USING DESCRIBED AUDIO TOURS TO ENHANCE CONSTRUCTION ENGINEERING EDUCATION

Brenda Y. McCabe

Civil Engineering, University of Toronto
brenda.mccabe@utoronto.ca

Abstract – In 2015, legislation was enacted to require mandatory 'Working at Heights' training for all construction workers in Ontario. While the legislation has been successful in reducing lost time injuries due to falls, it inadvertently raised barriers for engineering instructors wishing to give their students a field-related learning experience. Although construction management students completed WHMIS, safety awareness, and fall awareness training, the liability related to the risk of injury was sufficient to motivate construction companies to deny student requests to visit their sites.

To adapt to the situation, a novel program of described audio tours was developed, thereby allowing students to visit and learn about different construction sites without jeopardizing their safety or the risk tolerance of hosting contractors. The resulting program improved the learning experience in that students visited 20 to 25 sites during the term instead of one.

Keywords: Construction engineering; Construction safety; Active learning; Handling large classes outside the classroom

1. INTRODUCTION

One of the challenges of teaching construction management to civil engineering students, especially early in their program, is that they have little understanding the process of turning design drawings into an operating facility. The immense size of a construction site and the day to day challenges are difficult to appreciate without experiencing it in full scale. To address this, construction engineering students are assigned to work in groups of three to find a construction site that they could visit twice per week for six weeks. They then prepare a report summarizing what they learned, focusing in a particular aspect of the project. As such, the course also contributes to the communications thread that runs throughout the program.

Due to recent changes in provincial legislation related to fall-prevention training for anyone going onto a construction site, regular on-site visits were no longer

feasible. However, the students have very little exposure to construction activities and not going to site would be a major loss to their learning experience. How can one learn about managing a process to which you have little exposure or understanding? To address this issue, the assignment had to change such that it gave them an on-site experience without actually having to go into the construction zone.

2. BACKGROUND

All engineering disciplines require physical infrastructure to support their engineering products. Project management is a topic that all engineers cover to some degree in their undergraduate programs. Generally, these relate to an engineering design project and focus on team organizational structures, scheduling, and quality control. Often missing, however, is basic understanding about the skills, tools, materials, and processes needed to translate that design from paper to reality. That construction process is often disregarded and relegated to the contractors. However, understanding how design impacts logistics and costs in the field can improve design efficiency and the often adversarial relationship between designers and constructors. Civil engineers, with stronger backgrounds in the design and operation of many different types of infrastructure, tend to have a greater involvement in the construction process.

In civil engineering, construction management is a core course. While aspects of project management are included, there is also significant emphasis on the construction process and all of its challenges. These challenges span across aspects of codes and regulations, worker and public safety, environmental responsibility, community concerns, and resource management.

Due to changes in society itself, the backgrounds of students that discover civil engineering as their calling are not the same as those a few decades ago. Once dominated by the children of farmers, skilled workers, and immigrants with plenty of hands-on experience, today's students are more globally oriented, well traveled, but less likely to know how to fix their bike, change the oil in their car, or undertake home repairs. Instead, they are used to organized

activities, automation, and a connected world at their fingertips.

The number of women in engineering programs has also increased dramatically. From under 10% in the 1980s, we now have graduating classes with 30% women and incoming cohorts with 40% women. Finally, the proportion of international students has increased from 15-20% in the early 2000s to around 30% today. This creates some barriers, as the slang commonly used in industry is often new to a great majority of students, but especially those who have no construction experience and whose first language is not English.

2.2 Construction Management Curriculum

The learning outcomes of typical construction management courses are to:

- Explain the life cycle of a construction project
- Develop update & forecast a project plan with schedule, budget, and resources
- Recognize the responsibility of workers and employers to ensure safety

These translate into a number of course topics, shown in Fig. 1, that represent the major activities comprising the life cycle of a construction project.

Delivery: Lectures, Assignments, Guest Speakers, Case Studies, Site Visits			
Pre-Bid	Bidding	Construction	Project Control
•Introduction	•Prequalification	•Safety	•Quality
•Procurement	•Estimating	•Planning	•Cost, time
•Drawings	•Contract law	•Site methods	•Resources
•Request bids	•Contract award	•Equipment	

Fig. 1. Main Topics Covered.

