

Health and Safety in Civil Engineering CDIO
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Abstract

Embedding a culture of health and safety into engineering learning and teaching is an important objective in the development of a professional engineer. However the topic can appear very "dry" to students, who may lack engagement. This paper introduces a new virtual reality simulation which has been developed to illustrate real health and safety hazards on an industrial construction site environment. Students can explore the domain and discover realistic hazards. They are then invited to identify the risks associated with each hazard.

The virtual reality simulation has been used to support a realistic civil engineering experiential initiative, the Constructionarium. Each year students work together for a week-long team project on a real construction site to build realistic scale structures. Students are required to submit method statements and associated risk assessments to the contractor before being allowed to proceed. Some of the real health and safety issues encountered during the Constructionarium are reviewed, together with plans for linking this project with the virtual reality simulation more closely.

Keywords: health & safety, implement, operate, civil engineering, construction, active learning

Introduction

The Constructionarium ⁽¹⁾ is a new active learning teaching initiative, that forms part of the Liverpool Engineer ⁽²⁾ initiative, in which Civil Engineering students from the University of Liverpool engage with a real construction project. Students work in teams and interact with a civil engineering contractor and a design consultant. The project takes place over six days at the National Construction College in East Anglia, where a 6 hectare site has been dedicated to this initiative. There are a total of 17 work areas incorporating several lakes, a river gorge, a mountainous area and a swamp. The site has been developed to expose students to a range of different construction conditions including working with:

- Excavation
- Bad ground (waterlogged)
- Height
- Construction plant
- Power tools
- Water
- Lifting of heavy materials

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The University of Liverpool and the Health and Safety Laboratory have collaborated over the past 4 years or so to raise engineering students' awareness of health and safety risk issues by embedding risk education materials into the curriculum ^(3, 4). This has mainly focused on Year 1 where it was found that students entering an undergraduate engineering course have varying degrees of awareness of hazards and risk and their professional responsibilities towards it ⁽⁵⁾. Universities are believed to be better placed to deliver the theoretical aspects of risk education than industry. However, hazards and risk becomes more relevant when it can be related to aspects of daily life and business closely affecting the general public. To this end, a virtual reconstruction of an accident investigation was developed as a role-play exercise to merge the theory with practice and highlight how close to home risk and hazards can be ⁽⁶⁾. It is not practical or realistic in terms of timing and safety to take a group of students to an accident scene but it is possible to bring the accident scene to the students.

While health and safety is talked about and discussed in the lecture room and laboratory environment, this can often appear disconnected because the students have never experienced the conditions where it is both relevant and necessary to manage risks such as on a construction site. There is no substitute for real experience and so the opportunity of the Constructionarium project in Year 2 and its health and safety implications fitted well with the overall plan to give the students active experience of health and safety issues. The challenge facing academic staff together with the contractor and consultant is that with the Constructionarium some 90-100 students, most with little or no construction site experience are simultaneously exposed to a wide range of hazards and associated risks.

Constructionarium Health and Safety Training

The Constructionarium is introduced to all students in the second year of a four-year MEng course. As part of the build-up to the exercise, a series of introductory lectures and interactive sessions are given on planning, costing, teamwork and health and safety. Students are allocated to teams of around 20 and are required to choose their own professional role within the team, e.g. Project Manager, Project Engineer, Setting-out Engineer, Planner, Machine Operative etc. With guidance, each student is required to select one activity from the week's plan and to produce a detailed method statement and risk assessment.

At the start of the Constructionarium week, all the students who are designated power tool operators receive formal instruction from the National Construction College on the safe working procedures for a range of small tools, Figure 1. Only these students are permitted to use power tools during the remainder of the Constructionarium week.



Figure 1 Constructionarium power tool training

The team of students operate just as a small construction company and carry out the majority of the construction activities themselves, under appropriate supervision. Typical activities include placement and compaction of concrete, working at height, lifting heavy objects, either manually or using plant and working in water, Figures 2-6.

