AC 2009-721: RESEARCH GRANTS TO BUILD LABS: A SAMPLE--MECHANICAL BUILDING SYSTEMS LAB (MECHBUILD LAB)

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Research grants to build labs:
Mechanical Building Systems Lab (MechBuild Lab)

Abstract

As the requirement faculty to develop research increases, create projects with funding potential are needed. One faculty member developed a grant to support the development of a Mechanical Building Systems Lab (MechBuild Lab). This lab will to serve an accredited four-year Bachelor of Science program in Construction Management. Students learning in this lab will someday be responsible for the management of construction, verification of design, and inspection of installation of all types of mechanical systems in buildings. The MechBuild lab will bridge the gap between student learning and the implementation of innovative technology, and will stimulate students with real-world, hands-on exercises. It will be beneficial to STEM (Science, Technology, Engineering, and Math) education, faculty development, and community outreach. This paper will outline the goals and utilization of this lab.

Introduction

A proposal was written to seek financial support for the development of a Mechanical Building Systems lab (MechBuild lab) to serve three courses in an accredited four-year Bachelor of Science program in Construction Management. Buildings are living things and mechanical systems are what keep the contents of the building alive. Per the United States Health Department, people cannot occupy a commercial building without clean air, drinkable water, and flushable toilets. Piping systems are the veins of a building. The heating, ventilation and air conditioning (HVAC) systems are the heart and lungs that provides a healthy environment. The proper design, construction, and installation of mechanical systems are necessary to allow the safe occupancy of any structure. Like internal organs, most mechanical systems are concealed within the walls of the structure; therefore, it is more difficult for the students to comprehend something that lies beneath the surface. The MechBuild lab will allow students opportunities to study the life systems of a building, previously only viewable during the construction of a building.

On average, 75 students per semester complete the Mechanical Construction course that is a requirement for graduation in the Construction Management department Bachelor of Science (BS) degree. In addition, approximately 25 students per semester take a mechanical specialization course that would apply higher-level learning to the MechBuild lab. The third class utilizing the MechBuild lab is a course for non-majors offered by the Building Construction Management (BCM) department. Usually sixty computer graphics, interior design, and other interested students take this course every semester. Currently the students enrolled in these courses have show and tell type activities. The need is to provide students with more challenging activities applying measurable outcomes. At a minimum, 160 students per semester are enrolled in courses that require the completion of lab exercises related to mechanical construction.

Other students who could develop interests in this lab are Mechanical Engineering Technology (MET) students. The collaboration with the xxx and MET departments has been growing over the past two years with the sharing of an Applied Science Lab in the MET department. The MechBuild lab would allow for more projects with undergraduate and graduate students to complete research projects. The current space occupied by the xxx department is used for industry networking events. One vendor, NIBCO, provided an industry night for students and industry to demonstrate new products. Expanding the MechBuild lab with permanent demonstrations would also expand the industry partnerships.

K-12 outreach will be a major part of the MechLab through the activities sponsored by Purdue University and the College of Technology. As part of STEM (Science, Technology, Engineering, and Math) outreach programs Purdue markets to pre-college students through open house type events each semester. During the summer groups from 4-H, Science Bound (an outreach program through Indianapolis Public Schools), and other programs designed to better prepare under-represented populations visit the campus. The MechBuild lab would become a destination for these visitors to learn more about the construction industry.

In this College, many programs occur throughout the year to attract the best and brightest. Currently, four five-day residential camps occur during the summer with approximately 30 students each session. During the week, the students participate in activities related to all programs. The department currently has a piping activity showing how to go from plan to actual building. It has received good evaluations in past summers. The MechBuild lab would allow for more developed and age appropriate learning experiences. The current events are:

- TOTAL (Turned on to Technology and Leadership)
  multi-cultural students entering the 7th & 8th grades
- TEAM (Technology Expanding All Minds)
  female students entering the 9th & 10th grades
- Cheering in the Classroom –
  female students in both middle school and high school
- TAGS I: (Technology Advances Girl Scouts)
  middle school females
- TAGS II: (Technology Advances Girl Scouts)
  high school females

During the Fall semester, a one day WOW-IT (Windows of Opportunity for Women in Technology) workshop invites high school females to visit the college. The Spring includes two three-day workshops for high school juniors. The Vision session recruits multi-cultural high school juniors and the DO-iT (Discovering Opportunities in Technology) is specific to female high school juniors. Currently, the College of Technology hosts approximately 230 pre-college kids in eight camps with students ranging in age from eleven to eighteen years of age each year. The MechBuild lab would be one of the workshops for these students to attend.

