

Construction Safety Laboratory

Sathy Rajendran Ph.D., CSP, LEED AP, P. Warren Plugge, Ph.D. and William Bender, PE, Ph.D., LEED AP
Central Washington University
Ellensburg, WA

Since 1975, graduates of the Central Washington University (CWU) Construction Management (CMGT) and Safety and Health Management (SHM) Program have obtained knowledge and skills that help to maintain a safe and healthy workplace across the country. However, one of the major challenges for the SHM program has been the absence of a SHM laboratory that enhances their skill set with activity-based education. A new technology facility was opened in 2012 which includes a new SHM classroom and laboratory space. The major objective of this paper is to recommend necessary components for a state of the art activity-based learning for the construction component of the SHM lab. Recommendations include a list of equipment topics that meet current industry needs that will be used in activity-based learning laboratories. To achieve this objective, a survey of safety and construction professionals was conducted to help establish what types of activity-based learning most benefits entry level safety professionals. The major outcome of the survey was a list of perceived safety equipment important by industry professionals. Construction and safety programs across the country may use this list as guidance when setting up a construction safety lab. It was found that the most important safety equipment construction and safety graduates should be trained on include fall protection, different types of personal protective equipment (PPE), and excavation simulators.

Key Words: Safety, Health, Laboratory Planning, Construction Safety, Activity-Based learning

Introduction

Construction safety is important to construction contractors all across the country. The Occupational Safety and Health Administration (OSHA) Training Institute focuses on four main areas of construction safety. These four focus areas are fall, caught-in or between, struck-by and electrocution (OSHA, 2011). Construction is among the most dangerous industries in the country and construction inspections comprise 60% of OSHA's total inspections (OSHA, 2011). Due to its relatively high incidence rate and the volume of construction performed, construction safety is one of the main areas of focus with regards to occupational safety and health. The Bureau of Labor Statistics (BLS) report shows a slight decline in the incidence rate for the construction industry. However, the recordable injury rates are still amounting to four injury cases per 100 full-time workers. The Census of Fatal Occupational Injuries Summary from 2011 also state that "despite the lower fatal injury total, construction accounted for the second most fatal work injuries of any industry sector in 2011 with transportation and warehousing accounting for the most fatal work injuries" (BLS 2012).

Armed with these statistics, Banik (2005) asserts there is a need for construction safety education due to the fact that construction education contributes to the reduction of the number and costs of accidents. More importantly, Tepper (1994) also contends, "increased construction safety education is the key to overcoming a casual attitude toward conformance with OSHA Regulations that result in construction operations being conducted unsafely and without regard to injury or death to workers."

It is also important to understand how content within the classroom is delivered to students. For some students a standard lecture with the instructor in front of the classroom suffices as a way learning the content. Kennedy (2010) provides an argument for activity-based learning by stating:

> Having a teacher stand at the front of a classroom and transmit information to students may be an effective way for some students to absorb knowledge, but educators have realized that other students respond better to different approaches. Some respond better to hands-on experiences, or

> more relaxed, informal settings, or small-group interactions with their fellow students; some learn more effectively on their own curled up on a pillow reading, or tapping away at a computer keyboard.

In order to teach construction safety there are necessary components that are needed for a safety management course to be effective. Egger and Varzavand (1989) recommended content that should be addressed in a safety management course. They suggest this content should include such items as historical analysis of current practices and standards, regulations, identification of organizational responsibilities and duties pertaining to safety and health in construction, employee responsibilities, record keeping, insurance costs, cost savings, OSHA enforcement, OSHA consultation, professional associations, safety training and certification of staff, and local and state safety information. Research from industry professionals also show the necessary content to be incorporated into a construction safety course should include fall protection, trench and excavation safety, recognition of hazards, electrical safety, and safety planning (Banik, 2005). To engage students in the content of the class, Banik's (2005) research also suggests that site visits at actual construction sites, demonstration of safety tools in class and guest speakers are essential in the content and pedagogy of teaching safety in construction.