Health and Safety Training Using Computer Aided Learning

To ease the transition of health and safety knowledge and understanding from the lecture room to a real construction site an interactive computer aided learning tool ⁽⁷⁾ has been developed in the UK as part of a project promoted and developed by the Inter-institutional Group on Health and Safety (a group comprising representatives from the major UK Engineering Institutions and other professional bodies) working with the Health and Safety Executive (HSE) and the Health and Safety Laboratory (HSL). Funding thus far has been provided by the HSE, largely to obtain input from a company which is expert in developing e-learning materials. The work has been described in detail in two HSE Reports ^(8,9).

The framework for the learning resource has been developed to allow several working environments to be included, i.e. manufacturing, offshore petrochemical production and construction engineering. However the development is not yet complete. A sample CD has been produced which demonstrates the intent of providing basic health, safety and risk training in a thought-provoking, involving, enjoyable and interactive environment to young engineers in universities and possibly in industry. The resources for developing an interactive 'gaming' type approach have so far been focussed on civil engineers and construction issues, although samples of interactive tutorial material are more generally relevant.



Figure 2 Constructing a concrete ground beam



Figure 3 Working at height using a platform



Figure 4 Lifting heavy materials



Figure 5 Working with engineering plant



Figure 6 Working over water

Material within this resource can be categorised into several discrete sections:

- Case studies of real accidents and the associated lessons learned. This includes video clips of well-known accidents (such as Piper Alpha and Challenger) and audio interviews of people affected by accidents.

- Tutorial material, e.g. risks and hazards, risk statistics, health and safety guidelines, Figure 7.
- Interactive virtual reality construction site hazard spotting exercise.



Figure 7 Risk Assessment Tutorial

The virtual reality representation of a real construction site allows students to move around the site and explore activities that are taking place. After an initial induction, Figure 8, the user can explore the construction site with a first person perspective. There are a number of instances where clear breaches of safe working procedures are occurring. Students are required to identify hazards and comment on whether the associated risks are being correctly managed. Examples are business-men on site failing to set an example by not wearing suitable PPE, Figure 8, unsafe storage of construction materials, Figure 9 and scaffolding erected without toe-boards, Figure 10.



Figure 8 Health and safety induction



Figure 9 Inadequate use of PPE



Figure 10 Incorrect storage of construction materials



Figure 11 Unsafe scaffolding

The computer aided learning facility has been developed as a demonstration to show what can be done with modern interactive computer graphics and give an insight of a real construction site environment and some unsafe practices which might be encountered. It is appreciated that this facility requires further development and additional resourcing to turn it into a fully fledged product. Despite this the demonstration CD has proved to be a useful learning resource when used in conjunction with the Constructionarium. It is hoped that in the near future the virtual reality simulation of a generic construction site can be tailored to the specific environment and hazards of the Constructionarium. This will enable students to gain a realistic appreciation of the risks they might well be exposed to with the Constructionarium project before setting foot on site.

Other areas for development are being discussed with universities, institutions and industry and might include simulations incorporating other industrial environments such as offshore engineering and manufacturing/production engineering as well as the development of further interactive tutorial material to introduce basic health and safety concepts to all young engineers irrespective of discipline.

Constructionarium Experiences

The 2007 and 2008 University of Liverpool Constructionarium events were both very successful with all projects being completed. Most importantly, there were no serious accidents or injuries. For the first Constructionarium project in 2007 the contractor was Edmund Nuttall Ltd. Circumstances necessitated a change in 2008 and Morrisroe Ltd took over responsibilities as the contractor. Both contractors took full responsibility for health and safety during the Constructionarium week and ensured that students could only proceed with activities having first gained approval from a written method statement and associated risk assessment. Examples of good practice of these are appended. Students were urged to focus on important bullet points rather than lengthy statements which were unlikely to be read. All construction activities were carried out with due reference to the agreed safe procedures and wearing suitable PPE.

