



An Innovative Partnering Approach: Industry Led Construction Labs

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Abstract

The University of Oklahoma Construction Science (CNS) program was challenged with implementing a hands-on materials and methods lab to support related coursework. With the help of the Board of Visitors (BOV) and industry partners, the division created the Construction Fundamentals Lab. The industry partners constructed a facility to conduct the labs and provided trade instructors to teach the hands-on skills. The course objective was for student work crews to construct a mockup of a typical exterior wall section on a formed reinforced concrete foundation. Each stage of the wall section construction was taught by a trade professional from that particular trade and most materials were donated by suppliers.

The authors offer this replicable model for reinforcing the concepts of material and methods, construction tolerances, code and specification compliance, quality management, and safety concerns as the basis for other engineering and construction programs to explore in the development of similar lab experiences. As part of this paper the authors share their observations related to the initial course offering. The authors feel that many learning objectives can be met by the inclusion of preconstruction and post-construction activities with the physical construction of the simple wall. Partnering with industry benefits the program by providing facilities, materials, and instruction which in turn benefits industry by providing a path for university involvement in teaching future employees.

Introduction

After gathering feedback from current students, alumni, and industry partners, the Construction Science (CNS) program was challenged to implement a practical materials and methods lab to strengthen students' understanding of construction processes and the sequencing of construction tasks. The CNS Program educates students to become construction managers. However, previous studies have shown that hands-on experiences allow students to learn through discovery (Davis & Cline, 2009) and that the learning environment with visual and tactile teaching tools leads to greater understanding on the part of the students (Nirmalakhandan *et al.*, 2007). In response to this identified need the division developed and implemented a 2 credit hour hands-on lab in the Spring semester. The objectives of this course were to 1) create a practical hands-on lab experience that was replicable and 2) to integrate the lab with required materials and methods and construction documents courses. Specific development objectives included reinforcing basic materials and methods concepts and offering a first-hand opportunity to experience the physical properties of basic building materials and products and use them to assemble a wall mock-up in a student work crew setting. Along with developing a replicable experience and integrating the lab series with other CNS courses, another primary objective was to partner with industry and use their resources for instruction and as lab sponsors. At the beginning of each lab session, a local tradesperson demonstrated the work to be done. For example, during the foundation lab, a

representative from a local ready mixed concrete supplier discussed ordering and placing concrete. This class delivery approach enlisted the help of representatives of many local subcontractors, creating new industry partnerships and exposed students to specialty contracting jobs in the construction industry.

Integrating this class between the existing materials and methods class and construction documents class resulted in nine lab sessions dedicated to actual construction processes and seven lab sessions dedicated to the development of shop drawings to supplement the hands-on construction labs. For the labs, each 3 or 4 student work crew built an exterior wall mockup on an independent formed and poured concrete foundation. Once this work was complete, two parallel wall sections constructed by adjacent student work crews were connected by joists to create an interior space. HVAC (heating, ventilating, and air conditioning) ductwork was installed on each side of the space and a suspended acoustical ceiling system was installed by the two adjoining student work crews. Respective HVAC and electrical trim materials were then installed in the ceiling and on the walls. When the mockup was complete it was inspected by a third party and evaluated and documented for the final time by the student work crew who then demolished the mockups and stored the salvaged materials to be used for future labs.

Each student work crew was required to complete four tasks for each lab. The four tasks included 1) submission of a preconstruction submittal prepared in one of the labs associated with the Construction Documents class, 2) preparation of a tool box safety talk, 3) construction of the wall mock up, and 4) submission of a final work report including photos of the installations, a workmanship and tolerance assessment and documentation of challenges encountered during the actual construction process.

Partnering with industry benefits the program by providing facilities, material, and instruction which in turn benefits industry by providing a path for university involvement to better prepare future employees. The authors offer this replicable model for reinforcing the concepts of material and methods tolerances, code and specification compliance, quality management, and safety concerns as the basis for other engineering and construction programs to explore development of similar lab experiences.