Construction Safety at CWU

The Hogue Technology Building at CWU hosts all of the engineering technology and related programs on campus. This includes Safety and Health Management (SHM), Construction Management (CMGT), Industrial Technology (IT), Mechanical Engineering Technology (MET), Technology Education (TE), Electronic Engineering Technology (EET) and Masters of Science in Engineering Technology (MSET). Construction of a new addition and renovation of the existing Hogue Technology Building was completed in the spring of 2012 which was needed for expanding program sizes and outdated facilities. With the new addition and renovation it allowed the department to add new learning spaces for a designated SHM classroom and laboratory.

The addition of the SHM lab provides the program a unique environment to educate students on the concepts of Safety and Health Management. This lab is critical to the SHM program to provide the best educational experience for students majoring in SHM. The SHM program prepares students for entry-level positions in the construction, agricultural, manufacturing, government and related industries. The graduates become safety professionals charged with protecting human life and personal property. The curriculum focuses on course work based around a core of safety system classes and allows students to focus on areas of construction, industrial hygiene and environmental and safety management. In addition to the SHM major, the SHM program offers a minor in Construction Safety. The construction safety course, SHM 323, is a mandatory class for all students majoring in construction management. SHM 323 is offered three times a year with approximately 30 students in each section. Both the SHM and CMGT Industry Advisory Councils (IAC) value a strong construction safety program.

In 2012, the existing building was renovated to include new SHM class and lab space. Some of the characteristics of the class and lab are:

- Floor space of 2,000 SF
- Storage room with industrial racks
- Book and equipment shelves
- Lab tables
- Adjacent 32 seat safety classroom
- Tables and chairs w/ seating for 32 students with teaching station equipped with state of art AV equipment

As recommended by Kennedy (2010), technical and applied programs at CWU focus on activity-based learning. CWU's safety program has modeled components of their program after OSHA's activity-based construction outreach training program which uses activity-based model to train participants in fall hazards, caught in or between hazards, struck by hazards, and electrocution hazards. Activity-based learning developed by OSHA involves the participants in the learning process. OSHA (2011) suggests through their outreach training, that the best training programs take advantage of several characteristics of adult learners which include:

- Adults learn by doing and are self-motivated.
- Adults expect to gain information that has immediate application to their lives.
- Adults learn best when they are actively engaged.
- Adult learning activities are most effective when they are designed to allow them to develop both technical knowledge and general skills.
- Adults learn best when they have time to interact, not only with the instructor but also with each other and when asked to share each other's personal experiences from work and elsewhere.

Objective and Method

A survey was created to identify a list of lab equipment to be part of the SHM's construction safety laboratory. Using a survey questionnaire, a quantitative research approach was adopted to obtain data for the study. The survey instrument was distributed to industry professionals in construction and safety consisted of two sections. The first section solicited demographic information about the participant's title and construction experience. Additional demographic information was obtained to identify the participant's company type (e.g. – owner, contractor) and the types of projects the company performs.

The second section requested information about the safety equipment that should be part of the construction safety lab. The list included safety equipment, based on the author's experience and lab equipment lists referenced from two Accreditation Board for Engineering and Technology (ABET) accredited safety programs. In order to prioritize the equipment, respondents were asked to rate each equipment topic based on "degree of importance." A Likert scale of 1 to 5 for each type of equipment was provided: "1" being least important to be included in the lab and "5" being most important to be included in the lab for each type of equipment. Likert scales are common ratings format for surveys. Respondents were also given an opportunity to list other equipment outside this list that they thought should be included in the lab based on their experiences.

The survey instrument was administered through the Qualtrics online survey website (Qualtrics, 2012). A link to the survey was sent to the respondents via electronic mail. Respondents were informed that the objective of the survey was to determine types of hands on safety training equipment to be part of the SHM construction safety lab. They were asked to respond to the questions based on their experience with safety equipment. Qualitative and quantitative methods were used to analyze the data and establish the types and priorities of equipment to be incorporated in hands on activity-based safety laboratory.

