The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
Paper ID #42325

[Case Study] ”Any Given Classroom”: Seemingly Small Deliberate Moves (48 Inches) Gets You Big Space Gains (1,100 square feet)

Major Joseph Speight P.E., United States Military Academy

Major Joseph Speight is an Instructor in the Civil and Mechanical Engineering Department at the United States Military Academy. A graduated from the United States Military Academy in 2013 with a B.S. in Civil Engineering. MAJ Speight holds a M.S. in Geological Engineering from the Missouri University of Science and Technology and a M.S in Civil and Environmental Engineering from Stanford University. He is a licensed Professional Engineer in the state of Missouri.

Major Brett Rocha P.E., United States Military Academy

MAJ Brett Rocha is a third year instructor at the US Military Academy in the Department of Civil and Mechanical Engineering. She received her B.S. in Civil Engineering from USMA in 2012, her M.S. in Engineering Management from Missouri University of Science and Technology in 2016, and her M.S. in Civil Engineering from University of Central Florida in 2021. She teaches mechanics of materials, design of steel structures, and design of concrete structures.

Dr. Brock E. Barry P.E., United States Military Academy

Dr. Brock E. Barry, P.E. is the Director of the Civil Engineering Division and Professor of Engineering Education in the Department of Civil and Mechanical Engineering at the United States Military Academy, West Point, New York.

Case Study: “Any Given Classroom”: seemingly small deliberate moves (48 inches) gets you big space gains (1100 square ft)

Abstract

In early 2021, the University began a modernization of its academic spaces at a large scale and scope. While the long-term benefits of such an endeavor will significantly assist in modernization, one of the short-term effects has been a significant strain placed on available classroom space. Creative measures were taken to aid university planners in scheduling classroom space during the next decade of development. One promising course of action has been the migration to develop the “classatory”. This is a trend in higher education where classrooms and laboratories join in a single space. Such spaces maximize classroom square footage and help to create a more active learning environment. This case study paper showcases an ability to develop these multi-use spaces at a fraction of the cost. This shows how seemingly small, deliberate decisions can lead to a more significant number of more effective and engaging classrooms.

Introduction

For many years in higher level education, it was assumed that engineering labs had to be expansive, dedicated buildings filled with expensive equipment. And in many universities, that’s still the case. However, in Educating the Engineer of 2020 the National Academy of Sciences challenged educators with a goal it stated “to reengineer engineering education” [1]. That reengineering involves asking the questions: “How can we make our processes more effective, more quality conscious, more flexible, simpler, and less expensive?” [1] One potential approach to making our processes more flexible and less expensive is by satisfying multiple requirements of the ABET general criterion 7 for facilities with a single space. Criterion 7 states, “Classrooms, offices, laboratories, and associated equipment must be adequate to support attainment of student outcomes and to provide an atmosphere conducive to learning [2].” Educating the Engineer of 2020 states, “Although its form may change from one generation to the next, there is no substitute for blending, practical application with theory learned in the classroom” [1]. In recent years there has been a significant effort to create multi-use spaces that function as both a classroom and a laboratory. Most of the existing literature speaks about new construction and significant renovations in the creation of these multi-use spaces. This case study paper will focus on how examples of minor renovations and deliberate leadership decisions allowed already existing spaces to maximize available space and foster a more active learning environment.

Literature Review

To improve educational facilities by making them more flexible is not a new concept. In a 1996 American Society for Engineering Education (ASEE) conference paper [3] authors spoke about a new education space that would have flexible laboratory modules that would allow for future modification. The authors spoke that these new spaces would be utilized for clinic projects, multiple disciplines courses, for teaching / research, and be able to accommodate multiple courses of instruction. In the field of Civil Engineering, space was constructed to provide technology focused courses and research, discipline courses and research, and student team projects. More specifically it was made with three contiguous modules that form a 66 x 40ft open area with one half dedicated to environmental engineering and the other half dedicated to infrastructure engineering with a classroom centrally located in the center between the two lab space areas. In this instance the forcing function behind the development of these spaces was due in part to a generous donor grant that allowed for the construction of a brand-new engineering facility. The authors understood that the goal of those forecasting future needs was to create a flexible design that can accommodate ever changing technology.