The Field Lab Series

Table 1 shows the schedule for a typical lab meeting. Student work crews were assigned by the instructor prior to the Lab 1 Submittal preparation. The first offering of the class had nine student work crews of three or four members each.

Table 1
A typical lab period schedule

12:30pm-1:30pm	Introductions, Instructions, Craft Discussion and Demonstration and Q/A
1:30pm-1:45pm	Student led Safety/Tool Box Talk
1:45pm-2:00pm	Equipment and Material Procurement and Preparation
2:00pm-4:15pm	Place the work
4:15pm-4:30pm	Roll-up, Clean-up and Sign-out

For the purpose of this discussion work processes included in the instructions for *Lab 1: Place Concrete Slab Section* and *Lab 4: Install Metal Stud Wall and Exterior Sheathing* are included below as examples.

The work for *Lab 1: Place Concrete Slab Section* included the following processes:

- Layout the 22"x96" slab/foundation form - location centered both directions within the work area delineated by previously established control lines; orient the interior of the wall to the interior of a designated parallel wall in an adjoining work area;
- Place polyethylene membrane beneath the form to protect the sub-surface.
- Build a 22" wide x 5½" deep x 8' long wood form (on the polyethylene) including a block-out for a 5½" x 1½" brick ledge.
- Brace the form and verify all corners are level - both directions.
- Place rebar in the form.
- Layout and place 2 - 27" long, 2" diameter PVC pipes for water closet and sink drain rough-ins.
- Perform a concrete slump test.
- Place the concrete in the form.
- Trowel finish the surface until adequately set up.
- Document work for the Lab 1 Work Report.
- Rollup and cleanup the tools and work area and return tools to storage.

For Lab 2, a fifteen-block exterior CMU wall was built using normal weight and lightweight blocks. Vertical and horizontal reinforcing, vertical cell and bond beam grouting, brick ties and waterproofing were other components of this lab. For Lab 3 a thirty-brick running bond veneer was laid in front of the CMU block wall.

The work for *Lab 4: Install Metal Stud Wall and Exterior Sheathing* included the following processes:

- Layout/pop a line locating the wall on the slab parallel to the companion wall; assess the layout and permanently layout the wall using a chalk box.
- Install the bottom track using a powder actuated gun.
- Install 6" light gauge metal studs and top track as required to create an 8' long wall.
- Install 3-12' heavy gauge studs 48" on center as joists connecting the two companion walls.
- Plumb and temporarily brace the wall section using a bottom track to top track secured at an approximate 30° to 40° angle from vertical.
- Using screws, install the 4'x8'x 5/8" exterior sheathing sheets on the exterior side of the wall assembly and tape the joint.
- Rollup and cleanup the tools and cleanup the work area and return tools to storage.

During Lab 5, student work crews worked on the inside of the wall to install the plumbing top-out and the vent stack for the wall mounted water closet and sink. When this was complete, 4'

Danback flexible wood blocking was installed per the fixture specifications. Per the electrical code a ceiling mounted light fixture was wired in the ceiling and the light switch and a duplex receptacle were roughed in the wall using metal clad cable. In Lab 6, paper-faced and unfaced batt-insulation and drywall were installed. Drywall joints were taped and all screw heads were bedded. Per a shop drawing issued by the mechanical company sponsoring Lab 7, an HVAC duct assembly was installed above the ceiling. For Lab 8, the last construction lab, student work crews installed the suspended acoustical ceiling system. The light fixture and HVAC diffusers were mounted in the ceiling grid and connected to the switch and duct assembly. During the Lab 9 meeting the mockups were reviewed for quality and conformance. Also in Lab 9 the mockups were demolished, specific materials salvaged and stored and the site cleaned. Figure 1 is the graphic used to show students the lab components.