Notwithstanding the adoption of these procedures some incidents did occur, resulting in minor cuts, scratches and bruises, for example:

- Bruising of thumb with inexperienced use of hammer
- Cutting of thumb with inexperienced use of hand saw
- Bruising of coccyx from backward trip to the ground
- Dirt flicked into eye while walking across site

The contractor's requirement that all personnel must wear eye protection and rubberised canvas gloves at all times on-site certainly helped reduce the severity and number of injuries like these.

Conclusions

The Constructionarium experience has proven to be an invaluable site activity for civil engineering students, which fits well into the CDIO learning and teaching methodology. Participating in this activity, while ensuring adequate training and implementation of correct health and safety procedures, has provided a challenge for the academics and the civil engineering contractor and consultant. The use of a new health and safety computer aided learning facility, even when not a fully fledged product, has been beneficial and helped to ensure that no serious accidents occurred during two consecutive Constructionarium weeks. Future development of the e-learning package to tailor the virtual-reality aspect to better represent the Constructionarium site and specific health and safety challenges would ensure that this remains the case.

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Appendix 1: Example Method Statement

Naples Canopy (Day 2)

Method statement MS/003

Excavation of shaft

- ✓1. Before any works are carried out ensure the inner walls of the shaft are undamaged and are positioned accurately
- ✓2. Use excavator to dig to approximately 700mm deep
- ✓3. Access shaft via gate and stable footed ladder only and proceed to remove earth from around and underneath the shaft so that the shaft ring can lower. Proceed until the first shaft ring layer is below the level of the ring beam.
- ✓4. Apply the second ring beam layer via the use of a crane and position these sections overlapping the previous ring to give an overlap effect. Bolt these together, check that they are placed accurately. Exit the shaft via the ladder and gate only and repeat steps 2 and 3.
- ✓5. Apply the third ring beam layer via the use of a crane and position these sections overlapping the previous ring again to give an overlap effect. Bolt these together, check that they are placed accurately. Exit the shaft via the ladder and gate only
- ✓6. Use excavator to dig to a final depth of approximately 2000mm.
- ✓7. Access shaft via gate and stable footed ladder only and proceed to remove earth from around and underneath the shaft so that the shaft ring can lower. Proceed until the third and final shaft ring layer is down to the ring beam height.
- ✓8. Level the base of the shaft floor and exit the shaft via the ladder and gate only.

During the excavation and earthworks ensure that, wherever possible, personnel and plant are segregated to avoid collision and potential for major injury. In any case where this may not be possible and plant is nearer than preferred, be aware and avoid going to close or operating within the drivers 'blind spots'. Also when digging ensure that nobody or parts of a person are beneath the shaft rings as when these lower this could lead to crushing.

Compiled by

Position:
Signature:
Date:

Approved by

Position:
Signature:
Date:



① Banking of crane/machine to be covered by certified bankers only

Appendix 2: Example Risk Assessment



Nuttall management system
Safety form

SF103 Risk assessment Appendix A to MS/001

| 1. Contract title | | 2. RA number | 3. Element of work | | 4. Assessed by | 6. Date |
|--|-----------------------------------|----------------|-----------------------------------|---|-----------------------|------------|
| Liverpool Constructionarium Naples Canopy | | | Digging foundation and excavation | | 5. Approved by | 13/04/2008 |
| 7. Hazard | 8. Persons in danger | 9. Risk rating | | 10. Control measures | 11. Final risk rating | |
| | | Severity | Likelihood | | | |
| | | M | H | | | |
| | | M | M | | | |
| Moving plant | Site personnel | M | H | Make sure no one nearby when moving the plant. Only trained personnel are allowed to access the plant. | | L |
| Crane overturning | Site personnel and general public | H | L | The operator must be trained and knows how to operate the crane. In addition to that, when crane is being operating, nearby area need to be kept clear. | | L |
| Poor ground conditions | Site personnel / End user | M | M | Preliminary investigations show soil is adequate for design. Lab test need to be carried out on the properties of the soils. | | L |
| General hazards | Site personnel / End user | H | H | All standard PPE must be worn all times during construction work. | | L |
| 12. Review dates: | | | | | | |