

A CULTURAL DIVIDE? DIFFERENT MODES OF TEACHING CONSTRUCTION MANAGEMENT

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EXTENDED ABSTRACT

The area addressed in this paper deals with the Teaching Modes most suitable to educate and train Students and Practitioners in Construction Management. It posits that Construction Management might be taught more often and more engagingly through a Project-Based Learning approach. As demonstrated at Imperial College London, Active-Learning Based Programmes and Modules can integrate Construction Management learning in modules that are studio-based (Creative Design), classroom-based (Energy and Infrastructure: Project Management) and field-trip based (Constructionarium). Another well-known and widely-used active-learning project is the Peri Construction Exercise.

This paper looks at both the Peri Construction Exercise and the Constructionarium, both of which ask students to cope with real engineering questions and both of which are used in multiple universities across a range of engineering and building degrees, for students of various levels. The two different educational programmes feature, and are affected by, quite different attitudes concerning the project scope, procedures, locations, resources, assessment and accessibility. However, both Educational Modules allow Students to be aware of the real pitfalls of construction, the behaviours required of engineers, the application of theoretical knowledge and practical know-how, and the management of purposeful engineering activity to requirements of time, cost, quality and safety.

The main findings that the authors present involve the difficulties and desirability of potential International Educational Joint Modules which might enhance a pan-European Approach to Active Learning in Construction Management. The advantages that can be gained can serve the interests of academic standards through enhanced knowledge-sharing whilst achieving a sensible response to difficulties in the economy through better utilisation and sharing of resources. The industry-centric focus of active-learning means that it can help with a better uptake of Building Information Management (BIM) approaches and a better understanding of what BIM means in different countries and different sub-disciplines of engineering and construction. All active learning using team-based projects leads to students having to communicate, and International Educational Joint Modules that have a focus on management and practice are expected to lead students (and staff) to a better understanding of management cultures in different countries, and improved preparedness of engineers for more open markets in construction.

KEYWORDS

Project-Based Learning, Construction Management, Building Information Modelling and Management, Active Learning

1. INTRODUCTION

The paper aims to deal with Teaching and Learning Modes concerning Construction Management, through a 'comparison' between the so-called Constructionarium, conceived by Prof. Chris Wise and Dr. Ed McCann, on behalf of Imperial College, London, in 2003, and the well-known Peri Construction Exercise, an International Competition for Students which is particularly popular in German-speaking Technical Universities and Universities of Applied Sciences, established in the late 1990s. Both of these Special Programmes are practical in nature and have advantages and disadvantages pedagogically, administratively and financially. However, the aim is to make students more 'industry-ready' as future Graduates, trying to enhance their experience. The comparative analysis seeks to investigate and analyse each scheme and identify transferable elements.

1.1 The Peri Construction Exercise

The Peri Construction Exercise is an industry-sponsored competition, where student teams are given plans and specifications. The Exercise requires that the students submit their own Construction Site Management Plan dealing with formworks. They must respond to the Project-Based Case Study that is provided. They have to work in small groups in order to do it, without any field testing, prior to submitting their work to a Jury.

The Peri Construction Exercise defines the time to complete the concrete part of the structure: 12 weeks, and the average working time per week: 40 hours. Students are told that all excavation and drainage work will be done by Sub-Contractors: it has been agreed to allow a 2-week period for the excavation and drainage of the building site. This adds up to a total construction time for building site equipment, excavation, drainage and structural work of 14 weeks.

The Peri Construction Exercise has been conceived by Peri, a large German manufacturer of formworking systems, in order to improve the skills to be taught to the students in Construction Management. It is an exercise where students need to be able to 'think ahead' and visualize the processes and resources needed to achieve a project. The students do not actually construct the project but have to be able think as designers and managers. Time needed to complete the Exercise is estimated to be about 75 hours per person (for a team of five), depending on the team's background knowledge.