The need for students to understand science, technology, engineering, and mathematics (STEM) has become a forefront of education research. The MechBuild lab will be developed using the Circle of Knowledge Production and Improvement of Practice model from the Rand Corporation

as a model, MechBuild lab project components have been shown in Figure 1.[1]

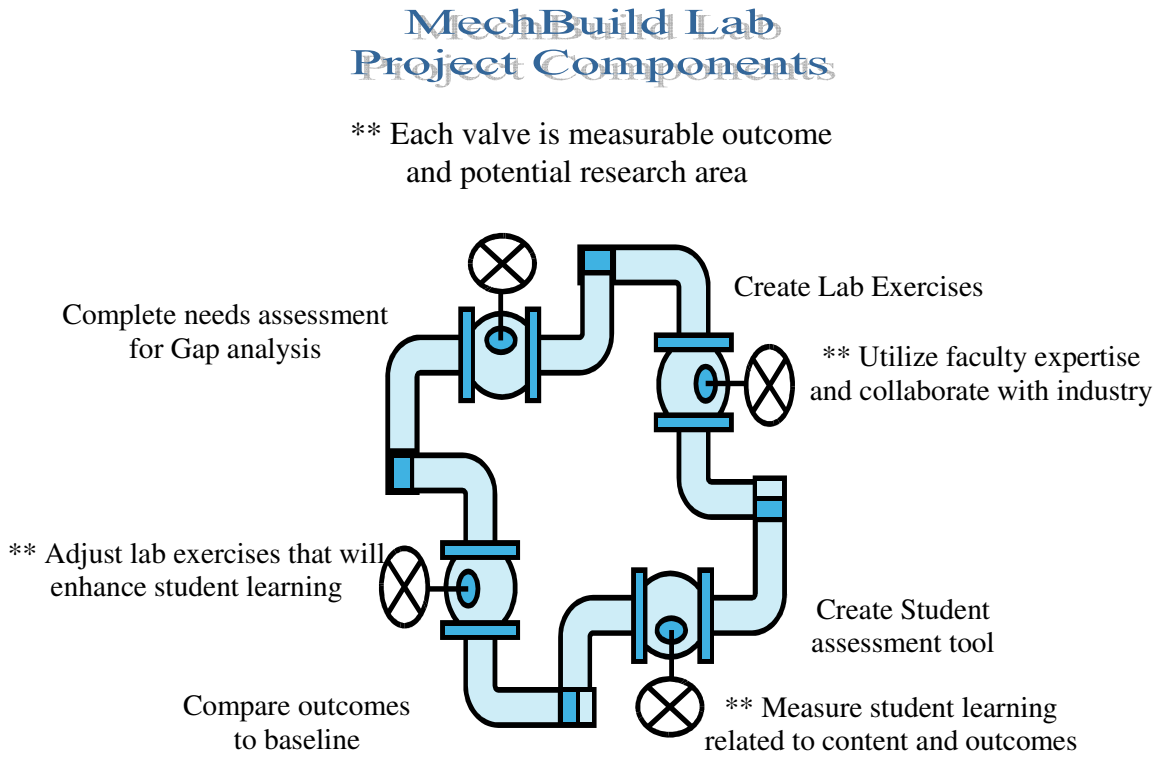

Figure 1: MechBuild Lab Project Components

To begin the development of the MechBuild lab, the major content areas required by the students will align with existing labs. As each section of the project is developed, a measurable outcome will support the content. The findings of gaps in the content versus the lab experiences will become the basis for the creation of the new lab exercises. As the MechBuild Lab project components flow through the piping diagram (Figure 1), the assessment tool is created. This process will proceed through two years of development, assessment, analysis and rework as necessary. The process can also be applied as needs arise with the donations of materials or new technology. For example, one manufacture has donated a box of piping supports. This is a major component of any mechanical system, but in its current state, in a box, it does not enhance student learning. Currently no lab exercises exist related to pipe supports. Developing an exercise that demonstrates the use of supports to hang pipe could be developed by building a wall or ceiling section where the students could visualize how the pipe supports are installed. Then an assessment could be a case study requiring the students to calculate the number and size of hangers outlined in a project. This exercise would begin with a student having no knowledge from the course of the pipe support element in mechanical systems. Upon completion of the lab, students would have demonstrated the use of the support and have measurable outcomes of learning. In addition to the lab assignment, lab questions question could be developed to assess knowledge.

Each goal of the MechBuild lab is outlined below with the specific plan related to the completion of the proposal.

1. Analyze the current practice to provide a baseline related to student learning, outcomes, and comprehension. Student evaluations to date have shown that students want more hands on exercises as part of the mechanical curriculum. There have also been comments from students in the required course evaluations that there is a disconnect from the lecture and the lab. The belief of the instructor is that the students are not making the connections from the written text to the hands on activities. One example is a diagram of a water closet carrier that was labeled as part of an in class assignment in lecture, Figure 2.