In 2002 the United States Naval Academy renovated Carter Hall then known as Maury Hall [4]. At the time of the renovation, Carter Hall provided most of the classroom and laboratory space for the Systems department. During the renovation the most significant changes that were made was to transform dedicated classrooms and laboratories into eight multi-use rooms which serve as both classrooms and laboratories. Benefits determined from this improved space design was higher student density in the multi-use rooms than in previously dedicated classrooms and laboratories. These new multi-use rooms also provided an increased flexibility in the space. The authors did note a disadvantage in the new requirement to schedule the spaces as one single space.

Then in 2009 ASEE authors with support from a National Science Foundation Course, Curriculum, and Laboratory Improvement (NSF CCLI) grant developed a project-based learning curriculum called, “Living with the Lab” (LWTL) at Louisiana Tech [5]. The portion of the project that was most relevant to this research was that an 1800 square foot classroom was completely remodeled for teaching the new freshman engineering sequence. The design of the space was to place the ownership and maintenance of the “laboratory” into the hands of the students. This space also enabled a significant increase in the number of hands-on activities reported by each of the students during the quarter and a boost in the amount of experiential learning.

In 2013, Harvard University created a more experimental atmosphere with its Scibox, a 2,500-square-foot-space where walls are covered in blackboard paint and tables are on wheels [6]. The space is half-classroom and half-lab that instructors intended to feel more like a workshop or a garage. It was done as part of Harvard’s broader interest in testing new ways of teaching and learning and reflects a departure from the traditional physics-lab curriculum. Authors noted that rather than performing different “canned” experiments each week, small groups of students now tackle more complex, open-ended projects.

In 2016 from the success of Louisiana Tech’s LWTL, Campbell University adopted a similar design as it created its engineering school [7]. As part of the adaptation, they employed an updated version of the “classlab” concept where traditional lectures and laboratory activities are seamlessly interwoven into the same course and added new support spaces dedicated to collaboration. The first-year collab space was the first main instructional space and was an integrated lab facility that supported traditional lecture (seating for 24 students at six tables with rolling chairs in the center of a large room, with both whiteboard and large monitors for PowerPoint) and lab activities (with lab stations for each table around the edge of the room). This layout enabled an easy transition between the different forms of instruction and different learning activities used in this “classlab” space.

Again in 2018, Robert Morris University, with the assistance of a $400k grant, were able to create an educational space that served simultaneously as a classroom plus a physical and computing laboratory [8]. This 1440 square foot space was broken into two halves: one with laboratory workbenches, 3D printers / storage and the other a teaching space with foldable furniture. The author concludes that the most important area for educational facilities development will be flexible innovative spaces that have access to design, analysis, and prototyping tools.

The literature points to countless examples of new spaces being designed as multi-use spaces. It also speaks frequently about renovation of spaces with the assistance of large grants and endowments that transform into new collaborative spaces that can support labs and classroom instruction. This paper will focus rather on the ability to create low-cost options (< $30,000) that transform already existing spaces into classatories or what is sometimes seen in literature as “classlabs”. These solutions have the potential to alleviate strain placed on available classroom space as universities undergo renovations that create space constraints in the short term. The paper will provide three examples of case studies that have been implemented and the costs and benefits that have arisen from such examples.

Structures Classatory

The room used to create a structures classatory was originally a woodworking and fabrication lab space. The room contained various equipment including sanders, drill presses, circular saws, and table saws. To facilitate the safe use of this equipment indoors a large ventilation system was included in the room as shown in Figure 1. The existing space did have chalkboards on two walls which were mostly covered by shelves to hold materials or woodworking equipment. The structures classatory needed to be transformed from a fabrication space to an effective classroom space to teach Structural Analysis, Advanced Structural Analysis, Design of Steel Structures, and Design of Reinforced Concrete. Each of these courses except for Advanced Structural Analysis are taught to two sections of students with a section size of approximately eighteen students. The first step to completing the transformation to a structures classatory was to remove the equipment, including the ventilation system. The space was further improved cosmetically with new paint on the walls and chalkboards added to a third wall which would serve as the front of the classatory. With equipment removed and cosmetic improvements complete the next step was to add the laboratory to the classatory environment.

