide easy viewing from all areas of the Learning Center. Television cable access is wired into the Learning Center and a fiber optics cable was installed during construction to provide for anticipated future capabilities.

The project fabrication, assembly and storage areas were combined. This was accomplished by locating the storage lockers under the fabrication workbenches. The lockers are provided for temporary use by student groups and have a grated front door that again promotes sharing of ideas since students can easily view other projects. The fabrication area houses five workbenches with electrical power provided from the ceiling to the center of each bench. There is also a 14 ft x 21 ft U-shaped area with a work surface around the perimeter. A section of this work-surface allows handicap access to workbench space. This area also contains a sink for wet experiments, compressed air, electrical outlets, and access to the University network. The students use this area to work on design projects, or learning modules. When working on a long-term project, the student can store their equipment in the storage lockers located under the workbenches. The walls in the U-shaped area are lined with large pegboard sheets for convenient storage of often-used tools and equipment.

The last area of the open section contains fume hoods, chemical sinks, computer network access, PC computer-based data acquisitions systems, an eye wash/shower station, and additional storage. The fume hoods provide access to natural gas, compressed air, vacuum, and hot and cold water and provide storage of flammable/hazardous chemicals. This area is intended for use by the portable learning modules that require this specialized infrastructure support.

The Center's open learning concept is also shown in the facility itself. Since the room is an engineering learning facility, it was designed so that most of the room infrastructure is exposed. The electrical conduits are mounted outside the walls and a network of exposed cable trays were used to deliver the wiring for the computers and the audio/visual system to the five "islands." All the utilities are distributed from the open ceiling, and the audio/visual chase is constructed with transparent walls to show all the equipment and wiring necessary to run the system. This helps illustrate to the students what materials and equipment are required and the way in which the infrastructure is designed to support this type of facility.

IV. Operation of the Learning Center

a) Manager and Staffing

A full-time manager staffs the Learning Center during the day. The responsibilities of the manager are to schedule student and faculty use of the Learning Center, recruit, train, manage and evaluate undergraduate aides for the Learning Center staff, establish and enforce safety and equipment maintenance policies, maintain procedures for equipment issue and storage, and specify new equipment. The manager also assists the faculty in the design of "learning modules" and other demonstrations or teaching equipment and works with the director of the first year courses to coordinate scheduling and project support.

Peer Mentors and Center Monitors are hired to staff the Learning Center. These undergraduate students staff the Learning Center during the manager's off-hours, i.e. during the evenings and on weekends. They help to maintain the Learning Center equipment and provide answers to student questions about the use of equipment. The students aides checkout equipment and track the Center usage. The students have also assisted with the design, fabrication and evaluation of the learning modules and the projects for the first year courses.

The Peer Mentors program serves a double purpose in that along with supporting the operation of the Learning Center the mentors also directly support the first year course sequence. These undergraduate students work closely with the faculty and engineering intents and fill the role of teaching assistant and mentors as well assisting in the Learning Center. The mentors provide a valuable resource to the students in terms of clarifying course material, discussing difficulties, and seeking insight into problem solving. The peer mentor's responsibilities include attending Engineering Learning Center and recitation sessions, grading student work, providing input into the activities to be pursued during Learning Center and recitation sessions. Since there is a Peer Mentor in the Center a significant amount of time each day, there is usually someone available to assist a first year student. The Peer Mentors themselves also gain valuable experience by participating in the program.

b) Scheduling

The development of the schedule for the Center has been a dynamic process. The Center hours of operation vary each day to accommodate student study patterns. Table 2 illustrates the current hours of operation. This schedule was arrived through student feedback and monitoring the usage pattern during the first semester of operation of the Center. The hours of operation will continue to change to meet the needs of the students and faculty as additional activities are planned for the Center. The original operating hours provided reasonable access for the students and were initially set to 9:00 a.m. to 10:00 p.m. Monday through Friday and 10:00 a.m. to 10:00 p.m. on Saturday and Sunday. During the weekend, the early morning and evening hours are not used to a great extent. As the semester progressed, those hours were eliminated and hours were extended on Sunday and Monday evenings. Selected data indicating the current usage pattern are shown in Figures 3 through 5 and will be discussed below.

Table 2. Learning Center Hours of Operation

Monday	Tuesday – Thursday	Friday	Saturday	Sunday
9:00 a.m. – 12:00 a.m.	9:00 a.m. – 10:00 p.m.	9:00 a.m. – 5:00 p.m.	12:00 p.m. – 6:00 p.m.	12:00 p.m. – 12:00 a.m.