Limitations

Survey instruments were sent to both SHM and CMGT Industry Advisory Council (IAC) members and various safety and construction professionals working in the northwest United States that hire CWU's graduates. A total of 60 safety and construction professionals received this survey. There was a purposeful selection process based on the participant's willingness to participate in the research. Although this method of sampling may be the least precise method of sampling, the authors chose this method to gain knowledge from industry professionals most intimately involved with safety and knowledge of the SHM and CMGT programs. Although 46 responses to the survey were received resulting in a response rate of 77%, there was a major sampling bias by limiting the participants to safety and construction professionals working in the construction industry familiar with our programs.

Results and Discussion

The results of the survey were collected using the Qualtrics database, the same medium through which the surveys were distributed. The majority of the survey respondents represented general contractors (74%, N = 34). Table 1 shows the percentage breakdown of the 46 survey respondents by their role in the construction industry. The respondent group consisted of an equal number of safety professionals (48%, N=22) and construction professionals (48%, N=22) Four percent (N=2) respondents selected others but did not report their designation. The participant's construction experience ranged from two to 42 years and a mean of 19.2 years of experience (M = 19.2 years). Except for six participants, all others had more than 10 years of experience in the construction industry. Together the survey respondents had a combined 826 years of experience in the construction industry. With a mean of 19.2 years of experience and a combined 826 years of experience it helps validate the data used in the study. It was found that the majority of the study participants were associated with commercial construction. Table 1 identifies the market sector in which the respondents operate.

Table 1

Categorization of respondents based on organization

Respondent Organization Type	Response (N)	Percent (%)
Owner	3	7
General Contractor	34	74
Subcontractor	3	7
Supplier	1	2
Others	5	10
Total	**46**	**100**

Table 2 shows the different market sectors the participants have experience in related to safety. In the survey, participants were able to select more than one sector category. The majority of the participants were affiliated with the commercial sector of the industry (59%, N = 27), followed by government (57%, N = 26), industrial (46%, N = 21), and civil (46%, N = 21).

Table 2

Market sectors of survey participants

Sector	Response (N)	Percent (%)
Education	23	50%
Healthcare	20	43%
Residential	10	22%
Commercial	27	59%
Government	26	57%
Industrial	22	48%
Civil	21	46%
Other(s)	9	20%

Note: N = 46

The survey requested the participants to rate 21 safety equipment topics on a scale of 1 to 5, with 1 being "unimportant" and 5 being "very important." The respondents rated these equipment topics based on their experience with recent college graduates. It was critical to obtain industry perceptions on the types of safety equipment a construction professional should have knowledge of upon graduating from an accredited construction or safety program. Information obtained through this survey will helps to inform the construction and safety professors on types of safety equipment that should be incorporated in a construction safety laboratory.

Participants responding to this portion of the survey provided a range of results. The range of responses for the ranking of safety equipment by their importance from the industry professionals provided the most important safety equipment to be fall protection (M = 4.74) to the lowest item of importance to be fire sprinkler heads and suppression equipment. The authors also found that eight safety equipment topics received a rating of 4.0 or higher and 19 with a rating of 3.0 or higher. What these ratings suggest is that these topics should be developed further to provide trainers in the safety laboratory. The ratings provide the authors a categorical order of importance based on the means in which to procure the equipment. Of the 21 equipment topics, none received a mean rating less than 2.0, which indicates that, according to the participants, all of the equipment has at least some level of importance and should be further developed in the safety curriculum. Table 3 presents the mean rating received by every safety equipment topic included in the survey.