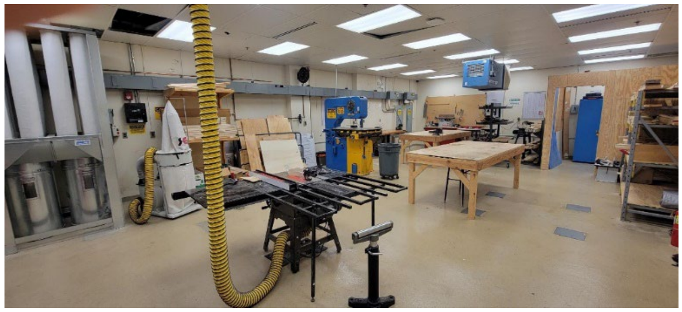

Figure 1. Woodworking and Fabrication Lab Space

It was determined that the available space would be divided into two areas, the front serving as the classroom and the back serving as a space for hands on demonstrations and laboratory exercises. A projector was added to the front of the classroom along with table space and chairs for twenty-four students, and two tables for instructor use. The tables were selected for use over individual desks because the rolling tables could better facilitate the group work that is often done for laboratory exercises. The front of the structures classatory shown in Figure 2 is an ordinary classroom. The back of the structures classatory is what makes the learning space unique. A large shelf was placed in the back of the classtory, which provided a location to place the physical demonstrations associated with the courses taught in the structures classatory. Many of the structures courses share demonstrations so having a space in the classroom to share these allowed for easier coordination between instructors. Additionally, the back of the classroom included a large table as shown in Figure 3 suitable for conducting laboratory activities. The open space in the back of the room also provided space for larger in class demonstrations. A second projector was added to the room oriented to the back of the room to allow the instructor to still be able to display course material while conducting hands on activities. The transformation from woodshop to classatory was completed in less than three months and the only costs associated with the transformation was the purchase of chalkboards, tables, chairs, two projectors with screens, and a few buckets of paint (~ $15,000). The resulting space is 1,083 square feet in size. The woodworking equipment that was previously located in this space, was relocated to a larger space more conducive to completing larger projects.

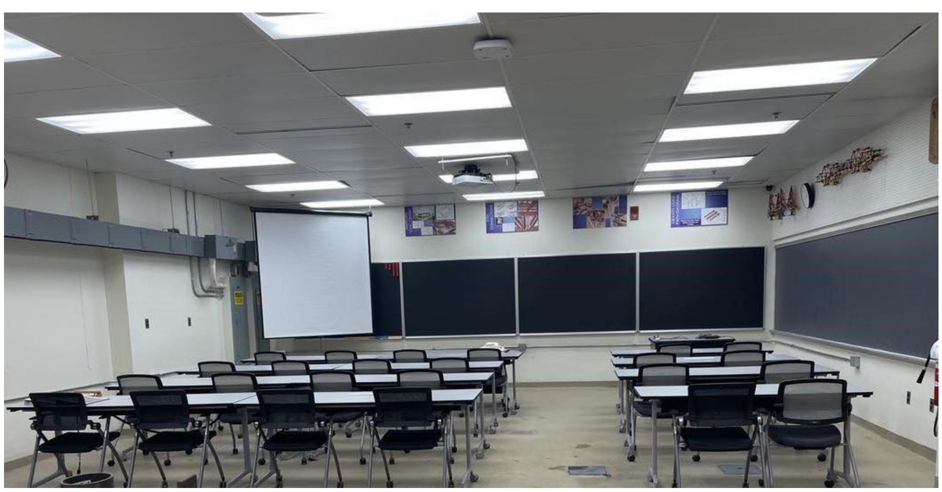

Figure 2. Front of Structures Classatory


Figure 3. Back of Structures Classatory

The structures classatory is the newest classatory to come online at the United States Military Academy and was first used during the fall semester of 2023. During the first semester Structural Analysis and Design of Reinforced Concrete were taught in the classatory. Throughout the semester the laboratory part of the classroom was used for various in-class demonstrations and hands on activities. One example of an in-class demonstration was bringing a Universal Testing Machine (UTM) into the classroom to demonstrate the difference between a tension controlled and a compression controlled reinforced concrete beam as shown in Figure 4. Another use for the laboratory space in the classroom, was providing the students with an opportunity to mix a simple 3-2-1 concrete mixture to get an idea of the effects of water to cementitious material ratio and the proper proportioning of a concrete mixtures as shown in Figure 5.