Topics were initially taught chronologically. However, feedback from students quickly identified the difficulty that they had learning, for example, estimating when they did not understand the construction process, its terminology, or the methods. Safety awareness was also identified as needing coverage as early as possible. Therefore, occupational health & safety (OH&S) and site methods were moved to the start of the course.

The need for greater familiarity with the construction process was originally met by assigning a course project. In this project, students worked in groups of three to follow a construction project of their choice for six weeks. Groups were responsible for finding a site, making first contact with site management, getting permission to visit it, following all safety protocols, and regularly interacting with the site management. They gained a lot of confidence in that process. After six weeks, they wrote a short report on what they learned, focusing on one topic to provide

some depth. The potential in-depth topics included but were not limited to:

- Unique project and site characteristics
- Safety practices for workers and the community
- Construction methods, equipment, and materials
- Site logistics and schedule control

Sites were limited to two groups to avoid situations where everyone bombarded the nearest site. This rule was especially necessary for large classes, where 40 or more groups of three would go out in search of a project. Some coordination was required but it prevented a backlash from the closest projects. Although drivers, pedestrians, and local residents may not agree, we were fortunate to have sufficient construction underway within 1.5km of campus to accommodate all of the groups.

Site managers were consistently supportive of student requests to learn from them. Over five years with 120 students on average in the class each year, only one or two of the 40 groups per year were turned down by a site. At that point, they were at a disadvantage because the remaining nearby sites had met their 2-group limit, forcing the group to look a bit further away. However, all groups typically found a site within 2 weeks of the start of the term.

One limitation of the project was that the group's learning experience depended on the site that the students chose with respect to the project's characteristics, its stage of construction, and the site management's willingness to mentor the students. While six weeks is sufficiently long to see a project advance, the activities could be repetitive. For example, the excavation for a large building in downtown Toronto could take six months or more. Much of the preparation for excavation, such as the installation of dewatering and shoring systems, are invisible from the surface. Similarly, the cyclic operations of forming and pouring concrete for the structure of a highrise may take a year or more depending on the design height of the building. The site's management team also had a major impact. In some cases, the students were invited to attend weekly coordination meetings where they learned about all aspects of the project and some of the daily challenges experienced by the subcontractors. Other teams were met with less enthusiasm if the site superintendent was overly busy or under pressure. The project that the students chose also impacted their learning experience. High profile projects, such as the Royal Ontario Museum, Union Station reconstruction, or Pan American Games Athletes' Village, typically involved larger general contractors who were encouraged to promote the project and had good public relations practices. Smaller projects run by smaller general contractors often had limited resources for activities that did not directly benefit the project.

In preparation for the site visits, students completed three safety-training modules in addition to the coverage of OH&S in the first few lectures of the course. Workplace Hazardous Material Information System (WHMIS) is a standard requirement for most workplaces. It informs

workers of the three-pronged approach used to relay material safety information, namely through labels, material safety data sheets, and education. The second module is the Ministry of Labour's Health and Safety Awareness Training for Workers and Supervisors. This generalized program introduces workers from across all industries to the Occupational Health and Safety Act and their health and safety rights and responsibilities in the workplace [7]. The third module is Fall Awareness, an online program developed specifically for the construction management course by the University of Toronto's Office of Environmental Health and Safety. It reviews the regulations related to working at heights, such as the proper use of ladders, the suite of available fall prevention strategies, and personal protection equipment requirements.

2.3 Construction Safety

The construction sector has many challenges inherent in its nature of work, which includes a mobile workforce, low employment tenure, exposure to weather, and workplace environments that change daily. These challenging conditions are reflected in their safety statistics. Fatality rates in the construction industry remain the highest among all other industry sectors in most regions, including Australia [8], Europe [3], and North America [2]. Over the past decade, fatality rates generally ranged from 3 to 14 work related deaths per 100,000 workers.

The Ontario construction industry is similarly challenged. For example, although the construction industry comprised 8.6% of WSIB-covered employment in Ontario in 2015, it accounted for 11% of lost time claims and 30% of long latency illnesses. In the previous 10 years, 28.3% of the occupational disease fatalities were from construction [10]. It is largely made up of micro and small enterprises. The number of Ontario construction employers grouped by number of employees was 7,433 (1-4 employees), 4,070 (5-99 employees), 71 (100-499 employees), and 9 (more than 500 employees) in 2013, which translates into 64% of construction employers having fewer than 5 employees [9].