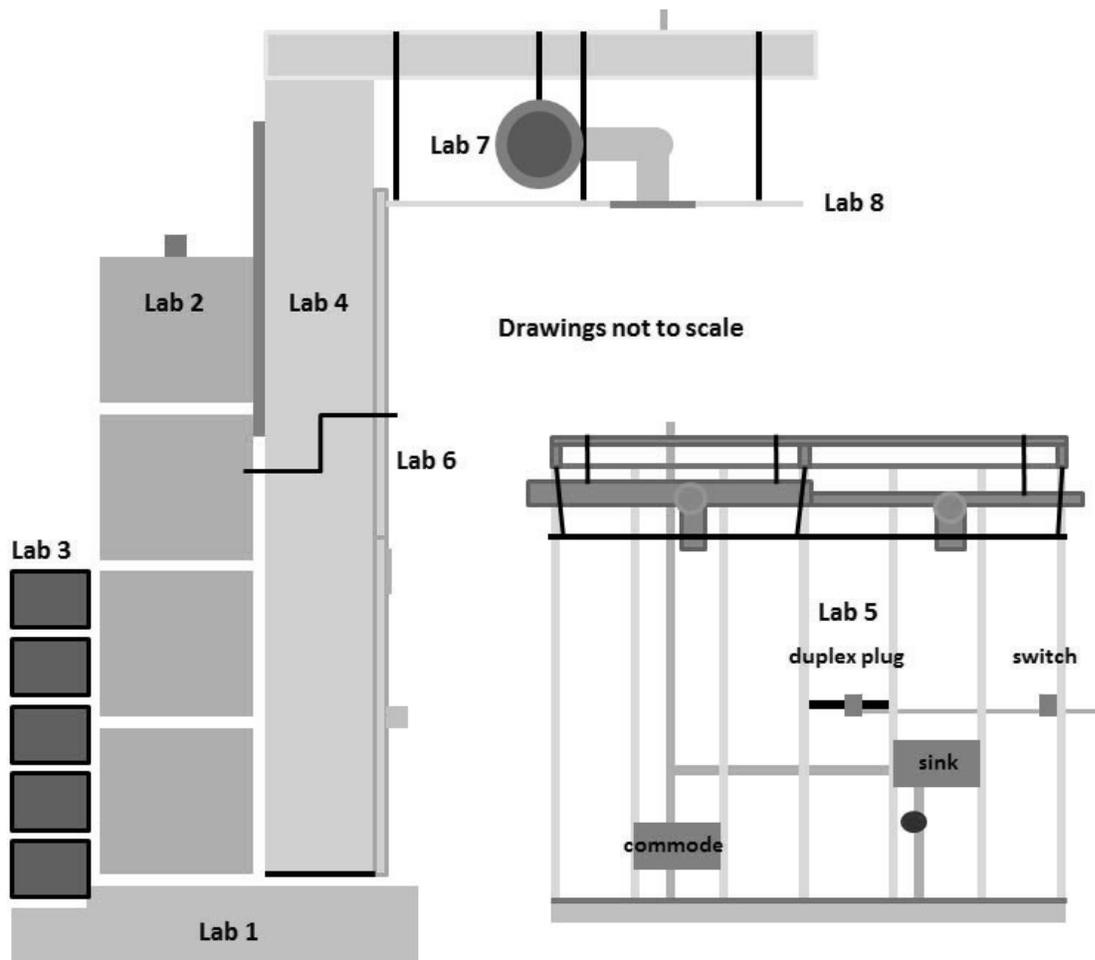


Figure 1: Graphic showing the Construction Fundamentals Lab series. Left is a section view and right is the front view.

Learning Mechanisms Incorporated into Each Lab

Each construction lab incorporated three primary learning mechanisms: the submittal process, the wall mock-up process and the use of skilled trade industry instructors. The requested submittals required planning and defining the work in a classroom environment and then

students measured and documented their performance based on actual field evaluation of the installation. The design and use of the mockup provided multiple opportunities for student centered learning. The mockup was designed to resemble a defined interior space with identifiable work components that could be understood, installed and visually assessed by typical construction students. The integration of the third learning mechanism perhaps yielded the most benefit and value to the overall experience. The unique partnership with industry provided benefits at all levels including students, CNS faculty, industry instructors and their companies. The following discussion defines these mechanisms and highlights the perceived benefits. The authors believe that the combination of these three learning mechanisms provided the basis for a unique replicable team based learning experience that strengthens the construction curriculum and one that can be replicated by other construction programs seeking to add practical hands-on labs to their curricula.

