The Implementation of a Classroom Laboratory Paradigm

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Abstract

This paper describes a novel classroom design used in the Systems Engineering department at the United States Naval Academy to more strongly couple the classroom and laboratory experiences for undergraduate systems engineering students. The Systems Engineering department has replaced *two* roughly equally sized rooms dedicated separately as a laboratory and a classroom with *one* lab-classroom equal to roughly one and a half times the size of the pre-renovation rooms. Designed for roughly twenty students, the lab-classroom are designed to integrate course-specific engineering laboratory equipment with the traditional lecture environment. The coupling of the physical environments serves to blur the distinction between formerly disparate events including: lecture, computer modeling and simulation, and hardware implementation. Lab-classroom can be dedicated to specific disciplines within the major such as control systems, robotics, environmental engineering, communications, and microprocessors. In addition, our lab-classroom are equipped with a variety of multimedia tools to facilitate student learning. For example, now one single room houses traditional desks, chalk boards, multimedia equipment, as well as ten robotic workstations including computers and vision systems. The paper discusses several of the lab-classroom activities that this new physical layout enables as well as faculty and student response.

1. Introduction

This paper discusses the Maury hall renovation design process, design rationale, and lessons learned. Maury Hall provides faculty office facilities, along with the associated administrative and meeting facilities, for the Weapons and Systems Engineering ("Systems") and the Electrical Engineering departments. The majority of the building is used to provide most of the lecture classrooms, laboratory spaces, and technical service spaces for the Systems department. As a result, approximately 75-80% of the building supports the Systems department, while the remaining 20-25% supports the Electrical Engineering department. The hundred-year-old Maury hall was extensively remodeled during the 2000-2001 academic year. The most significant change was the move from dedicated classrooms and laboratories to eight multi-use rooms which serve as both classrooms and laboratories. Prior to the renovation, the Maury hall faculty and staff conducted a year-long design requirements review resulting in fundamental changes to the organization and utilization of interior spaces. Essentially all of the committee recommendations where incorporated into the renovation. Partly due to historic Annapolis restrictions, very little change was made to the exterior of Maury hall. The Maury hall renovation followed similar

renovation programs for the adjacent Sampson and Mahan Halls. Upon the completion of the Maury Hall renovation, the entire three building complex was brought up to appropriate standards as an integrated and connected unit.

Maury hall provides office and most of the classroom and laboratory space for the Systems department. Although the electrical Engineering offices are also located Maury hall, electrical engineering classrooms and laboratories are located in buildings which have not yet been renovated. Therefore, this paper focuses on experiences from a Systems department point of view. The Systems department teaches two service courses to all Naval Academy students and graduates approximately 125 ABET accredited Systems engineering majors per year. The ten-fold increase in Systems department enrollment since moving to Maury hall in 1976 required an innovative facility design to provide the most laboratory, classroom, and design project support space within the existing building structure.

During the 1999-2000 academic year, the joint Systems and Electrical Engineering department renovation committee performed a requirements driven study. Initial steps included the requirements questionnaire summarized in Appendix A and the formation of subcommittees to study:

- Temporary swing space facilities
- General facility design
- Lab-classroom design

Concurrently, a pilot "classroom-of-the-future" was established to evaluate the lab-classroom concept and to try out various classroom technologies. The renovation committee generated a design requirements and recommendations report[1] which provided primary guidance to the renovation contractor team. The renovation committee identified the following pre-renovation deficiencies:

- Lack of adequate or controllable heating, ventilation, and air conditioning
- Lighting which was not sufficiently adjustable for multimedia presentations
- Inflexible room layout due to permanently-mounted desks

The following improvements were identified to adapt to evolving teaching styles and technology:

- Flexible seating arrangements which support innovative teaching styles such as cooperative learning, group discussions, group projects
- Integrated multimedia presentation facilities which are easily operated and visible to all students
- Access to power and communication network throughout the classroom