Figure 4. Reinforced Concrete Beam Demonstration with UTM

Figure 5. 3-2-1 Concrete Mixture Lab Activity

While the additional classroom space was useful in the first implementation of the structures classatory there are additional improvements to be made to the laboratory space to expand the functionality. Before the fall semester of 2024 a Forney Compression and Tension testing machine as shown in Figure 6 will be added to the laboratory space in the back of the classatory. The addition of the Forney Compression and Tension testing machine does not require the purchase of new equipment. It simply requires moving the testing machine from a dedicated lab space to the classatory. The Forney Compression and Tension testing machine will provide opportunities to conduct more in-class demonstrations similar to the comparison between tension-controlled and compression-controlled reinforced concrete beams that was completed using the UTM. Additional opportunities for reinforced concrete demonstrations could include the difference between a one-way and two-way slab and 4-point bending tests to show shear cracks versus flexure cracks. Demonstrations for the Design of Steel Structures could include a demonstration of lateral torsional buckling of a wide flange beam. The structures classatory provides many opportunities for in-class demonstrations and hands on laboratory activities that were not possible before in the time constraints of a single instructional period.

Figure 6. (a) Forney Compression and Tension machine (b) 4-point bending test of small reinforced concrete beam

Soil Mechanics Classatory

The space that now houses the soil mechanics classatory was previously underutilized. Laboratory exercises were conducted in this space and secondarily it was used for storage of course-related equipment. The space was not used in effective or efficient manner (see Figure 7 and 8 of pre-classatory space).

The soil mechanics classatory was renovated during the summer of 2017 using funds secured from external donors. Renovation items included the addition of an ~20 ft long wall (see Figure 9) to create the third wall of the classroom space, creation of enclosed storage areas, and creation of a classroom entrance area complete with coat hooks and space for backpacks. A pull-down project screen and projector were added. The finished classatory includes ~500 square-feet of traditional classroom space with chalkboards on three sides and a pull-down projector screen on the fourth side of the classroom. The remaining ~1200 square feet includes modular team work stations and common usage spaces. When the projector screen is in an upward position, the classroom area opens up to the modular work stations. Student tables and chairs were purchased to complete the classroom portion of the space. The space can comfortably accommodate 18 students, as well as the instructor table near the “front” of the classroom (see Figure 10). Total expense for the renovation, new furniture, and new audio-visual equipment was ~$30,000.

After the renovation was completed, the course was also re-designed from a 40-lesson (55 min/lesson) plus separate lab period format to a 40-lesson (120min/lesson) format with labs integrated into the lessons. This permitted performance of lab activities during the lesson immediately following the in-class introduction of the topic (as opposed to waiting upwards of two weeks for the next scheduled lab period). In many cases, new content is introduced at the start of a lesson and as time permits performance of lab activities during that same lesson. There is great benefit to learning about a new topic and then immediately having the opportunity to reinforce understanding through lab activities.

Having all course related teaching demonstrations and supporting equipment in the same space as the "classroom" makes it much easier to pull items into discussion to help introduce and reinforce concepts. For example, when introducing the topic of grain size distribution, it is immensely helpful to have a stack of sieves handy to pass around, and then to run a sieve shaker while discussing the concept, followed by passing around individual sieves with soil particles retained on each sieve. In other examples, it is easy to have students walk from the classroom side of the classatory to the laboratory area to demonstrate a concept and then have them return to their seats to continue the conversation.

