

Development of professional Civil Engineering construction skills and health and safety awareness through active learning

Prof. Steve Millard

University of Liverpool, Liverpool, UK

Dr Zhongwei Guan

University of Liverpool, Liverpool, UK

ABSTRACT

In 2007 the Department of Engineering at the University of Liverpool launched the Liverpool Constructionarium ^[1] initiative as a core component of the unique **Liverpool Engineer** ^[2] professional degree, based on CDIO learning and teaching principles. The Constructionarium is an immersive week-long experience in which students work in teams of 20 alongside industrial construction and design professionals on a series of real construction projects. The construction site working environment presents real health and safety hazards and associated risks and a significant risk of personal injury. This must be managed by the students in a professional manner and adopting the working practices and procedures of the industrial contractor.

The paper will present and discuss good practice procedures and will also discuss some health and safety incidents and near-misses encountered during the Constructionarium week.

Keywords

Construct, build, method statement, risk, hazard, professional, responsibilities

INTRODUCTION

The Constructionarium^[1] is a full-week residential learning initiative in which students work in a realistic construction site environment to build real engineering projects. The students are grouped into teams of approximately 20 to form a small mini-company. Professional roles such as Project Manager, Liaison Officer, Site Engineer, Health and Safety Officer and so on are set up and students self-select their individual role. The students are supported by academic staff and staff from a collaborating construction company and consulting engineers. The University of Liverpool take the entire second-year student cohort to participate with the Constructionarium project early in the year, when inclement weather is common. The challenge presented by this initiative is how to handle around 100 inexperienced students working on a construction site with all its hazards and risks and to keep all operations safe and injury-free.

The construction takes place in the grounds of the National Construction College, located in Norfolk, in the south-east of England. A dedicated Constructionarium site has been set up which is permanently available for use by any UK university wishing to participate with the Constructionarium project. The site contains a number of conditions to expose students to the full range of construction challenges they will meet following graduation. These include a river gorge, a deep and a shallow lake, a dry dock facility and a large 20 m gap to be spanned, Figure 1. The individual projects present their own construction hazards, including working in excavations, working at height, working with construction plant and so on. It is imperative when planning and operating the construction projects with a large number of relatively inexperienced students that health and safety is paramount. The academic staff, construction staff and design staff must all work together as a team to ensure that all risks are minimised. This paper will discuss how health and safety is embedded into the Constructionarium learning initiative.