Table 3

List of safety equipment ranked by importance

Equipment Name	Responses (N)	Mean
Fall Protection Equipment (e.g. harness, lanyards, retractable, etc.)	46	4.74
PPE: All types of PPE	45	4.64
Excavation Training Simulator	44	4.41
Ladder Types and Training	46	4.24
Lock Out/Tag Out Simulator	46	4.24
Confined Space Simulator	46	4.22
Electrical Safety Simulator	46	4.22
Crane Safety Training (using real cranes and simulators)	46	4.02
Rigging Apparatuses	46	3.98
Accident Investigation Kit	46	3.91
Scaffolding Setup	46	3.85
Air monitors (e.g. multi-gas meters, single-gas meters, etc.)	46	3.85
Emergency Response Simulators (e.g. radio equipment, etc.)	45	3.78
Environmental Safety (e.g. spill kit)	46	3.72
Respirator Test Kit	46	3.61
Fire Extinguisher Trainer	46	3.50
Noise Measurement Instruments	46	3.46
Flammable Storage Container	46	3.24
Heat Stress Monitors	45	3.24
Fire Alarms	45	3.07
Light Meter	46	3.02
Moisture Meter (e.g. used for mold related measurements)	44	2.93
Types of Fire Sprinkler Heads and Suppression Equipment	45	2.84

Results were reviewed further to identify trends in the participant rating. Even though the “accident investigation kit” received a mean rating of less than 4.0, seventeen participants felt it was “very important” to be included in the lab. Appendix A shows the distribution of the participant rating for each piece of equipment.

The final question of the survey was an open-ended question which gave participants an opportunity to identify and elaborate on the safety equipment topics they see as important to be included in the safety laboratory. Only seven participants responded to this question. The responses included:

- Load cell to demonstrate the effects of falls when wearing a harness with shock absorbing lanyard vs. non shocking absorbing lanyards; Manfully Elevated Work Platforms (MEWP); Hand tool usage; Tool lanyard use (falling objects are still a high exposure), and CPR/First Aid/AED/Training.
- Air monitors for airborne contaminants i.e. Hexavalent chrome, dust, inorganic arsenic, lead, mercury, solvents.
- Traffic Control Design and Set up
- Heavy Equipment a short class or a field trip and powered industrial trucks, MEWP.
- Safety nets understanding, confined space extraction materials, Self-Contained Breathing Apparatus (SCBA) use and understanding, and various respiratory devices.
- Lift Training i.e. Man Lift, Scissor Lift, Fork Lift, etc.

Safety Training Activity-Based Learning

Below is an example of one of the simulators created as a result of this study: Lock out/ Tag out (LOTO) Simulator**.** Because failure to control hazardous energy is one of the major causes of serious accidents in the construction industry, proper LOTO practices and procedures safeguard workers from the release of hazardous energy. As future construction/safety professionals, the students should have a hands-on training on LOTO practices. Hence, the LOTO simulator shown in Figure 1 was developed with assistance from a local mechanical contractor. The simulator includes components such as a butterfly valve, true union PVC ball valve, gate valve, check valve, variety of ball valves, pump trap, tank, and a pump connected to an electrical disconnect, capturing a real-world scenario typically encountered in the industry.

Figure 1: Lock Out/Tag Out (LOTO) Simulator

The LOTO simulator is an example of one activity-based model in the safety lab that exposes students to the importance of the LOTO process using a visual model. Students are given a hypothetical LOTO scenario to demonstrate their ability to control hazardous energy types and sources. Student outcomes and assessment strategies used for this activity-based learning exercise are shown in Table 4.

Recommendations

Based on the participant ratings, the authors recommend all the equipment topics with a mean rating of 3.0 or above, to be included in a construction safety lab. Additionally, since MEWP was mentioned twice by the respondents and it is a subset of fall protection/scaffold system this topic should also be part of the lab. The purchase of the list of equipment was prioritized based on the "rank" listed in Table 4. Some of the equipment can be purchased "off the shelf," for example fall protection equipment such as lanyards and beam attachment devices. Other equipment will need the further development of specific learner outcomes to define exactly what needs to be purchased.