2. Temporary Swing Space

During the year-long Maury Hall renovation, the Systems and the Electrical Engineering departments each "camped out" in temporary swing spaces. Having a dedicated Information Technologies Services Division representative allowed continuity of voice and data communications services throughout the renovation. The ability to configure virtual Local Area Networks (LANs) over the Naval Academy's Asynchronous Transfer Mode (ATM) network also lessened the disruption of moving out of and back into Maury hall. The primary swing space problems encountered during renovation where:

- Physical separation of classrooms, laboratories, and faculty office
- Time consumed packing and unpacking offices before and after the renovation

3. Renovation Requirements

The primary renovation requirements focused on effective use of the existing building space and flexibility for future technologies. Specific requirements were summarized as:

- Provide effective, controllable heating, ventilation, and air conditioning
- Combine at least seven separate lecture / laboratory room pairs into combined lecture / laboratory rooms to improve space utilization
- Use movable classroom desks or tables to permit various arrangements suitable to the various educational processes including: team teaching, strict lecture, and group activities
- Provide effective, easily controlled lighting for lecture and multimedia requirements.
- Provide maximum blackboard space
- Provide central, easy-to-use multimedia control
- Mount permanent flat panel displays or projection screens with ceiling mounted projectors above the blackboards
- Provide pervasive data connection and power distribution capabilities
- Provide conduits, floor outlets, and / or raised floors to permit future upgrades to communication and computer networks, connections, and equipment

4. Renovation Observations

The move to combined classrooms and laboratories provides improved space utilization and teaching flexibility. As has been noted by many other authors, the ability to mix blackboard work multimedia, group, and laboratory exercises can significantly improve teaching effectiveness. The combined lab-classrooms also bring a few limitations:

- The entire lab-classroom must be scheduled as a single unit
- Faculty and students can not use the laboratory section of the classroom while a class is scheduled for the same room

Considerable flexibility for future requirements has been obtained:

- All laboratory and classrooms have floors 4" raised floors. The floor panels are carpeted, screwed down and quite serviceable.
- All rooms contain multiple category 5 enhanced cable runs and conduits with pull cords for future cabling
- Seven of the eight new lab-classrooms where designed with two independent doors, lighting and HVAC controls. With the addition of an interior wall or partition, these rooms could be converted back into independent classrooms and laboratories.
- Each lab-classroom contains a integrated multimedia system including
    - Ceiling mounted projector with projection screen above blackboard
    - Computer and document camera at instructor station
    - Locked audio / visual storage cabinet with VCR and DVD player
    - Integrated handheld infrared remote control and laser pointer
- Moveable two-student tables with caster equipped chairs

The ability to display the instructor computer screen, plain documents, or multimedia images above the blackboard is especially useful. One unanticipated consequence is that the blackboards are mounted lower than usual, which limits useful board space. This limitation is offset by the increase in the number of blackboards.

5. Application Example: Robot News

Robot News is a five-minute interlude during the classroom lecture allowing an individual student to provide a robotics related news item gleaned from current media sources. Usually, a picture relating to the news item is projected for the entire class, and in-class discussion follows the short presentation. A commonly used resource is naturally the Internet, with NASA's cool robot of the week site[2] being one of the most common sources. This assignment is especially easy to implement using integrated multimedia equipment and classroom Internet connection. This type of assignment reaps huge rewards in the classroom. By immersing the students in examples of robotic applications every day, we:

- Maintain a high interest level
- Educate as to current trends in popular (consumer) robotics
- Tie in daily lectures to current events

The following photograph shows a student presenting Robot News in a recently renovated Maury hall classroom:

Robot News in Maury Hall, United States Naval Academy

Research has shown that in a standard lecture, student attention wanes after the first ten minutes[3]. Breaking up the lecture with a quick intermission provides a simple means of regaining student attention. In addition to providing an opportunity to practice communication skills, the short discussion that follows provides an opportunity for active learning. Since there is no need to bring down a projection screen or set up equipment, there is little interruption in the instructor's use of the chalkboard.