Figure 7. Soil Mechanics Classatory Prior to Rennovation

Figure 8. Soil Mechanics Classatory Prior to Renovation

Figure 9. Soil Mechanics Classatory During Renovation

Figure 10. Completed Soil Mechanics Classatory

Hydrology Classatory

The new Hydrology classatory has always been home to a large open channel flume used for instruction in the undergraduate civil engineering course on hydrology and hydraulic design. This lab space also functioned as a storage space for all course-related equipment, including four smaller portable open-channel flumes. In past years, its usage was limited to only five times a year while conducting open channel labs. In 2019, the university spent significant resources to replace the original flume with a modern model for life-cycle replacement. Along with that decision-making process, it was also determined that the new flume would be installed in a different location within the room to allow for additional space in the front of the flume. It was moved back 48 inches (see Figures 11 and 12). While seemingly insignificant, it was those 48 inches that allowed for a transformation of the space from a lab used only 3-5 times a year to a 1,078 square-foot multi-use classatory space supporting two forty lesson courses in open channel flow and fluid mechanics.

Like the structure's classatory transformation, the only costs associated with the transition were tables, chairs, and two televisions placed on movable stands (costing ~$15,000). The chalkboards were moved into this space from another room that would no longer function as a classroom. With the additional space provided by the classatory, all course-related physical demonstrations and supporting equipment could now be stored in the room. This makes it much easier to conduct demonstrations during lectures while introducing new topics and reinforcing concepts. It is also very effective to have pre-emplaced models in the teaching flume demonstrating various concepts discussed during a lecture. The flume also enables in-class practice problems with flow conditions displayed, and if time allows, measurements are made in the flume to help solve such problems. This method showcases data collection in the field without leaving the classroom. The methods described above have been particularly helpful when demonstrating the effects of constricted flow in an open channel. Having the flume in the classroom creates a more active learning environment where students are engaged in their learning by thinking, discussing, investigating, and creating. The new desk layout also helps create a more active learning environment, where students who sit in groups can collaborate more effectively when working on in-class problems and discuss more productively when asked to provide feedback about a specific question in a lecture.

The classroom with chairs and desks on wheels makes it very easy to transition from a lecture teaching format to a lab with students utilizing either large or smaller flumes to take measurements and gather data. Another great benefit of this classatory is that because of the room's costly and technical equipment (i.e., open channel flume), its scheduling is maintained at the department level. Only being utilized for two courses allows professors to set up the classroom prior to the start of class without worrying about something changing, such as labs, in-class exercises, and examinations. Another surprising effect is that the classatory environment has created a space that students want to be in. The number of students that stay after class to continue to work on school work and collaborate has been a welcome change to typical classrooms where students leave as soon as the lecture is complete to find someplace elsewhere to work.