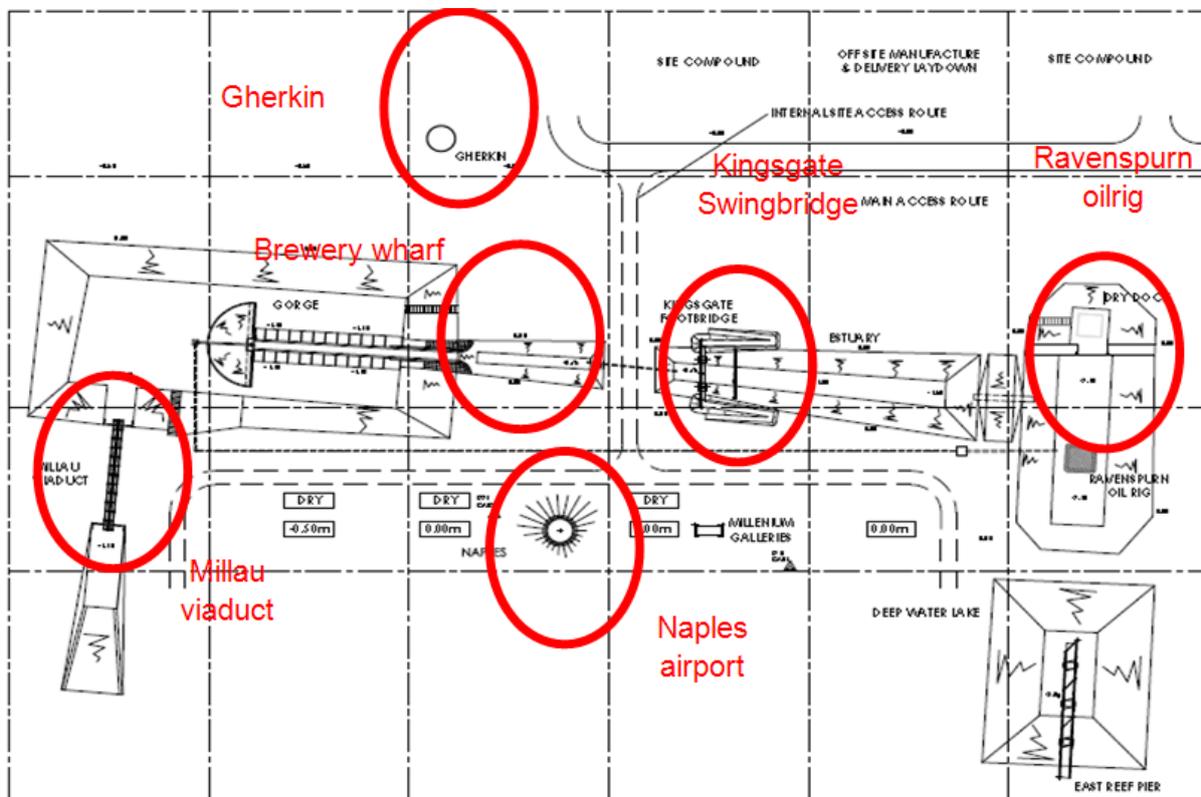


Figure 1 Constructionarium site

PROJECTS

A portfolio of construction projects has been developed by several universities initiating the Constructionarium. These are based on real life structures, which are scaled down to enable students to complete the construction within five working days. Projects which University of Liverpool has undertaken over the past three years comprise:

Ravenspur oil rig
Kingsgate swingbridge
Brewery Wharf cable stayed bridge
Millau viaduct
Naples subway entrance and canopy
London Gherkin

Each project requires the student team to plan and execute the entire construction process from excavation of foundations and fabrication of timber formwork to steel-fixing, concreting, formwork striking and steelwork or structural timber erection. The projects are planned to finish with a grand finale on the last day, e.g. flotation of the oil rig into the lake and sinking on a predefined location. In addition to the construction processes, each student team must undertake full project planning and costing and must ensure that all site operations are conducted safely and with full written approval from the construction company, who have overall control of the project.

PRE-CONSTRUCTIONARIUM HEALTH AND SAFETY TRAINING

Before the Constructionarium week, students are engaged with a number of lectures, interactive exercises, coursework and formal induction to raise their awareness of health and safety on construction sites. An interactive virtual reality computer package^[3, 4] is introduced in which students are encouraged to explore a fictitious construction site and identify hazards and their associated risks, Figure 2. As part of the preparatory coursework each student researches the real full-size structure on which their Constructionarium project is based and must report on the construction procedure and any associated health and safety issues. Immediately before the Constructionarium week, the collaborating Contractor presents a Health and Safety induction, which is a legal requirement before any site activities can be permitted. In addition the National Construction College has its own Health and Safety induction video, which all the students must watch.

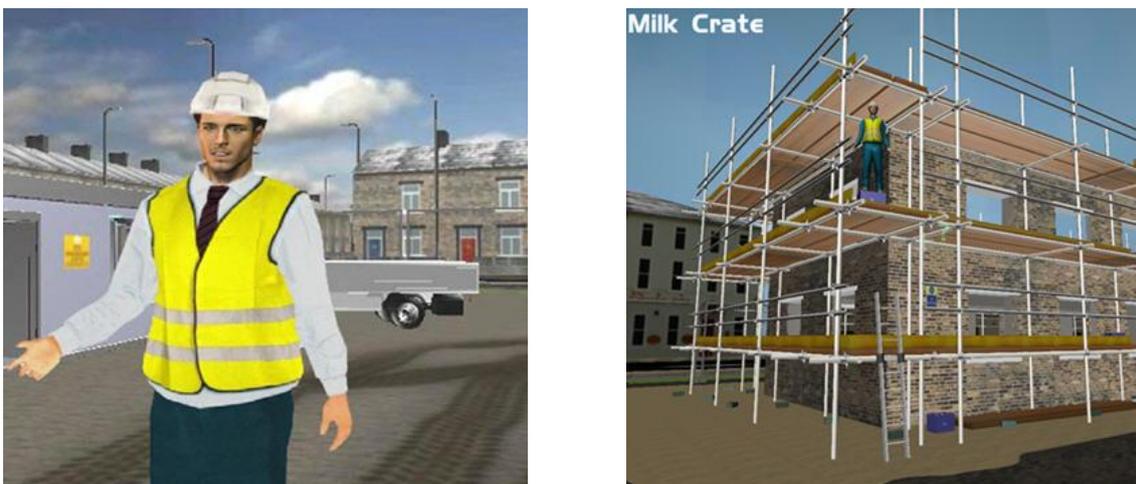


Figure 2 Construction site health and safety virtual reality package

PERSONAL PROTECTION EQUIPMENT

Personal protection equipment is provided partly by the students themselves and partly by the Contractor. All students must purchase their own steel toe-capped safety boots for use on site. The contractor provides high visibility jackets, construction helmets, safety eyewear and rubberised cotton gloves. These must be worn by every student at all times while on site. In addition for further activities some specialised PPE is required and supplied. Wood or steel cutting operations involving dust and noise are carried out by students wearing a suitable dust mask and goggles, together with ear defenders, Figure 3. Operations over water are carried out by students wearing personal flotation safety equipment, Figure 4.