The Eighth Peri Construction Exercise 2011 involved a host of Universities all over the world, as this Project-Based learning activity has become popular quickly. In 2009 almost 400 information folders containing assignment details for the Institutes and Faculties were distributed, according to Peri itself, resulting in a total of 36 entries that were received from Germany, Austria, Italy as well as Malaysia and USA.

As an indicator of the strong German take-up, it can be noted that in 2005 the Competitors were ranked as follows:

Winner: Technical University Braunschweig

Second: University of Applied Sciences, Munich

Third: University of Dortmund

Fourth: University of Applied Sciences, Kaiserslautern

Fifth: University of Cooperative Education, Mosbach

In 2007 the Higher Education Institutions were assessed and ranked as follows:

Winner: University of Applied Sciences, Munich

Second: University of Applied Sciences, Wiesbaden

Third: Technical University, Graz

Fourth: University of Stuttgart

Fifth: University of Applied Sciences, Zittau/Görlitz

German interest shone again in 2009, when the Exercise prize was awarded to the Hochschule München whilst the Technische Universität München came fifth. The other main competitors were: Technische Universität Graz, Hochschule Zittau/Görlitz, Fachhochschule Kärnten, Fachhochschule Erfurt, Fachhochschule II Kaiserslautern, Hochschule für Technik Stuttgart, Technische Universität Braunschweig IBB. The highest-ranked non-German-speaking universities have been Università degli Studi di Brescia (from Italy) and Roger Williams University School of Engineering Computing and Construction Management (from USA).

Whereas the Peri Construction Exercise focuses on the planning and visualization of construction, with the construction management plan being judged, the Constructionarium presents students with completed designs and an obligation to construct them in 5 working days on site. The two events are highly complementary with one focusing on the ability to plan and the other on the ability to execute plans. Both require teams of students to work together, thus requiring them to practise team management. Both activities require student teams to think deeply about construction management and how to make construction choices under pressure of time.

1.2 The Constructionarium

Since 2003, the Constructionarium, pioneered by Imperial College London, has spread rapidly amongst built environment schools in UK Universities (mainly in England and Scotland), because it immerses students in the responsibilities of engineers: technical, managerial, financial and legal, whilst giving them a realistic site experience. On a genuine commercial construction site, it would be illegal, and/or a breach of contract, to permit students to take so much responsibility for actual construction. Hence, the Constructionarium takes place on an 'academic site'.

A number of universities in the UK use or have used Constructionarium already, and more have expressed interest. Universities which have used constructionarium include:

- University of Greenwich with Atkins;
- University of East London with Atkins and P J Carey;
- University of Liverpool with Mott MacDonald and A J Morrisroe;
- University of Salford with United Utilities and William Pye Ltd;
- University of Birmingham with Birse Rail;
- University of Southampton with Aecom and Laing O'Rourke;
- University of Westminster with Robert Bird Associates and Byrne Bros;
- University of Cambridge with Ramboll and Laing O'Rourke;
- University of Nottingham with Walsh Associates and Sir Robert MacAlpine;
- Imperial College London with Expedition Engineering and John Doyle Construction;
- University College London with Watermans and Laing O'Rourke.

University of Northumbria was an early adopter of Constructionarium and events have been held in Scotland and discussions have occurred in Wales about future events. There is an expansion of interest into the nuclear power station sector with Further Education Colleges looking at introducing this model of learning, particularly near new-build nuclear power stations such as Bridgwater College for the Hinckley Point C station in Somerset.

The Constructionarium was created because Imperial College London found that classroom-scale practicals on the undergraduate MEng Programme in Civil Engineering

could not instil the behavioural and practical skills and attitudes acquired through site-scale construction. Using dedicated land at the National Construction College, the Constructionarium tries to replicate UK site conditions as authentically as possible, whilst accelerating the time span: students move from 'breaking ground' to 'topping out' a sizeable structure in 5 working days.

