122nd ASEE Annual Conference & Exposition
June 14 - 17, 2015
Seattle, WA
Making Value for Society
Paper ID #11104

Design and Implementation of an Experiential Learning Exercise for a Mechanical Piping Systems to Enhance Construction Engineering and Management Education

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Abstract

Over the past several years, the building codes that govern commercial building construction have become increasingly prescriptive in nature, specifying detailed information related to the design and installation of the systems, while offering no reasoning behind their prescriptive measures. For example, mechanical piping systems commonly found in commercial and industrial facilities are used for a variety of building systems. Students now read and study construction details about piping system and installation methods in textbooks, and using published productivity rates, they perform in-class exercises estimating quantities and scheduling their installation, but they lack the experience working with the material and understanding the challenges trade workers face in the field during installation. This paper describes the design and implementation of experiential learning exercises that allows construction management students to perform "hands-on" fit-up exercises of mechanical piping systems.

Key Words: Commercial Building Construction, Experiential Learning, Construction Education

Introduction

Beginning in the autumn quarter of 2008, the Construction Management Department at California Polytechnic State University, San Luis Obispo launched an integrated project based construction management curriculum. The basis behind the integrated curriculum was to create a series of practice courses, similar to an architecture studio model; however, each course would focus on a specific sector of the construction industry - Heavy Civil, Residential, Commercial, and Specialty Construction. The concept behind the seminars was to integrate project controls, construction estimating and construction contracts and law into each of these courses and combine them with the construction methods topics pertinent to each industry sector. The integrated curriculum that the California Polytechnic State University, San Luis Obispo construction management faculty settled on led to the development of seven (7) project-based courses. They are as follows:

- Fundamentals of Construction Management
- Residential Construction Management
- Commercial Building Construction Management
- Heavy Civil Construction Management
- Specialty Contracting Construction Management
- Jobsite Construction Management
- Integrated Services Construction Management

Each of the project-based courses was based on a model of six (6) quarter-hours of laboratory credit total of sixteen (16) scheduled contact hours per week and an additional two (2) hours per week to be arranged for by the instructor. Based on a ten (10) week quarter system, students would receive a total of one-hundred eighty (180) hours of instruction. Similar to courses offered through an architecture program, their concept was teach each course in a dedicated space equipped with models, samples, contracts, marketing documents, specifications, estimating guides, computer references, and other tools appropriate to that construction industry sector. In addition, the laboratory would be furnished with work stations for twenty-six (26) students who would have twenty-four (24) hour/seven (7) days of week access to the space.

The concept for the specialty contracting construction management course was to focus on the work performed by a specialty contractors who self-perform a majority of their own work items required for the construction of a mechanical, electrical, plumbing system, etc. and who fabricate and install the components of the their work items. As one can imagine, the work of a specialty contractor involves coordinating with multiple trades, with whom they have not directly contracted with, but are required to work with and fabricate and install the system components mentioned above. Therefore, learning objectives focus on students understanding the construction methods for numerous work items.

New Facility creates Opportunity for Experiential Learning

Since 1990, the Construction Management Department at California Polytechnic State University, San Luis Obispo had been soliciting donations for the construction of the Construction Innovations Center (CIC) on the California Polytechnic State University, San Luis Obispo campus. As part of the fundraising effort for the new $33 million, 30,000 square foot building which includes seven (7) dedicated labs, twelve (12) classrooms and lecture halls, and faculty offices, which was dedicated in October 2008, it was the goal of the College of Architecture and Environmental Design (CAED) to create an interdisciplinary learning laboratory for the CAED where students across the college would be able to design, build, and test a variety of building components. The result was a privately funded laboratory 5,000-square-foot lab named the Simpson Strong-Tie (SST) Materials Demonstration Lab for the donors to the laboratory which was dedicated in October 2010.

The integrated curriculum model described by Hauck and Jackson provides tremendous opportunities to engage teaching strategies far beyond the common lecture approach typically utilized in many single subject courses[6]. They proposed that various methodologies, such as cooperative learning and the use of interactive learning stations, could be utilized in an integrated learning lab environment. Furthermore, they proposed a teaching approach for construction management education which requires students to be active participants in their own education. Students learn far more by doing something active rather than by simply watching and listening[2]. Therefore, to take advantage of the studio-laboratory format of the course proposed in the new curriculum, the faculty was challenged with developing experiential learning experiences to enhance student learning.

Experiential Learning

Experiential learning is learning through reflection on doing, which is often contrasted with didactic learning. Experiential learning is related to, but not synonymous with, experiential education, action learning, adventure learning, free choice learning, cooperative learning, and service learning. While there are relationships and connections between all these theories of education, there are also separate terms with separate meanings[1].