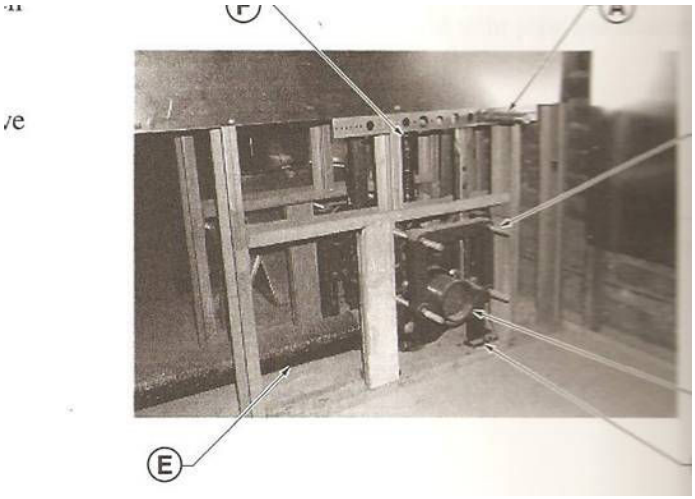

Figure 2: Water Closet Carrier and Fitting [2]

Upon testing the students about this diagram on an exam, many failed to identify the parts. The same exercise was done with a valve shown in Figure 3, but the valve was also viewed in lab and the students were given the opportunity to look inside the valve and each one demonstrated how it operates.

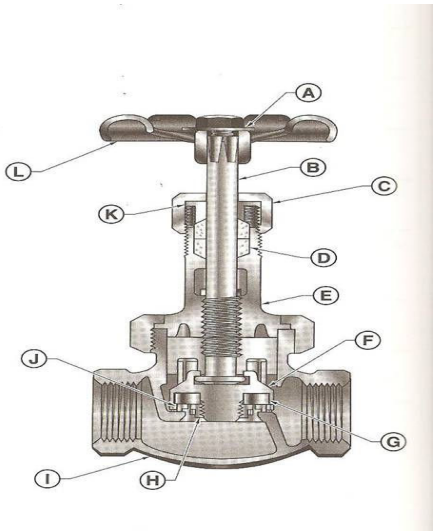

Figure 3: Components of a globe valve[2]

This area of the exam had much higher marks. These two examples show the faculty member that students are learning more when they combine the lecture information with hands-on exercises. The belief is the MechBuild lab exercises can assist the students in learning, comprehension, and application of information related to mechanical systems.

2. Provide a needs assessment with gap analysis of existing versus needs relating to student learning, outcomes and comprehension. Research has revealed that students come to class with their own ideas of how things work, and do not grasp new concepts unless they are engaged.[3] That better way to engage students than to develop hands-on real world exercises related to mechanical building systems? The key to accomplishing this task is to design the appropriate assessment tools. A survey of faculty members discovered that it is important to assess student learning, especially when developing new materials.[4]

Currently, the lab related to the mechanical construction course does not include assessment of all knowledge. There is a lack of transition between what the students need to learn and what is available in the lab for demonstrations. The MechBuild lab would provide opportunities for students that would be based on the needs of the students in terms of learning, outcomes and comprehension. Examples given throughout this proposal explain needs that have been discovered to date. The belief is that the needs assessment would become a natural outcome of the course content that student assessments would reveal. From this would evolve the natural cycle of continuous improvement to ease in the yearly refinement of the MechBuild lab.