The robot news assignment also provides a means for students to become more aware of global and societal trends in the area of robotics. The content is diverse and includes personal robots (e.g., robotic lawn mowers), medical advances (e.g., robotic surgery), military applications, and space exploration. In a field that is continually growing and changing, this exercise provides students with an understanding of the current state of robotics research and robotic products within our society in a way that a textbook is unable to do.

In our experience, robot news items often have some aspect that ties into daily lectures. A robot news item on the international space station's robot arm with 26 degrees of freedom can motivate lectures on coordinate transformations and robot kinematics. A robot news item on robotic

surgery motivates discussions on repeatability and accuracy. A discussion of what qualifies as a robot can follow the presentation of the latest robotic pet. Students with sensory and global learning styles benefit from the big picture presentation, and it helps them understand the need for the theory and the mathematics that typifies the standard lecture.

6. Application Example: Image Processing

Image processing is an example of a topic that is easier to teach in the classroom laboratory facilities. Obviously, the topic is inherently visual. Overheads and chalk or white boards are sub-optimal mediums for presenting lecture material. The use of the projector equipment with an instructor's computer greatly facilitates the presentation of image processing methods. These can be followed up by short 15-20 minute investigative lab experiences. For instance, in the robotics course, we teach a unit on machine vision with introductory image processing techniques. An early lecture presents the concepts of histograms and thresholding for binarization. For added interest, sample images can be captured on the spot by the use of a digital camera. The 50-minute lecture is concluded early, and the students move to the laboratory where they worked through a short MATLAB exercise on thresholding. The students read an image into MATLAB, implement a histogramming function, and experiment with binarization using different thresholds. The 15-minute lab time provides the students with an interactive learning experience. This type of short lab experimentation can be difficult if the laboratory facilities are not located within the vicinity of the classroom. The integrated classroom lab allows the instructor incorporate quick laboratory activities that reinforce lecture topics and more strongly couple theory and application.

7. Conclusions

The United States Naval Academy faculty and staff successfully influenced the recent renovation of Maury hall to significantly improve the utilization of space, teaching support infrastructure, and flexibility. The lab-classroom format supports a higher student density than the previous dedicated classrooms and laboratories. The primary disadvantage of the lab-classroom is the requirement to schedule the ensemble as one unit. An integrated, easy to use multimedia capability is much more effective than the previous patchwork of independent monitors and displays. The "classroom-of-the-future" experiment was very useful at assessing candidate media technologies. In particular, it was determined that large, flat panel displays were not yet cost effective and had too narrow a viewing range for effective use. The renovated teaching capabilities certainly outweigh the considerable burden of planning and executing the renovation. Our students enjoy the flexibility of the new lab-classrooms and the mobility of chairs with casters.

Appendix A - Summary of Results from Maury Hall Questionnaire

1. What types of media do you use to present course material to your students?
   - (All) Blackboard/whiteboard
   - (Some) Overhead Slides
   - (All) Computer Presentations (such as PowerPoint)
   - (All) Computer Software Demos (such as Matlab & VisSim)
   - (Some) Video Tape (VCR)
   - (All) In class Demos
   - (All) Lab Demos (i.e., Servo Motors, Oscilloscopes)

2. What modes of interaction do you use with your students in the classroom?
   - (All) Lecture/Taking notes
   - (Some) Individual Problem Solving
   - (Some) Group Discussion (2-5 students)
   - (All) Group Problem Solving (indicate class & group size)
   - (Some) Working at a computer terminal
   - (Some) Working at a lab bench

3. What should be different in our new classrooms. What media would you like to work with. How should the classroom be arranged? (Yes/Total)

   - (5/14) Individual row/column desks
   - (9/14) Rows of tables with individual chairs
   - (4/14) Small problem solving groups
   - (2/14) Large conference table format.
   - (8/14) What if we could reconfigure a classroom with modules, which of the above need to be supported? Do you need/want to be able to rearrange the classroom?
   - (11/14) Merge some classrooms and labs

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