During the Fall 2000 semester fourteen first year course sections were scheduled in the Learning Center Tuesday and Thursday from 9:30 am to 5:50 p.m. and on Wednesday from 12:50 p.m. to 1:40 p.m. This somewhat limited student access to the center and it also influenced when the first year students wanted to use the Center. Since many of the assignments in the course involve use of the Center, the demand on the Center facilities is correlated with the course scheduling. Other classes can schedule time in the Learning Center for tutorials and demonstrations on a space-available basis. The Learning Center has enough space that students not in the scheduled class may study or work on a project during another class as long as they work quietly and are not using the equipment required for the class.

c) Utilization

When classes are not held in the Learning Center, students use the Center to work on group and individual projects. Faculty members also schedule time in the Center for hands-on activities, demonstrations, and presentations. Traditional "lecture" classes have used the Center to provide the students with a hands-on activity outside the normally scheduled class time. The students are able to come to the Center at their convenience to checkout the equipment and perform the activity. One of the key roles the Center plays in this area is to remove the burden of storing and maintaining the equipment from the faculty member. Some examples were a simple mixing experiment in a chemical engineering course and an evaluation and testing of a simple mechanism in a mechanical engineering course. It is important to note that neither of these activities had taken place before the development of the Center nor would they have been developed without the support of the Center. These instructors did not have the space available to them where the students could engage in these activities outside of normally scheduled classes and the Center provided that support.

The computer network and video projection capabilities in the Learning Center have been used to introduce engineering software to students in a group/interactive setting. The Civil Engineering and Chemical Engineering Departments have used the Center for this purpose. The large multiple projection screens and ability to provide small group access to networked PCs allow for a very effective exchange of ideas and presentation of examples.

The Learning Center has been used for the demonstration of design projects and various video presentations. A review and presentation of student group projects to faculty members and industry representatives has also been scheduled.

During the Fall 2000 semester, selected data was collected to begin to assess student use patterns and limited samples of these data are shown in Figures 3 through 5. The data presented in these Figures do not include students who are in the Center for scheduled classes or demonstrations. They were intended to provide an idea of the Center usage outside of the normally scheduled classes. Figure 3 details the Center usage by days of the week during its first semester of operation, Fall 2000. Figure 4 shows the average over the semester for a single day of the week, Sunday, and illustrates the number of students using the Center based on time of day.

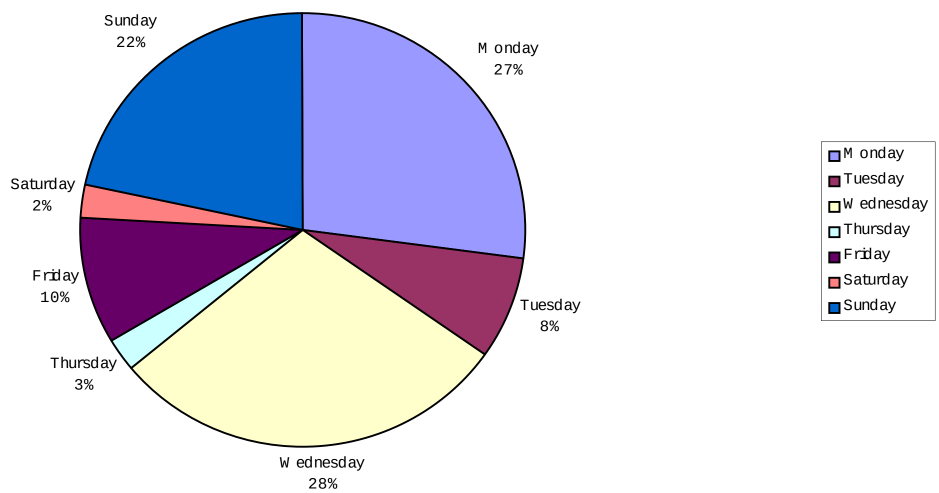

Figure 3. Learning Center Usage by Day of the Week

Most of the activity during the first semester involved engineering students using the Learning Center as a place for their group projects and a place to study where there would be other students available for assistance or collaboration. Another use involved students working with the electrical test equipment to resolve questions encountered in other laboratory courses or projects where they did not have ready access to a specialized laboratory. In this case that laboratory was only available to them during regularly scheduled classes.