Current curriculum includes plumbing, heating, and air conditioning with information for each related to: Materials, Equipment, Codes, Design criteria, Plan reading and specification interpretation, Green products, and Sustainable design.

Much of the information related to mechanical systems is based upon the textbook, industry input, and experience of the faculty member. This project would also add the student's level of understanding information. This information would be used as the starting point for the information that the students would be required to learn. Lab periods for each topic would be analyzed and compared to lecture materials to identify the areas that are currently not meeting expectations. The development of the MechBuild lab can be a model for other universities teaching mechanical systems.

3. Create new and adapt existing lab exercises to include new technology and increase student outcomes in terms of learning and comprehension. Using data collected in the gap analysis, improvement area will be identified. One graduate student, undergraduate hourly workers, and the faculty would develop lab exercises that meet expectations. Applying research developed by the National Research Council (NCR) the new lab exercises will be developed to:

- Engage students
- Improve the assessment of leaning outcomes
- Produce subject matter that can be reviewed and utilized by other faculty, and
- Provide a model for other curriculum development.

Manufacturers are very happy to donate products; it is just having the time to develop meaningful exercise around the products. Additional materials will be purchased as necessary to fill the gaps. Some items are consumable products that will be replaced on an ongoing basis. Upon completion of Phase I of the MechBuild lab, further funding will be investigated.

Currently many lab exercises are a "show and tell" type activity with no assessment of student learning. One example is a connection the Carrier Corporation. United Technologies is the owner of Carrier and has been supportive of the Construction Management (CM) program and the Mechanical Engineering Technology (MET) programs, by providing training equipment. The MET department currently has an applied energy lab that they allow the CM department to use for one lab period each semester. With the expansion of the MechBuild lab, the MET and CM students could further collaborate with exercises related to new technology of sustainable (energy efficient and clean) products. Challenging activities can be developed with outcomes that can assess student learning.

This lab would replicate examples of daily mechanical construction issues and transfer the knowledge to the student by their completing the labs. One example would be the development of a wall section without the finished drywall where the students could see the difficulty in placing pipes for water supply, waste and vent into a small space. An assignment can be made to replicate the interpretation of plumbing drawings and the inspection of what is installed. Parts of the system can be installed incorrectly and the students then earn points by understanding the mistakes. This would be very related to real-world applications that students would encounter.

The outcomes of the Phase I of this project would be to develop labs from the materials that are currently available from industry donations. This includes Pipe Support materials, Victaulic pipe and fittings, Trane HVAC equipment, NIBCO valves, Apollo Valves, and others. Lab assignments would be created utilizing hands-on activities to teach students fundamentals about mechanical systems in construction

4. Implement and assess new lab exercises as student learning, outcomes, and comprehension. Formative evaluations will be performed in the first two semesters after the completion of the labs with a summative evaluation at the end of the spring semester. At this time the data can be analyzed to spend some summer time improving or adding to the lab assignments.

The challenge in teaching mechanical systems (Plumbing, Heating, Air Conditioning, Hydronic Systems, Utilities, etc.) is that major components are hidden underground or in the wall. Students have difficulty visualizing areas that are not the exposed portion of mechanical systems in their daily lives. Exams currently given in this class reflect that the students miss questions related to the areas of the system that they cannot touch. In addition, they do not have as much interest in the subject matter because they have not had the opportunity to touch it and look at all of the moving parts. By defining student outcomes the comprehension and improvement of students learning will develop and improve.

5. Develop evaluation model for continuous improvement to sustain MechBuild Lab. According to an estimate by the Bureau of Labor Statistics, employment of construction managers is projected to grow by 16% between 2006 and 2016. [5] Further, graduates in construction management programs are in demand due to an aging workforce.[6,7,8] These statistics indicate that

programs in construction management are needed to grow in order to meet with industry needs. Developing the MechBuild lab that can becomes a model for other programs while continually evaluating, improving, and involving new technology is necessary.