Figure 11. Hydrology Classatory Prior to New Flume

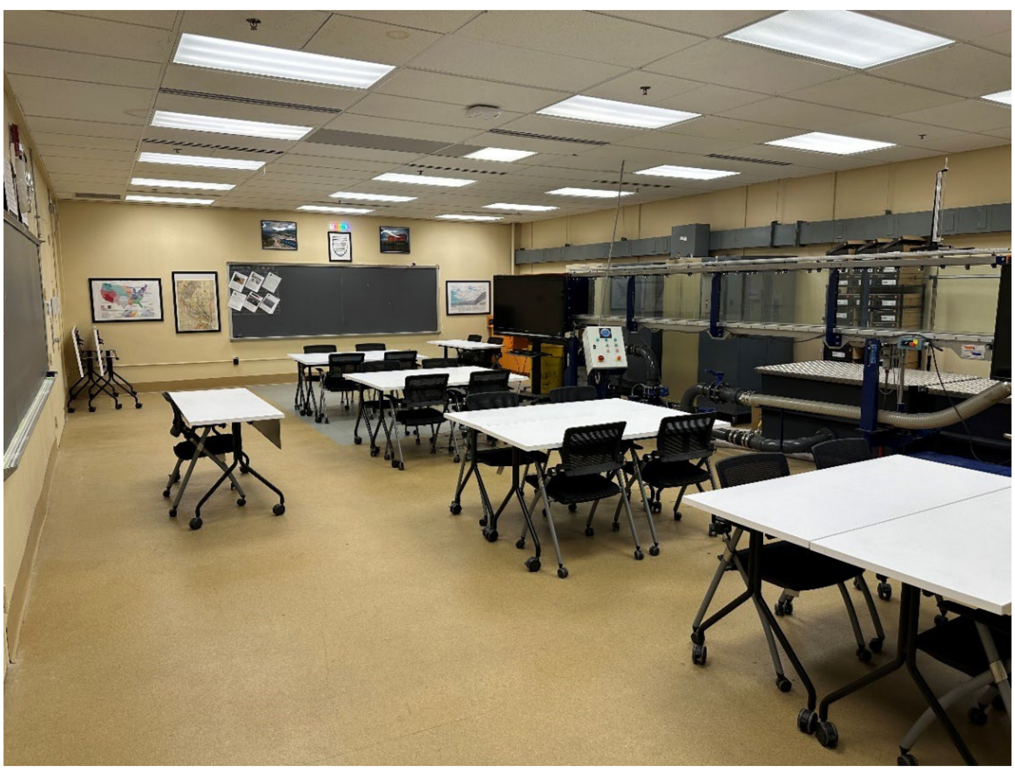

Figure 12. Hydrology Classatory After New Flume Installed

Concluding Thoughts

As educators continue looking for ways "to re-engineer engineering education," we have learned that modern classrooms must be flexible in design to accommodate ever-changing technology. Developing a classatory through new construction and major renovations can be expensive, making them unrealistic for constrained University budgets. This case study paper has demonstrated three examples of classatories where a flexible education space is possible with a relatively small budget (~$30,000), minor renovations and forethought from leaders during the decision-making process. These classatory spaces can create an active learning environment by integrating hands-on activities.

Space is always at a premium due to ongoing renovations educational buildings, and instructional space scheduling continues to become more complex. The sharing of classrooms between different departments and a rapid transition period between classes makes it difficult to mobilize large demonstrations. Classatories have been labeled as unique spaces, which excludes them from being listed as schedulable classroom space, thereby limiting the ability for individuals outside of the department to schedule use of the space. Classatories create a space that is owned and controlled by the department.

Most importantly, these low-cost classatories create spaces and environments that students want to be in. In higher education, where everything seems to be competing for students' time, it is nice to have a space that excites students to put in a little more effort and dedicate more time.

References

[1] 2020, C. on the E. of, & Engineering, N. A. of. (1900). Educating the engineer of 2020: Adapting engineering education to the new century. National Academies Press.

[2] ABET General Criterion 7 – Facilities. https://www.abet.org/wp content/uploads/2022/01/2022-23-EAC-Criteria.pdf

[3] Chandrupatla, T. R., & Dusseau, R. A., & Schmalzel, J. L., & Slater, C. S. (1996, June), *Development Of Multifunctional Laboratories In A New Engineering School* Paper presented at 1996 Annual Conference, Washington, District of Columbia. https://peer.asee.org/5990

[4] Zivi, E., & Piepmeier, J. (2002). The Implementation of a Classroom Laboratory Paradigm. 2002 Annual Conference, 7–1158.

[5] Cronk, Stan, David Hall, and James Nelson. "Living with the Lab: A Project-Based Curriculum for First-Year Engineering Students." 2009 GSW. 2021.

[6] “SciBox 1.0”: An Innovative, Experimental Learning Space Inspiring Creative Approaches to Teaching.” Harvard Initiative for Learning and Teaching, Web. 05 JAN. 2024.

[7] Carpenter, J. P., & Rynearson, L. K. (2017). Design of Classlab and Supporting Spaces to Enable a Multidisciplinary Hands-on First-Year Engineering Design Curriculum. 2017 ASEE Annual Conference & Exposition.

[8] Sirinterlikci, A. (2018). Development of Multifunctional Educational Spaces. 2018 ASEE Annual Conference & Exposition.

[9] “The Evolving Classroom: Creating Experiential Learning Spaces.” The Evolving Classroom:. Creating Experiential Learning Spaces, EDUCASE, Web. 05 JAN. 2024.