Each structure has a team of 20 students for Construction Management (managing Time, Cost, Quality, Safety, Personnel, Training, Media Relations, Client Liaison and Evaluation). Students face the physical consequences of their management decisions as they build their structure. Thus, it differs from work experience because Constructionarium student teams take all roles including Managers and Chartered Engineers, Specialist Trained Operatives and General Operatives. The exception is skilled work where the law requires operatives to be licensed (e.g. scaffolding and crane driving): students then work with the licensed operatives. By taking a designer's drawings and translating them into physical reality, students learn the meaning of 'constructability'.

Based on the above, both Constructionarium and Peri Construction Exercise involve either the leading Technical Universities (Imperial College London, University of Cambridge, UCL, ETH Zurich, TU Munich, Uni Stuttgart) or the former Polytechnics and the Colleges in the UK and the Universities of Applied Sciences in Austria and Germany (and may include Switzerland, too). Some students of the University of Brescia (School of Engineering) were involved in both of these Educational Programmes: this provides a basis for comparison of the student experiences whilst discussions between teaching teams from the Peri Exercise and Constructionarium enable analysis from 'expert educational witnesses'.

The authors investigate how such Educational Programmes might be integrated and assess how Project-based Learning or Active Learning could be improved by accommodating different ways of thinking, managing and educating whilst recognising the impact of differences in local 'construction management culture'.

2. CONSTRUCTION MANAGEMENT AND ACTIVE LEARNING

At Imperial College, according to Prof. Julian Bommer, "visiting professors from industry have also been used significantly in the Department of Civil and Environmental Engineering to help understand and address industry needs. The first appointment (Professor Chris Wise, with sponsorship from the Arup Foundation) addressed feedback from accreditation bodies that there was not enough practical design in the course and this led to a number of changes, including the development of the Constructionarium". The partners available to fund and to support the Constructionarium came from Engineering Consultancies (Arup, Buro Happold, Ramboll, WS Atkins, etc.) and the Construction Industry (John Doyle, Laing O' Rourke, Morrisroe, etc.), whilst, as it has been reported, the Peri Construction Exercise is wholly managed by the German Manufacturer. However, a similar event has been seen with the Doka Exercise (Doka being the main Austrian Competitor of Peri). Clearly, industry sees benefit in having students rehearse the skills and knowledge required, and it exposes students to the existence of the companies.

Clearly, any University can use both concepts, - the Constructionarium and the Peri Construction Exercise, - according to its own needs and goals. A comparison allows the authors to investigate any sort of cultural divide that could exist between the approaches to education in Project & Construction Management: the British approach and the Continental (in this case, German-Speaking) one.

The British approach, as used at Imperial, is experiential learning-based: the Students are forced to respond to practical challenges of matching theoretical knowledge and vacation work experience to the engineering task they have been set. It picks up on team-work skills learned in group-based classroom activities, such as Creative Design classes. The Constructionarium grew from the need to introduce "constructability" to students, so that their design work would be more realistic and pragmatic from a contractor's point of view. The universities came to realise that the hands-on construction education was valid in its own right, not only to serve design classes but to help students synthesise many engineering concepts and construction management.

The Constructionarium concept was invented for Imperial College by two industry partners, John Doyle Construction Ltd (Engineering Contractors) and Expedition Engineering (Consulting Engineers). This triangular partnership was created to allow the construction industry to have a more direct impact on student learning at Imperial College, helping to address the balance between the teaching of theory, design and construction. Imperial College has a long tradition of excellence in teaching theory and technical design. From 1997, Chris Wise, then of Arup and latterly a founder-director of Expedition Engineering, brought in Creative Design teaching as compulsory element of the first three years of Imperial's four year undergraduate degree in civil engineering. He was joined by Expedition's Ed McCann as co-teacher and they realised student understanding of design was undermined by students' lack of hands-on experience with issues such as Site-working practices, Client realities, Budget realities, Safety realities, Time pressure, Physical limits of people and materials and general 'know-how'.