The Submittal Process

Submittals are an essential part of the design and construction process and consist of shop drawings, product data, and samples (O'Leary, 2003). For the purposes of this lab, shop drawings and product data were the most applicable aspect of the submittals. As defined by the AIA, shop drawings include "diagrams, schedules and other data specially prepared for the Work by the Contractor or Subcontractor ... to illustrate some portion of the work" (AIA, 2007, 15). These are typically drawings of items fabricated for a specific project. Product data information is generally viewed as information on a product or piece of equipment that may not be designed for any specific facility and includes "performance charts, instructions, brochures, [and] diagrams..." (AIA, 2007, 15). For each Construction Fundamentals Lab, a pre-construction submittal was required prior to each installation including data on the materials, products and processes used during the lab. Documentation was collected, assembled and submitted to the instructor at the end of the in-class session. The pre-construction submittals were returned to the student work crews with corrections prior to performing the work. Specific submittal requirements were based on the work to be performed and what was requested by the PM. The basic parts of each pre-con submittal included the following requirements.

1. Digitally sketch and label a plan, section and/or detail view of the work to be installed based on submittal requirements.
2. Collect and document material/product/equipment specifications, applicable code standards, acceptable installation tolerances, MSD Sheets and other information based on submittal requirements.
3. Prepare a safety plan identifying perceived risks associated with the work.

The following is the text from the request for submittal for Lab 4: Install Metal Stud Wall and Exterior Sheathing.

"Prepare dimensioned and labeled work sketches (also show exterior sheathing and wood fixture backing for an American Standard wall-mounted AFWall FloWise water closet and a Kohler Brenham™ wall-mount lavatory with single-hole faucet drilling, less soap dispenser hole-K-1997-1); list the difference in gauge of a heavy gauge stud and a non-load bearing stud; section/location in

building specs addressing wall backing/blocking; list the sheathing screw pattern; wall bottom track, wall stud and above the ceiling horizontal frame member placement level and plumb tolerances; a safety plan addressing perceived risks (confined area, sharp metal edges, working on a ladder, using a screw gun) and remedies and emergency information, including contacts.”

Resources (such as plumbing, electrical and building codes) are available online or in the College library and are accessible to the student work crews during the class meeting. The submittals required the use of a digital drawing package to prepare sketches, simple exploration of building codes and manufacturers’ and vendors’ specifications and group work planning and communication including safety considerations.

The Lab 4 safety plan required the following planning:

- Assign a responsible person for administering the safety plan – primarily to make sure all workers wear safety protection and someone is always monitoring the work and work area during the installation process.
- A plan to control movement thru work areas – identify a responsible person(s) to coordinate foot traffic and communicate with the student work crew and others in the area.
- Routing of cords run on the floor across work areas.
- Safe procedures for moving and erecting 9' metal studs in a confined space.
- Safe procedures for installing overhead work from a ladder.
- Prepare and present a related Tool Box Safety Talk to the class prior to the start of the related field work if requested

After the work was completed, student work crews submitted a Work Report to the instructor. The following items were typically included in each Work Report.

- Crew member names.
- Equipment and tools used.
- Materials used, including quantities.
- A work breakdown or list of sequential steps necessary to complete the work, including a brief description about each step/activity and approximately how much time was spent on each.
- Work related management, coordination and installation issues experienced.
- Assessment of placed work quality based on tolerances included in the pre-con submittal.
- Include images to support actual field measurements of the work in place and recorded assessment.

The Wall Mockup Process

The wall mockup was designed to promote student centered learning. The work for each lab required initial planning utilizing student work crew/team interaction and task management. As demonstrated in the examples included in the Field Lab section of the paper, each installation had a defined start and finish for the work establishing the scope required for planning and

execution. The work components and materials were identifiable and understandable by the student work crews. The sequence of the wall construction required student work crews to work together for most of the installations. After the walls were connected to make an interior space, greater planning, communication and work coordination effort was required as two student work crews joined their mock-up walls. Figure 2 shows three pairs of completed joined mockups.