Experiential learning focuses on the learning process for the individual (unlike experiential education, which focuses on the transactive process between teacher and learner). An example of experiential learning is going to the zoo and learning through observation and interaction with the zoo environment, as opposed to reading about animals from a book. Thus, one makes discoveries and experiments with knowledge firsthand, instead of hearing or reading about others' experiences.

Experiential learning requires no teacher and relates solely to the meaning-making process of the individual's direct experience[5]. However, though the gaining of knowledge is an inherent process that occurs naturally, for a genuine learning experience to occur, certain elements must exist. According to David A. Kolb, an American educational theorist, knowledge is continuously gained through both personal and environmental experiences. He states that in order to gain genuine knowledge from an experience, certain abilities are required[8]:

- the learner must be willing to be actively involved in the experience;
- the learner must be able to reflect on the experience;
- the learner must possess and use analytical skills to conceptualize the experience; and
- the learner must possess decision making and problem solving skills in order to use the new ideas gained from the experience.

Course Approach, Learning Objectives, and Delivery Method

The specialty contracting construction management course described above was designed to introduce students to the construction methods for various work items common to commercial building construction. Therefore the course was developed and delivered with the following goals:

- Understanding the types of materials used in fabrication and installation of mechanical, electrical, and plumbing building systems.
- Understanding how to read project plans and specifications for mechanical, electrical, and plumbing systems.
- Knowing the different types of equipment and materials installed in mechanical, electrical, and plumbing building systems.
- Comprehend the design intent and constructability issues in mechanical, electrical, and plumbing building systems.
- Synthesizing the knowledge gained through class readings and exercises by participating in construction site visits.

Learning Objectives:

The learning objectives of the exercise are:

1. To give the student a first-hand chance to observe the management factors that affect job productivity
2. To be able to articulate and apply recognized techniques that improve labor productivity.
3. Watching the exchange during the installation, the planning that goes on, and the discussion that follows will convince any instructor of the ability of this exercise to achieve the goals set forth by the exercise. There are many opportunities for the students to articulate and apply the instructor's teachings from a previous lecture on productivity. The students walk away with a firm understanding of the complexity of building, the actions to achieving good productivity, and the requirements needed for better planning, leadership, and management. Most will be able to articulate the different factors that lead to a highly successful project or at least the factors that discourage success.

Method used for the exercise

The exercise is intended to have a lecture the day before on productivity, work sampling, productivity improvement, etc. Students are placed in three (3) teams, composed of four (4) student members. Each team is provided with the plans for the pipe model and for homework they are to work as group to prepare a quantity take-off (QTO) and develop a time estimate (in total labor minutes) to determine who will be awarded the opportunity to build the job. The "low bid" is allowed to go first.

Each team is allowed to organize themselves in any method or hierarchy they wish, i.e. one superintendent making all decisions, all others acting as labor, etc. When this is accomplished, the "mid bid" team is sequestered and the timing of the exercise commences. It must be noted that each team must act independently of the other teams. No verbal or physical help between teams is permitted.

The "mid bid" team is sent from the laboratory with the plans and specifications after briefly being allowed to examine the pipe model components. The "mid bid" team, while waiting outside the laboratory, is encouraged to study the plans and specifications for constructing the pipe model. They are also encouraged to plan, both a method and sequence, they wish to use once they have been brought back into the room, which will occur after the "low bid" team has attempted to build the model, which could be the next class session.

The "low bid" is directed to begin building the pipe model immediately without time to first evaluate the project. They are allowed to stop in the process, but the specific instructions to plan the work before starting is not given by the instructor.

The "high bid" team is required to then observe while the "low bid" teams construct the model. During the observation they are required to classify and record the work as: Primary, Secondary, and Recoverable Lost Work time. After the "low bid" team has either completed constructing the pipe model or given up, the two "high bid" teams are given the opportunity to construct the pipe model. Note that they may opt to do some planning and organizing before starting the physical work, but this time is recorded as secondary time by the now observing "low bid" team.

The "high bid" team is also required to keep track of the time spent in both the planning task and the method and sequence task for constructing the model and encouraged to ask written questions in the form of request for information, RFI's, which will be answered before they begin work and also after they incorporate answers into their work plan. The

Method of measuring and observation

Each student from the "observation" team is paired with a student on the "active" team – the team tasked with constructing the pipe model at that time, for the purpose of making observations and recording of work activity. One student observer from "observation" team is designated to start the clock on the instructor's direction at the beginning of the exercise and to announce each period. The periods should be in five (5) minutes increments. At each period, each student on the "observation" team observes his/her designated individual on the "active" team and records the type of activity they are doing at that time: primary, secondary or recoverable lost time. The following definitions and explanations are provided to the students:

- Primary time – time that work that is directly responsible for putting a piece in place.
- Secondary time - time spent planning, organizing work, laying out the work, etc.
- Recoverable lost time – time that used to correct errors during the installation, rework.