While the Constructionarium can address learning objectives relating to Time and Cost through the experiential learning process, it is perceived as less suited to addressing longer-term quality issues, as the students know that no one is truly purchasing their end product. The students can afford to 'fail' on quality because there is no genuine client who will create a legal dispute. However, they do face the immutable 5-day time limit (see Table 1). Also, the financial costings aspect forces students to think very hard about the financial implications of their engineering decisions on site.

Table 1: Timeline for students on a Constructionarium

Thursday	Friday and Saturday	Sunday	Monday and Tuesday	Wednesday and Thursday	Friday
Day 1	Days 2&3	Day 4	Days 5&6	Days 7&8	Day 9
Brief Students on projects and safety, allocate student teams	Two days off before intensive field trip	Arrive at CITB campus Site safety talks	Meet client. Contract negotiation and finalisation; Break ground.	Works. Deal with contract manager on claims And variations	Finish works Final Accounts Depart

The Constructionarium entails a course designed to generate an atmosphere that is as close as possible to the experience of running a real engineering project. During the Project, students use their own initiative and engineering knowledge gained during the first three years of the MEng course, and are guided by experienced Contractors and Engineers. The emphasis is on the experiential learning of applied design and construction: students gain experience of Team-working and Communication, Management, Engineering Judgement, Creativity and Problem-solving.

Likewise, according to the Peri Construction Exercise's rules, an exercise submitted must concentrate on the specified tasks only. Any extra tasks provided by the participants will

not be evaluated. Students are faced with the reality that, unlike school where they might try to do 'extra' to please their examiner, an industrial client will not pay extra (or give extra reward) for things the client did not request. Peri Exercise lays down a reality that the specification/brief must be adhered to, with precision.

Constructionarium requires that the student teams take on all roles from Chartered Engineer and Project Manager down to General Labourers (this distinguishes a Constructionarium from ordinary work experience where students only function as a student labourer or student engineer).

The Peri Construction Exercise asks the students to generate the most suitable option, compelling them to show how they solved the given question/challenge. Indeed, Peri envisages that, should there be more than one solution for a given exercise, an explanation for the selection of a particular solution should be documented in an easily understandable way. The work must be based on the given layout.

The main purposes of the Constructionarium could be summarised as:

- to bring industry and academia together in educational setting where industry's strengths dominate, but mesh with academic objectives in engineering education.
- to provide students with shared points of reference for reflective learning that draws on a wide body of technical, practical and academic knowledge;
- to keep academic staff in touch with construction site reality, practices and culture;
- to provide a safe way for large groups to gain site experience together;
- to simulate working for a client, but to actually experience physical construction and decision-making.

The Peri Construction Exercise simulates that a consortium of companies will carry out the construction work. An agreement has been reached that all required equipment will be rented. The equipment costs should be acquired from the corresponding documentation, for example RS Means. Rental rates for the formwork materials are given in the task. Students are told that a Sub-Contractor will do the reinforcement work. But, just like the Constructionarium, the students must exercise engineering decision-making. They must commit resources and price work, using engineering knowledge to identify the work and make predictions about time, safety, quality and cost.

The Constructionarium entails that students must schedule the tasks and have to quantify materials, equipment, manpower resources, and predict when they will need concrete delivered, etc. They have briefing days and chances to work as teams before going to site but most of their time together is during the actual construction task.

During Constructionarium the students discuss the choices they made together with the representatives from Consultancies and Companies: for example it is left to the student group to resolve issues such as Project Management, Economics of a Project, Time Management and Materials delivered on time. Members of the teaching team are available for on-site consultation to develop the brief so that students receive immediate feedback as to their progress. Teachers report that students struggle with the idea that there can be multiple correct choices or a variety of ways to approach a task: they tend to want a single correct answer. If three staff give three different opinions, the students can get stressed.

The Peri Construction Exercise requires that missing information must be carefully selected. Reasons should be explained in a short paragraph and include the source. The Peri Exercise necessarily requires students to consider the information they have available and the justification for the decisions they make.