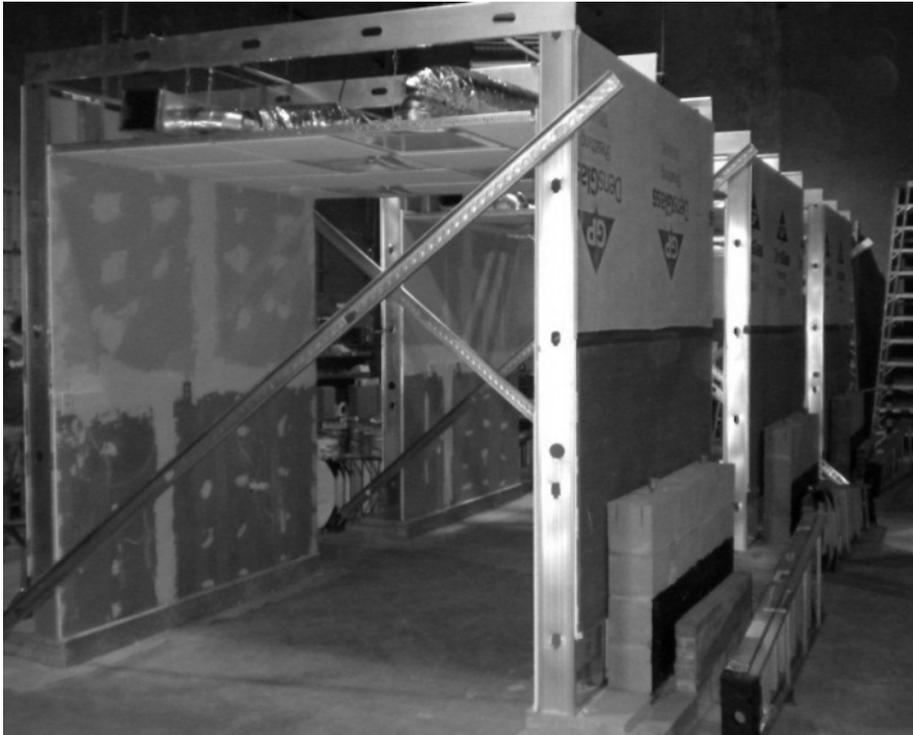


Figure 2: Three completed interior space mockups including dropped ceiling.

To provide a realistic plumbing installation scenario, the opposing walls of each student work crew's mock-up were treated as two bathroom walls. Plumbing rough-in was installed for wall mounted water efficient dual flush water closets and wall mounted water efficient sinks. The walls have light switches and duplex receptacles to service the lavatory areas. This work requires product specifications to determine installation locations, MEP code verification, work sketching and planning, and using special tools and work expertise for the installation. Preparing for water efficient fixtures resulted in a better understanding of the sustainable features of the requested products

Pre-construction submittal requests given to student work crews listed materials, tools and equipment included in each work installation, but the student work crews had to plan the use and the physical expertise required for the actual installation of the materials. The wall component materials were chosen to reflect typical products and installation procedures, tools and equipment used in the industry today. Each installation was visually inspected and assessed by the work student work crews based on the understanding gained from lectures and collection of the required submittal information.

The 9' tall wall was designed for installation using an 8' step-ladder. This was the safest solution to brace the walls and provide a 1' ceiling cavity with the suspended acoustical ceiling installed at 8'. The requirement to join the two walls together using three heavy gauge studs as joists offered several benefits. The walls had to be laid out parallel at the beginning of the work placement (Lab 1) requiring the student work crews to plan their layout and to interact with the associated student work crew while using control lines and baseline offset dimensioning. Using the studs provides a simple economical structural solution for bracing the two walls and providing structure to suspend HVAC ductwork, diffusers, light fixtures and the suspended ceiling that was safe to install from the ladders.