The variations in use of the Learning Center during the semester can be strongly correlated to the scheduling of the project activities that provide the basis for the First Year introductory courses. Figure 5 presents summary data to illustrate the variation in use during the semester. Figure 5 represents an “integral under the curve” of Figure 4 for each Sunday during the semester. The heavy usage occurred, as expected, prior to the submission of the two major “projects” in the introductory course. The “zero-use” dates correspond to the beginning and end of the fall break and thanksgiving vacation periods. This information highlights the challenge in developing a facility that can adequately support a relatively large number of students for selected periods. Coordinating the users of the facility as more course activities begin to establish activities in the Center will be an ongoing challenge.

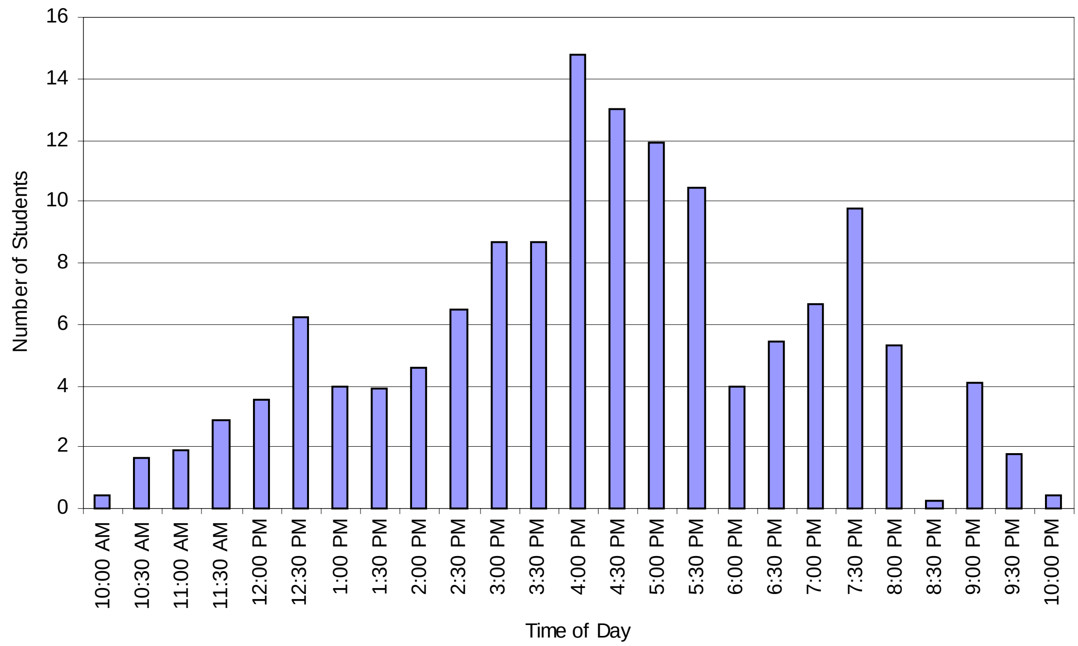

Figure 4. Average Usage on Sunday

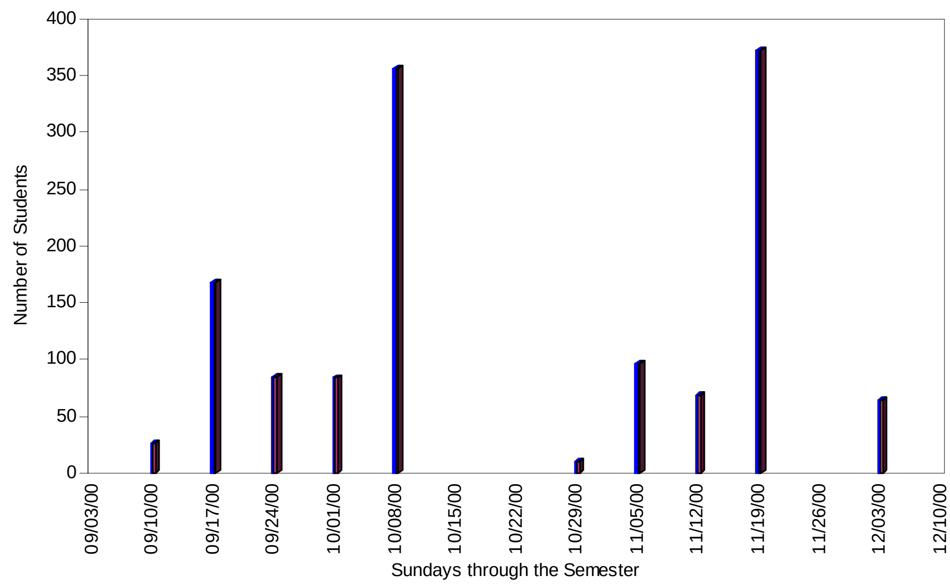

Figure 5. Sunday Usage Patterns During the Semester

V. Final Comments and Future Plans

One of the first and most important lessons learned in the development and operation of this facility was the need for good communication. This is a unique facility with many uses and many users. Students and faculty alike need to be able to view this as their space. To achieve this goal, the staff and the facility itself must remain flexible and open to change. As suggestions are made and concerns raised, the resolution must be communicated to all the users. If effective communication is absent, so is the feeling of ownership. Faculty, student staff members and student users must be informed what they can expect from the Learning Center and what they must provide in return.

There are still a number of remaining issues related to the hours of operation. The facility must be accessible at times desirable to students and when support staff is available. The Learning Center hours will be consistently adapted to meet peak usage patterns. Scheduling of support personnel must also be flexible. Since the Center primarily uses students to staff the facility, schedules must be flexible, as set schedules are difficult for the students to maintain. Students must also accept responsibility for their own schedule and be proactive in making adjustments or changes with other students.

Continued improvements are also needed in the areas of usage tracking and the equipment checkout system. It is important to have an effective and efficient method of determining room and equipment usage and this has not yet been developed. This information must be gathered and maintained to make informed decisions about future needs. It is much easier to implement changes when you have quantified data to support the need for change. This information will also be valuable during the planning for the new building Learning Center.

As more faculty begin to use the Center, one of the most important new elements will be the development of the "learning modules" which individual students or groups, may checkout and use to engage in self-directed knowledge exploration. These modules can take on various forms including portable roll-around experiments that will interface with the Center's equipment and instrumentation or interactive software/hardware simulations uniquely tailored for the Center's facilities. Students will use the learning modules to gain firsthand experience with a particular phenomenon or process. The modules will be developed, stored, and maintained in the Learning Center. Preliminary planning for these units has begun but integrating them into the Center will present further challenges.