Constructionarium gives commercial organisations the opportunity to encourage young people to enter the construction industry by showing them what it is like to work on real Construction Projects. The Peri Construction Exercise has a focus on the students doing work to meet a brief: the deliverables by students on the Peri Exercise are documentation of the following:

- Building site equipment, including all necessary specific values, all necessary equipment items, a plan of the construction site setup.
- Bid documents for concrete and reinforcement work, including a list with all positions titled concrete and reinforced concrete with hourly estimates and material costs with reference statements, a bid for the concrete and the reinforced concrete work.
- Choice of procedure / calculation, including comparison of slab formwork systems, comparison of wall formwork systems.
- Formwork solutions, including all necessary formwork solutions for the straight walls, for the slabs, and for a formwork solution for the round wall found in the basement.
- Details of construction implementation.
- Construction development plan.

In contrast, Constructionarium students do not design what they build. For the Constructionarium the students are given the drawings of their assigned project. They are organised into groups of 16 – 24 students: in the Peri Construction Exercise, chiefly groups of up to five students are accepted.

An essential objective of the Constructionarium is the self-management and organisation of students, where they take responsibility for allocating tasks within the separate teams. The student teams of 16 or 24 acted as contracting companies and had to deliver their projects to time and budget within the five day on site period (although the event runs for 6 days, the first day is arriving and induction, with no site work). The site teams were required to do all the work, establish a programme for the works and provide a schedule of costs. To be involved in the Peri Construction Exercise, groups of up to five students are accepted. They, too, self-organise. The Exercise is based on a real project that has actually been completed. The geometry of the building and the basic conditions have been modified to simplify the Exercise.

The Constructionarium originally formed the first part a five-week main Design Project, which potentially contributes up to 16% of their 3rd year degree marks but, at Imperial, Constructionarium has now been separated from the Design Project and made into its own module in its own right. The design course is held after the summer examinations so that there are no other academic distractions: the Constructionarium originally 'merely' informed the students about constructability so that their design projects were more realistic about processes and resources required: like Peri, the Imperial design project is mostly document based but, at the end of each week, the Imperial design teams make a milestone presentation of their work for discussion with a critical panel of the academic Project Supervisors and invited industry critics. On site at Constructionarium, each project team will have their own portacabin, where they can plan work, report to tutors, and use for lunch breaks and wet weather shelter. There will also be a manned store with all the necessary equipment and materials to carry out the scale constructions. In contrast, the Peri submitted Exercise is document-based, and must not exceed 100 pages including all layouts and plans (A4 or letter format, font 10, font 8 only for charts). Exceeding the page limit will result in a deduction of points in the evaluation. There is, necessarily, an emphasis on communicating, on paper, as engineers.

Constructionarium can monitor projects against the pre-agreed programme and time and measures taken to ensure timely completion. The project is a demanding exercise in

terms of personnel, within the student teams and for staff supervising student teams. Peri also involves serious application of effort but has the advantage of not requiring actual site infrastructure.

Table 2. Comparison summary of the two educational modules.

	Constructionarium	Peri Construction Exercise
Experience	Yes	No
Theory	No (partially)	Yes
Tailorability	Yes	No
Role playing	Yes	Yes (partially)
Scope	Widened	Narrowed
Design	No	Yes
Construction	Yes	No
Specialism	Low	High
Compulsoriness	Mandatory	Elective
Competitiveness	High	High
Size of the Team	20 persons	5 persons
Duration	10 days	6 months

3. CONSTRUCTIONARIUM: DIFFERENT POINT OF VIEWS

The University of Cambridge adopted the Constructionarium learning module within a larger work module, defined as it follows:

- Week 1: Monday and Tuesday. Introduction to Constructionarium. Lectures from Consultant and Contractors about planning and safety issues. Planning of work to be done and assignment of roles. Brief preliminary report handed in by Friday. Two days on Structural Modelling Project
- Week 2: On Constructionarium site
- Week 3: Two days to write individual final report. Three days on Structural Modelling Project
- Week 4: Structural Modelling Project

Students choose, or are allocated, a role within the team. The team then has to work together to decide how the structure is to be built and to fabricate the necessary elements. Some equipment will be available on site. Engineers from the Contractor and the Consultant will assist but it will be the responsibility of the students to produce a safe, workable and economic scheme, and then to put it into action.