Use of Skilled Trade Instructors

Based on the authors' perspectives, the partnership developed with the local industry to teach the labs was the most beneficial part of the lab development and administration. The use of skilled trade instructors to help lead the labs provided numerous benefits. The skilled trade instructors provided current field based expertise that the academic instructor could not provide. The trade instructors provided valuable insight into the content of each lab and suggested improvements related to the materials, work process, tools, equipment, and shop drawings for each specific lab. Additionally, they represented specialty trades that typically students have less exposure to during course activities, career fairs or program events.

The labs offered formal and informal opportunities for the skilled trade instructors to discuss their background, their company, relevant products, material or tool information and offer suggestions about the work installation to students. Skilled trade instructors provided students the opportunity to learn directly from personnel involved on a day-to-day basis with the work. They provided valuable insight to students about how to start the work and techniques for installing different types of materials and products. The instructors also provided field safety considerations and experience into pre-task planning. Skilled trade instructors circulated through each student work crew's worksite and inspected the work during the installations. The skilled trade instructors' participation and inspection heightened student work crew performance accountability and offered a resource to answer questions and review the work as it was installed. The skilled trade instructor was also a trained observer to help the academic instructor minimize safety issues and tool/equipment misuse. For most labs, the companies represented by the skilled trade instructors supplied the materials or purchased the materials for reimbursement using their discounted pricing. Their participation is replicable and can be crafted to meet the specific craft and installation to be performed.

Outcomes

Based on feedback from all participants in the Construction Fundamentals Lab, the authors believe that the course met the development objectives. The financial benefits from the industry partnering model have been calculated and are positive, but the strengthening of the curriculum and local industry relationships is harder to measure.

Student evaluations for this course were higher than other courses in the department. Several comments from taken from student evaluations are:

“Excellent class, very useful information, loved it.”

“This lab was a great learning experience, it helped me to actually learn what we have been talking about in class, the concepts were taught in the materials class the semester before...”

“Overall this was a great class, and I had a lot of fun and an amazing learning experience.”

Conclusions

The submittal process is an effective way to guide student learning that highlights the need for planning, communication, management and documentation and also reinforces basic written communication and documentation skills. The level of detail and concept complexity can easily be adjusted to the level of student knowledge. Also the required planning, installation and assessment activities for each lab reinforce materials and methods concepts. The information research required to complete the submittals helped prepare the students for typical entry level positions in the industry that requires researching building standards, codes, products, and installations. The submittal assignments can be replicated by future Construction Fundamentals Lab instructors or instructors from any other program desiring to incorporate hands-on labs into their curricula. In addition, the submittal process can be easily customized based on the work materials and methods.

Students offered very positive feedback about the mockup construction. For many it was their first time to use the tools and install the various types of materials. For some it was the first time they had ever worked in a construction crew setting requiring teamwork to move, hold, erect, or secure a building component. The need for teamwork was reinforced in every lab as part of the submittal or installation processes. As the actual work was performed, the importance and use of the pre-construction and final report submittals for planning, installation guidance, and as-built assessment became more apparent to the student work crews. Though the work scopes for each lab are limited, performing the work created greater empathy for the conditions and quality required of the different specialty contractors.

For the work selected for the construction lab series, tools and materials were all readily available. Installing different types of the same materials offered a hands-on opportunity to see and feel the differences in the products and the installation. Connecting two wall mockups to create an interior space proved a manageable, realistic, and efficient solution for several issues. One of the issues was the creation of a more complex work environment that required greater communication and coordination of student work crews. The increased communication and coordination challenged students to better plan and often leaders emerged based on motivation, competence or interest.

Based on the authors’ observations, the contribution of the craft instructors was perhaps the greatest influence on the lab success. Their contributions came from the many years of experience working with the materials and most contributions occurred naturally as they worked

with the students. The willingness of industry to help educate construction students should not be underestimated. For the most part, a simple phone call was all that was required to get skilled trade instructors to eagerly participate. The authors believe that the willingness exhibited by this local construction community exists in most areas where engineering and construction programs reside.

The lab series installations and learning mechanisms discussed in this article are defined, replicable and obtainable. The authors feel that the mutual benefit to academia and industry should be a strong motivator for other construction programs to consider this approach. At the time of printing, this lab has been offered for 3 consecutive years and industry involvement is still strong,

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