One of the challenges that these micro organizations face with regard to their safety practices is to have a meaningful evaluation of the safety culture in their organization and their safety performance against the industry standards and national and international best practices. Finding ways to reduce safety incidents in construction has been a major focus of the research and safety professional communities.

Many approaches have been used to improve construction site safety and ultimately the overall safety climate. Some jurisdictions have implemented region-wide safety blitzes to proactively raise awareness and improve compliance with health and safety legislation [6]. In 2015, the Province instituted mandatory "Working at Heights"

training for all construction workers. Training includes four hours of classroom learning and four hours of practice with a maximum of 12 students per class. With these efforts, lost time injuries (LTI) due to falls from heights dropped by 15% between 2014 and 2015 in Ontario. Still over 2000 fall-related LTI occurred in 2015 [4] – that's one fall *every hour* in Ontario's infrastructure sector alone. In a survey of 837 Ontario construction workers between 2015 and 2016, 5.5% reported experiencing a fall from height at least once in the previous three months [1]!

Construction managers became understandably reluctant to allow students on site as a consequence of the focus on fall-related injuries, the new mandatory training requirements, and the liability to them should an accident occur. As such, the construction management curriculum needed to adapt to continue allowing students to gain construction site experiences.

3. CURRICULUM RESPONSE

Options to address the new challenge in construction engineering education included eliminating site visits, finding visit-friendly sites, using videos to replace visits, or to devising something new.

Eliminating the site visit component was the least favorable option. Students expressed enjoyment, awe, and learning at the tangible full-scale nature of construction. From the depth of excavations to the height of the tower crane, from pumping ground water to pumping concrete, it is a civil engineer's candy store.

The second option was to find sites that were willing to host site visits and capable of managing large groups or multiple visits from smaller groups within a short timeframe. The strength of this option is that all students would have the same experience. The limitation is that the onus of finding a site was put on the instructor. The students did not engage in the journey of finding a site and connecting with site management to gain access to their knowledge and experience. Further, they did not gain as much from the visits when they were in large groups. Often, they could not see or hear what the tour leaders were pointing out.

The video option provided several potential positive outcomes. First, numerous videos are already available online. They could allow a great variety of learning opportunities without significant effort. Once captured, they could be used year after year, which would bring consistency to the types of materials that they would see. The videos could also be viewed outside of the classroom, thereby allowing time for discussion about the activities rather than passively watching them. Finally, they could be used to demonstrate differences in practices around the world. The limitations related to the effort, cost, and potential resistance to capturing videos of local projects, which would be more meaningful than projects from elsewhere. Site managers are sensitive to the capture of any

pictures or videos that might depict negatively on their operations. For example, a short video might capture a worker appearing to be in an unsafe situation, or work appearing to be performed incorrectly. If students did not watch the videos in advance, then the discussion in class would be less meaningful and again become a passive experience. The excitement of seeing something in person as it is being built would be lost.

The final option related to developing a new method for exposing students to the construction site that did not require them to go *onto* the site.

3.1 Selected Response

A solution was developed that responded to the desire to expose students to the reality of the construction site and involved active learning where students could openly discuss what they were observing. The plan was to have students visit sites and observe them from public areas that were safe and accessible. The challenge was to give them sufficient guidance so that they would know what they were seeing.

Guided walkabouts with 120 students were not feasible. Getting everyone together would require the visits to be scheduled during class time. Further, there would likely not be enough space around the site for everyone to have a clear view of the site at the same time. Finally, they would not likely be able to hear what was being said about the site. Therefore, a method perfected by museums – the described audio tour – was adapted for our purposes.

An area encompassing about six blocks outside the campus boundaries was divided into the same number of subareas as there were teaching assistants (TAs) in the course. TAs were responsible for exploring their assigned areas and collecting information on active construction sites, including location, stage of construction, and type of project. Five walking routes that went past three to five sites were developed, including a map that would guide the students.