The evaluation model would be based on the Circle of Knowledge Production and Improvement of Practice model from the Rand Corporation as a model as outlined in Figure 1. The research aspects developed from the development of the lab would be disseminated to faculty in other construction management programs. Opportunities for research on mechanical systems would also evolve that would create new interest in this area. Industry collaborations would also expand as pure research data are produced and published.

Some of the concepts that are not covered in the lab include the utilization of new energy-efficiency technology in mechanical systems assists in lessoning emissions into the environment. According to the U.S. Green Building Council (USGBC) research, in the United States alone, buildings account for:

- 70% of electricity consumption,
- 39% of energy use,
- 39% of all carbon dioxide (CO2) emissions,
- 40% of raw materials use,
- 30% of waste output (136 million tons annually), and
- 12% of potable water consumption.[9]

Waterless urinal, high efficiency furnaces, higher Seasonal Energy Efficiency Ratio (SEER) ratings on air conditioners, and grey water systems are just a few topics which need to be added to a mechanical systems lab. These are examples of new enhancements involved in the mechanical systems of buildings that assist in creating less impact on the environment.

The MechBuild lab would provide more opportunities of industry interactions and student learning. Currently, piping materials such as copper, Polyvinyl chloride (PVC), Cast Iron, and Steel are used in the lab. One class meeting is dedicated to understanding the ways in which the materials are connected by showing soldered joints for copper, glued joints for PVC, and threaded joints for Steel. The next step for this lab would be to integrate new and green technology into the course. One such product approved by the U.S. and Canadian green building council is Victaulic grooved piping systems. Victaulic Company was established in 1925 in New York.[10] It is the leader in grooved piping systems; it is to grooved piping systems what Kleenex is to facial tissue. Many people in the industry refer to grooved fittings as Vic fittings, but other manufactures do exist.

The higher-level concepts of the materials apply to management related decisions that will be required of the students when in industry. For example, by utilizing Victaulic systems contractors can: Improve jobsite safety: Reduce the risk of injuries and associated direct and indirect costs: Improve their safety record; Reduce material handling; Reduce construction man-hours; Shorten construction schedules; and Reduce total installed costs .

Other aspects of the Victaulic fittings that provide new information is the sustainability of the

products in that they are produced from all recycled materials. They have been proven to also provide flexible systems that sustain massive seismic activity. This type of new materials is a great example of what should be included in MechBuild lab to assist students in building their base knowledge.

Conclusions

The intellectual merit of the MechBuild lab is a critical part of students' learning related to the design, construction and inspection of a building. Providing the newest technology in exercises that involve real world, hands-on components will assist the student in understanding mechanical concepts. This department is has one of the few specializations in mechanical construction in accredited programs in the United States. The faculty member coordinating the mechanical courses has a PhD in education and over ten years experience in mechanical construction. Integrating the new technology and sustainable products into the MechBuild lab would create an original model for teaching and learning mechanical systems. Current support from the industry includes donation of materials, guest speakers, and national recognition from Mechanical Contractors` Association of America (MCAA).

Utilization of the MechBuild lab will not only be a requirement for the construction management students, but will also provide exercises for a service course in the xxx department required for students in interior design and computer graphics. Each summer this College and the University campus have hundreds of K-12 visitors for summer camps including 4-H, girl scouts, and other diversity initiative events. This lab will assist these students in understanding construction and mechanical systems through visualization and hands-on exercises. The MechBuild lab will serve as a model for other construction management programs across the country. Research projects are possible in the areas of faculty expertise, industry collaboration, student learning, lab development, and effectiveness of teaching techniques. Products discovered through the development of the MechBuild lab will be disseminated through an existing community of industry and faculty.

Phase I of the MechBuild lab will provide a final product of lab exercises related to mechanical systems. The exercises will be based upon an assessment of student learning, outcomes, and comprehension. This lab will be a model for other institutions to assist in teaching this critical component of a building. Future development in this area would be to add online mini commercials to assist the students in self-paced mastery learning. Further collaborations with K-12 and industry would also be beneficial to development.

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