Table 4

Student Outcomes and Assessment for LOTO Simulator

Student Outcomes	Assessment Strategy
• Students will demonstrate an understanding of the terminology associated with hazardous energy sources and the different types of energy sources.	• The student should score 80% or more on the LOTO quiz.
• Students will demonstrate the ability to select appropriate LOTO devices based on the type of valve or electrical disconnect.	• The student should successfully participate in hands-on LOTO exercise.
• Students will demonstrate an ability to de-energize mechanical valves and electrical disconnect by isolating or blocking energy sources.	• The student should successfully participate in hands-on LOTO exercise.
• Student will demonstrate the ability to write a pre-task plan for the hypothetical LOTO scenario provided to them using the simulator.	• The student should prepare and submit a pre-task plan for simulated LOTO scenario using the simulator.

Conclusion

The study provides perceptions on equipment to be included in the construction safety lab. The findings that can be drawn from the study include:

- Current literature does not provide any guidance on the list of safety equipment to be included in a construction safety lab. Since little research has been found, this research is the beginning of future studies in this area.
- The study provided a list of important safety equipment construction and safety graduates should be trained on which includes fall protection, PPE, and excavation simulators.
- Responses provided by the participants in this study identified the same “focus four” hazards targeted by OSHA as shown in Table 3.
- Although some items in the survey were ranked low such as the light meter, moisture meter and fire sprinkler types these topics could still be explored at a later time or presented in a different format outside the laboratory such as a field trip.
- This research is valuable because it provides a guide for the author’s, and other construction and safety programs when setting up a safety lab.
- The lock out/tag out simulator provided in this paper is one example of an activity-based learning tool that can be developed and used in the classroom. Researchers in this study also found it is a way to get the program’s industry partners actively involved in the program to build and provide activity-based learning simulator. Construction and safety programs across the country may use the sample LOTO simulator as guidance when developing similar activity-based learning tool.

This study provided a list of equipment that should be incorporated into a safety laboratory. Currently, equipment for the safety laboratory is being procured based on the results of this study.

Future Work

The authors want to share their instruction strategies for selected equipment topics from this survey such as: (1) fall protection equipment, (2) lock out/tag out simulator, (3) confined space simulator (4) crane safety training, and (5) MEWP. These active learning laboratories are being set up by defining learner outcomes, purchasing equipment and offering pilot sessions. Future work would include research on the learning pedagogy that takes place with each of the modules as they are presented in the classroom and laboratory, then acquiring data to identify the learning that has taken place in the two different environments.

The intention of these modules is to challenge construction and safety students to adopt safe construction practices while in the classroom or laboratory and practice them once they enter into the workforce. Additional future work will capitalize on the work of previously mentioned researchers and the findings of the presented survey. The goal of this educational work is to identify how the safety modules can reduce the number and costs of accidents, increase safety education, develop a positive philosophy towards safety and create an understanding of acceptable safety standards. Other topics of future interest are considering survey input from residential contractors, with a larger sample size, and how the university training influences worker safety over time.

References

Banik, G.C. (2005). Content and Pedagogy of Teaching Construction Safety at the Undergraduate Level.*ASC Proceedings of the 41st Annual Conference*. University of Cincinnati, Cincinnati, OH.

Bureau of Labor Statistics (2012, September 1). *Summary of Fatal Occupational Injuries 2011*.http://www.bls.gov/news.release/cfoi.nr0.htm

Kennedy, M. (2010).In Position to Learn. .*American School & University*, *82*(6), pages (20-22)

OSHA, (2011). *Construction Focus Four: Outreach Training Packet*. OSHA Directorate of Training and Education. Published by OSHA Training Institute, Arlington Heights, IL.

Qualtrics, (Oct 2012) www.qualtrics.com

Roy, K. (2010). Building Safety into Construction or Renovations. *Science Teacher*, 77 (9), pages 8-9.

Tepper, H.M. (1994). Construction Safety Education a Moral and Ethical Issue. ASC Proceedings of the 20th Annual Conference.www.ascweb.org

Appendix A

Distribution of Participant Rating of Equipment