Observation and Work Sampling

Another element of this exercise is work sampling. Work sampling has been used in the construction industry for many years. Work sampling can be defined as a method of measuring how labor, time and/or equipment are utilized on the project to complete specific work processes. This should result in the same information that cost control systems gather and report. In using work sampling in construction activities, individual workers are observed at a particular moment during a job related function on a regular basis. The observations fall into three or four categories. These categories are:

- Direct work (Primary time),
- Supportive work (Secondary time),
- Delay (Recoverable lost time / rework), and
- Standby.

As part of the exercise and work sampling in general, the students must have a clear definition of each type of work. Having clear definitions allows the results of the exercise to be discussed when the exercise is completed. Concerning the pipe model exercise, primary time is defined as the work that is affecting the task of completing the permanent structure. Measuring, holding the material for another as it is being installed, and installation of the permanent pieces are all considered primary work. Secondary time for the exercise is the supportive work of planning, supervision, the moving and handling of material, and instructing the primary work. The next category is recoverable lost work, rework, or delay types of work. This is usually considered waiting for another worker to complete their task, standing and watching the process unfold, non-action or taking breaks, and taking apart and putting back together work that is wrong or will not accomplish the specification. Groups are allowed to use standby if they feel that the crew size set by the instructor is too large and a more appropriate crew size might work better.

This exercise has observations occurring at five (5) minute intervals with the same number of students watching the ones performing the construction. By doing work sampling on the exercise, it gives the students and instructor one more point of discussion.

The information gathered can also be applied against quantities extending the exercise even further. Direct work does not necessarily correlate with productivity, and with this exercise it may become apparent there is a real difference between students who have worked with their hands versus students who have not. Also, it should be understood that the pipe model cannot be completed using the original drawings which are not exact, or with all precut pipe pieces. The plans do not show unions or a place for water to enter or exit the model. These two items have been left unchanged on the drawings and are used as points of illustrations for discussion. It is important that the student must understand and thoroughly plan his/her work along with having all material needed on hand to complete this activity. If not, this generally leads the students to rework along the process. If a team recognizes these issues early and requests unions, they are readily supplied the number requested up to a maximum of six (6) unions. This also applies to the other issue of being able to charge the model with water. The students are supplied with tees, an inlet (hose connection) and outlet (hose bib value).

Discussion and Recommendations for Future Implementations

The instructor should have a follow up discussion on productivity, productivity improvements and summarize the results of the measuring and observations. Each team should be asked to write a report that outlines their method and approach to solving the exercise along with the conclusion and lessons learned from the exercise.

Integrating the course content of commercial building construction methods for construction management students is one approach to help change students' and future constructors' thinking to look at systems as a whole, rather than as independent systems, which helps to enhance and reinforce learning by arranging content around overlapping concepts and themes. The use of the common interactive learning station for the systems further helped to reinforce connection points between the multiple systems. Future laboratory experiential learning exercises may include fabricating a mock-up section of an exterior wall section.

The student work performed on the experiential learning exercise also emulated the work of light gauge steel framing contractors who they may find themselves managing upon graduation. In order to install the light gauge steel systems in the interactive learning station, students were forced to consider design, construction, and operations and maintenance criteria in order to achieve proper functioning systems. Upon graduation, most graduates of construction management departments take positions with construction companies and are placed into roles as field engineers and construction managers, or take positions with owners as facilities managers, owners' representatives, and construction inspectors who perform quality control task. Often they are asked on construction jobsite "How can you manage construction if you have never performed construction yourself?" or "What qualifies you to inspect my work?" Using the experiential learning exercises allows students to qualify themselves by giving them the hands-on experience in installation and testing the systems and furthermore giving them the capability to describe the theory behind the building code and to explain the effects of improper installations rather than just citing the building code.

The experiential learning exercise allowed an enhanced level of student-faculty contact by allowing the students and faculty to work together in a fashion other than the traditional lecturer-listener relationship that is most commonly found. Use of the experiential learning exercises encouraged students to work with their peers and the faculty member to achieve the above listed learning outcomes. The experiential learning exercise also encouraged active learning by experimentation and gave students prompt feedback by allowing students to test their mock installations.

The interactive learning station also allowed students to learn in a multitude of ways by allowing students of all learning styles to develop from laboratory experiences related to the experiential learning exercise. From subjective observations, kinesthetic learners benefited from the "hands-on" fit-up exercises, visual learners benefited from being able to observe, and auditory learners benefited from working in student groups by either giving or receiving fit-up installation instructions.

It is the authors' opinion that the experiential learning exercises are innovative in the fact that it is a laboratory tool that focuses on getting "back-to-basics". As described above, the building codes that govern the design and installation of commercial building construction have become increasingly prescriptive in nature, while offering no reasoning behind their prescriptive measures.

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