Figure 3 Students with appropriate PPE using power tools



Figure 4 Use of flotation gear

CONSTRUCTION SITE PROCEDURES

Five or six members of each student team are selected to become "power tool operators". These are students who will use petrol or electric powered tools such as a timber rip saw, steel/masonry cutter, drills and grinders. The students are given basic training and issued certificates by the National Construction College to ensure that they can use these tools safely. Following this training, these are the only students permitted to use any power tool for the rest of the Constructionarium week. They are identified by a bright coloured helmet sticker, which ensures that supervisory staff can control the safe use of power tools. However, hand tools such as hammers, saws and shovels can be used by any student, Figure 5.



Figure 5 Student with PPE using hand tools

At the start of the project, each team must prepare an overall plan of the method and the sequencing of the construction operations. This is then submitted for approval to the Contractor. For every subsequent operation to be carried out on site, the student team must prepare a written Method Statement together with its associated Risk Assessment. No activity is allowed to proceed without written approval from the Contractor of the Method Statement and Risk Assessment. This process is identical to that used when the students begin their professional career working on a real construction site and it provides a valuable introduction into how an inherently risky construction site can be operated safely. Students learn to differentiate between a "hazard", i.e. a dangerous situation (e.g. open water), and a "risk", i.e. the possibility of an accident occurring from a specific event (e.g. drowning). The use of Method Statements and Risk Assessments to control and manage all operations provide real risk awareness and enhances safety. It is not simply a "box-ticking" exercise.

GOOD PRACTICE

Using the training and procedures described, University of Liverpool together with two different Contractors, Edmund Nuttall ^[5] and Morrisroe ^[6] and design consultants Mott MacDonald ^[7] have successfully run 12 individual Constructionarium projects safely and without serious injury. Students have experienced working with heavy construction plant and

excavations, Figure 6. Manual lifting of heavy items has been carried out using sufficient student numbers and correct lifting procedures, Figure 7. Potential injury has been avoided during steel-fixing by using the correct procedures, PPE and safety caps on all steel bar ends, Figure 8. Students have worked at height using suitable safe access facilities, Figure 9 and have worked with corrosive materials (concrete) using correct training and PPE, Figure 10. Students have worked safely with ground excavation using appropriate construction procedures, Figure 11.



Figure 6 Working with construction plant



Figure 7 Manual lifting



Figure 8 Steel-fixing



Figure 9 Concreting



Figure 10 Working at height



Figure 11 Excavation work

HEALTH AND SAFETY INCIDENTS AND NEAR MISSES

The challenge of getting 100 students to work safely in a construction site environment has been considerable. It is inevitable that some minor incidents and near misses will occur but it is important to learn from these events to prevent recurrence. Events which have involved both University of Liverpool students and students from other universities, working with a different Contractor have included:

- A student using a steel-saw to cut through reinforcing bars and while wearing nylon trousers. The cutting sparks (Figure 12) melted the trousers and caused minor burns to the leg. All students had previously been advised to wear clothing made from natural fibres. This will be more closely monitored in future.



Figure 12 Cutting using steel-saw

- A student was observed using a hand saw to cut through a piece of timber while awkwardly positioned. This resulted in him working with his arms crossed so that his left forearm was close to the hand saw blade. He was stopped and advised how to position himself and cut the timber safely.
- A student used a power rip saw to cut through a large sheet of plywood. The plywood was poorly supported and both the student and the plywood fell to the ground. During the fall the rip saw was still activated but the safety guard came up and prevented any damage or injury. The student was reminded of his training regarding how to support timber effectively before cutting.
- A student used a length of string of inadequate strength to pull on a structural timber member. The string broke and the student sat down heavily. Although this was a very minor incident, the entire Constructionarium site came to a halt for over one hour as medical services were brought in to ensure there was no serious injury. All students were advised that they must adhere to the approved Method Statements and not improvise procedures on site using inappropriate materials.
- Using a hand saw with excessive force caused the blade to bow and jump out of the cutting slot. Although the student was wearing safety gloves, the blade caused a deep cut to the thumb. This was a difficult accident to foresee. Although safety training is given in the correct use of power saws, it was incorrectly assumed that students could use hand saws safely. The use of PPE mitigated the injury. This incident is being used as a case study with the health and safety training for future students.
- A similar small accident occurred with a student nailing timber. He missed the nail and hit his own thumb with the hammer. On this occasion the student was not wearing safety gloves as instructed and some minor bleeding occurred. Correct use of PPE would have mitigated the injury, which in any event was quite minor. This incident was used to illustrate all students the need for wearing PPE at all times on site and for taking care when using tools.
- A potentially serious incident occurred when two students stepped over a safety barrier and walked on a bridge structure which was not properly secured and in an unstable position. Sharp sightedness and quick action from supervising staff prevented this situation turning into a major accident. Subsequent discussion revealed that the students knew that stepping over a safety barrier was wrong but they had not appreciated the seriousness of their actions. It is vital that although all students should enjoy the Constructionarium experience, they should not be allowed to let their enthusiasm overrule their judgement and health and safety training. It had not been anticipated by supervising staff that students would deliberately step over a barrier placed to keep them safe.