While some of the modules will be developed for existing courses that do not contain hands-on activities, it is currently planned that selected modules and activities will be developed that are truly multidisciplinary. These modules will engage students and faculty from various disciplines who would not normally work together in their undergraduate programs. Coordinating the development and use of these modules will represent a major focus in the Center's development during the next two years.

Finally, the issue of assessing the impact of this facility on the programs in the College must be undertaken. Since there will be many users with diverse expectations, it is important to clearly define what roles the facility is expected to play and to measure its success in doing so. These issues of assessment will become important aspects of preparing to move forward from this prototype learning center into the planning stages for the new building center that represents the eventual goal for this effort. To date much of the anecdotal input has been provided by upper-class students who have indicated that they "wished" this facility had been in-place earlier in their program and from the faculty who have begun to use the Center for a variety of activities in their courses. Surveying students and faculty and documenting this information, particularly as it allows the faculty to include activities heretofore unavailable to them in their courses will be an ongoing activity and will be invaluable in the new building planning.

VI. Acknowledgments

As indicated the development of the Learning Center was a collaborative effort involving individuals from every department in the College of Engineering and a number of other organizations. The following faculty members participated in the College self-study and Steering Committee: Gary Bernstein, Jay Brockman, Ramzi Bualuan, Patrick Dunn, Patrick Fay, Thomas Fuja, David Leighton, Andrew Lumsdaine, Joseph Powers, Stephen Silliman, and Eduardo Wolf. The Dean of the College of Engineering Frank Incropera, the Senior Associate Dean John Uhran and the Director of Budget and Operations, Robert Cunningham, were instrumental in all aspects of the development of the Learning Center. The Project coordinator from the University's Facilities Engineering Department was Robert Ringel. The project architect from the firm of Mathews, Purucker and Anella, Inc. was Jacquelyn Hilderbrandt. The activities outlined in this paper would not have been possible without the efforts and important contributions of all of these individuals. The authors also wish to acknowledge the information and advice provided by Michael Lightner and Lawrence Carlson at the University of Colorado, Boulder.

STEPHEN BATILL
Professor of Aerospace and Mechanical Engineering and the Associate Dean for Educational Programs in the College of Engineering at the University of Notre Dame. His teaching and research interests are in the area of multidisciplinary systems design and optimization.

NATALIE GEDDE
Manager, College of Engineering Learning Center at the University of Notre Dame. Ms. Gedde holds degrees in Electrical and Mechanical Engineering and had extensive industry experience before joining the University in her current position. She is responsible for the staffing, operation and program development for the Learning Center.