Each week for five weeks, the course instructor and teaching assistants visited the sites and discussed the project characteristics. Contact was made with the site superintendent to explain our objectives, ask about the project, and warn them that 120 university students would be coming by to observe the site over the next week. The site managers were typically very helpful, providing very interesting background information that would otherwise not be available to us. From the information provided and from our own observations, we made audio recordings that described the project. Phrases such as *I am standing on the northeast corner of the intersection of Peter and King Streets* helped orient the students. Background information about the project created excitement and interest e.g. *The site superintendent told us that the steel framework supporting the historic façade is the tallest of its kind in North America at this time*. The recordings also posed

questions about certain aspects of the sites. For example, *why are three sides of the excavation shored using soldier piles and lagging while the fourth side is stabilized using a caisson wall*, or, *how has this site created a safe environment for pedestrians passing by the site relative to the previous site?* The audio files and a map showing the locations of the projects and a suggested walking route were uploaded into the learning management system (LMS). Students downloaded the files and visited the sites in small groups using the recordings as a guide. Each group of three submitted a report outlining some of the themes that they saw across the sites and recommendations for improved operations.

For the first few weeks, insufficient material was covered in class to allow for meaningful assignments to be undertaken during tutorials. Therefore, students were encouraged to use that time for their weekly site visits. After week 3, however, students had to complete the site visits for weeks 4 and 5 on their own time.

4. DISCUSSION

The new format resulted in several unanticipated benefits, which are summarized in Table 1. First, students were exposed to 20-25 projects whereas the old method gave them exposure to only one. They also saw projects in all phases of construction, from mobilization to excavation, structural, topping out, cladding, and final finishes. They saw a broad variety of methods for construction, for pedestrian protection, varying degrees of attention to housekeeping, diligence to safety, and overall materials management. Some site personnel offered to make themselves available if the students wished to ask questions while they were visiting. One manager was concerned at the idea of having 120 students stopping to point at and huddle around their site because it could cause uncertainty or distress to the general public if they thought that something was wrong at the site. Instead of chancing this outcome, they chose instead to invite the entire class to a visit over the course of two weeks. They dedicated five of their staff to lead small groups around the site and share with them some of the unique aspects of the project. As a result, the class had a highly engaging visit on site in and amongst the equipment, materials, and growing structure.

Table 1. Comparing original and new site visit methods

Issue	Original	New
Number of sites visited	1	20-25
Project phases observed	1	many
Consistency of experience	varied	high

We saw some spectacular projects that would have otherwise been missed without our search for current projects. We saw how an excavation for a highrise exposed the subway tunnel and how the foundation would be installed to avoid damaging the tunnel or disrupting the

operations. We saw 30 floors being added to the top of an existing 25 floor building.

One of the challenges is that construction progresses and new sites need to be found each year, investigated, visited, and audios files created. However, it is a great way to stay informed about all of the interesting projects going on in our city and to keep the course fresh and current. On the other hand, students saw only snapshots of many different projects rather than an in-depth longitudinal study that was previously achieved.

It is always challenging to remember what it is like to learn, especially when the target of our interest is an industry as old, ubiquitous, and unique as construction. Terminology is difficult as there are a lot of slang and euphemisms, ranging from iron (heavy equipment) to flyforms (formwork for concrete slabs used in high rises). I have been asked what a “2-by-4” is, and where the washroom is on a tower crane (there isn’t one). When told that they have to take WHMIS training, I was told by a group of young men that they didn’t mind taking women’s training, but wondered whether they should go together or separately.

Feedback from students has been very positive. When asked how helpful the site visits were to improve their understanding of the course concepts, 1 responded *not at all*, 22 *somewhat helpful*, 32 *moderately helpful*, and 45 *extremely helpful*, resulting in a score of 3.21 out of 4. Students from prior years who learned about the change were equally enthusiastic about how it could have improved their learning experience.

The site visits will be challenged if and when the Toronto construction boom ends, but that could be several years away. With mega-projects such as the Eglinton Crosstown LRT underway, we may have the opportunity to continue for some time.

5. CONCLUSIONS

Although the new rules related to working at heights was fundamental to bringing attention to a serious hazard in the construction workplace, it posed a challenge to the way in which students learned about construction. It also presented an opportunity to improve their experience. Whereas students used to follow one site for six weeks, their experience was significantly impacted by the project type, stage of construction, and engagement and willingness of site personnel to mentor them. They were also limited to experience one site at one stage of construction. With the new format, students see approximately 25 sites each year in different stages of construction and learn about the challenges and successes experienced by the various project management teams. The organizational culture differences between contractors became readily apparent.

It is anticipated that in the near future, we will use virtual reality environments or augmented reality to

provide realistic, immersive experiences to students safely and efficiently. Even so, they will miss the interactions with site personnel, the sounds and activity of the site, and observing first hand the incredible skill with which workers apply their trade to create something that will likely last a century or more.

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