PROGRAM REVIEW AND ASSESSMENT

The Constructionarium is a new initiative which has provided students with an invaluable hands-on experience of construction site working practices and methodology together with management/planning/costing procedures and team working skills. The embedment of health and safety into every practical construction activity has been essential to ensure a safe working experience. This reflects practices that students will encounter when they begin employment in the construction industry.

This module cannot be compared directly with the previous student experience because there was no comparable implementation of this active learning. However some modules have been reduced in content to make space and avoid replication. For example students no longer manufacture a large reinforced concrete beam in the laboratory for testing. In place of this there is plenty of site concreting experience associated with Constructionarium. The

students test in the laboratory a precast reinforced concrete beam which has been commercially made to specification.

One of the unintended consequences of the success of the Constructionarium has been a surge in demand for the MEng Structures and Civil Engineering course, to the detriment of the Environmental and the Maritime MEng courses. All of the Constructionarium projects involve construction of one structure or another. The students enjoy this so much that they then opt to do the Structures MEng course in their 3rd and 4th years. Plans are in hand to redress the balance by introducing Constructionarium projects with more relevance to Environmental and Maritime projects.

The Constructionarium module has been subjected to independent review by the Joint Board of Moderators accrediting the Liverpool degrees and has been highlighted as an example of good practice in learning and teaching.

CONCLUSIONS

The Constructionarium initiative has provided a large number of students with an invaluable active learning experience of construction site techniques and procedures. By working with Contractor and design Consultant professional staff on realistic construction projects, the students gain an appreciation of real life operating procedures. The embedment of Health and Safety into both the preparation and operation for the Constructionarium has prepared the students for safe working practices in their future career and also to maintain a safe working environment for the Constructionarium itself.

The Constructionarium has been operated for three years by the University of Liverpool in conjunction with Contractors Edmund Nuttall and Morrisroe and with design consultants Mott MacDonald without any significant health and safety incidents or accidents. Lessons have been learned from several minor incidents and will be used to improve and enhance future Constructionarium events. It is clear that no amount of training and instruction can be provided to guarantee a 100% safe working environment. Students must be actively engaged in thinking about every action they wish to carry out on a construction site and the potential health and safety implications. Supervisory staff must maintain constant vigilance to reinforce the health and safety training and to maintain the good safety record so far enjoyed from the Constructionarium by all the participating universities. It is vital that Method Statements and Risk Assessments are conscientiously prepared and followed. These procedures are not merely a box-ticking exercise to provide a real contribution to a safe working environment.

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- Morrisroe



REFERENCES

1. The Constructionarium, <http://www.constructionarium.co.uk/>
2. The Liverpool Engineer, http://www.liv.ac.uk/engdept/liverpool_engineer.htm
3. Taylor RH, Stacey N, Cummings R, Vallance S, Bellenger D and Smyth V 'Further development of an IIG/HSE e-learning health and safety risk education package for engineering undergraduates'. HSE Research Report 482, 2006.
4. Inter-Institutional Group on Health and Safety/Health and Safety Executive, 'Engineering a safer future', software CD, available from Paul Davies, PDavies@theiet.org , 2006
5. Edmund Nuttall Ltd, now known as BAM Nuttall Ltd, <http://www.bamnuttall.co.uk/> , website accessed 24/3/2009
6. AJ Morrisroe & Sons Ltd, <http://www.morrisroe.co.uk/> , website accessed 24/3/2009
7. Mott MacDonald, <http://www.mottmac.com/> , website accessed 24/3/2009

Biographical Information

Steve Millard is a Professor of Civil Engineering and Leader of the Construction and Infrastructure Research Group in the Department of Engineering at the University of Liverpool in the UK. He is interested in pedagogical developments such as computer aided learning (CAL), computer aided assessment (CAA), asynchronous and distance teaching and many aspects of active learning within Civil Engineering.

Zhongwei Guan is a Senior Lecturer in the Department of Engineering at the University of Liverpool in the UK. He is interested in active learning within Civil Engineering through collaboration with construction professionals.

Corresponding author

Prof. Steve Millard
Department of Engineering
University of Liverpool
Brodie Tower
Brownlow Street
Liverpool
L69 3GQ
UK
+44-151-794-5224
ec96@liverpool.ac.uk