The marking will be on an individual basis, primarily for a final report, but students will be awarded (or lose) marks depending on how well they contribute to the team effort (in contrast to Imperial where students receive team marks, not individual marks).

The University of Leeds defines the Constructionarium as Construction Site Field Course, where the students are pre-allocated into project teams (each of about 18 students). The students receive an individual assignment to research and have to write a report on the design and construction of a corresponding real (i.e. full-scale) project. The students only receive the briefing packs for their (scaled-down) project when they board the coach for the journey to the Constructionarium. These packs contain a description of the site and the required structure together with the necessary engineering drawings.

Finally, the University of Liverpool reckons that the Constructionarium initiative can be classified as the implement section of the conceive, design, implement, operate (CDIO) educational framework for civil engineering students. CDIO is an international learning

and teaching initiative which is based on the principle of embedding active learning into engineering education at all levels. Students are required to follow the same professional and health and safety procedures that a construction contractor follows on a real construction project. Following their site week, Liverpool staff distributed a post-Constructionarium questionnaire, to assess the student perception of the learning outcomes. A de-brief meeting with the contractor and consultant was then held to report/discuss student feedback and to help run the Constructionarium more effectively next year.

Students also gave helpful feedback and recommendations to improve future Constructionarium, which are selectively listed here as indicators of reflective practice:

- a) Shorten the management meetings with academics and combine with the contractor meeting.
- b) Installation of Autocad software onto the group laptops provided.
- c) Use Constructionarium projects as part of the design coursework in other modules.
- d) Election of the project manager or devise a better way than self-selection.
- e) Create a new role of environmental manager.
- f) Organise more team meetings during the Constructionarium Week.
- g) Develop a better understanding of the project before the Constructionarium week and share views and personal previous construction experiences.
- h) Provide more guidance on the preparation of a method statement.
- i) Enable familiarisation with the team roles and responsibilities before the Constructionarium week.
- j) After the Constructionarium, introduce a follow-up meeting with the contractor and consultant.

From this type of feedback, it can be seen that Constructionarium has students engaged in micro-tasks as well as big tasks. They identify their gaps in knowledge (e.g. method statements) and skills (how to form effective teams and manage individuals) and processes (fewer meetings, please) and resources (Autocad on our laptops please). The resource demands and attention required of lecturers is very high and onerous.

4. BIM(M)-BASED CONSTRUCTIONARIUM AND SUSTAINABLE CONSTRUCTION

The input data for both the Constructionarium and for the Peri Construction Exercise are provided with precision. But in the Constructionarium case, the students must then deal with the evolution of real situations and with representatives of Consultancies and Contractors, while the Peri Construction Exercise is only likely to require students to consider their selection by lecturers at the universities, as well as the Jury for the first five admitted to the final stage. The client input is more clearly defined for the Peri Exercise. In any case, the Constructionarium often belongs to a structured educational programme based on the experience learning, while Peri Construction Exercise is a task that can only be attended on a voluntarily basis.

Regarding the level of the internationalization, UK Universities have many international students and EU student numbers are also very high, so it can be assumed that the experience is multicultural, and in case of Construction Exercise origin of students is more homogeneous: however, the Exercise itself has several participating countries.

It is clear that the assessment's criteria for the Peri Construction Exercise are based on the ability of the students to apply construction techniques to the case study through a detailed analysis of the constraints and to define in detail a logical way of solving the Exercise, also relying on a large body of technical literature. Peri Exercise requires students to have (or develop) information literacy skills, to find the right information.

The Constructionarium, based on the primacy of the Project Management-oriented principles and on the technical support coming from the professional and industrial partners, asks the students to cope with topics as Health & Safety Management, Environmental Management, or Financial Management: these are quite different from the Peri Construction Exercise.

It could be argued that to make a real comparison between the Constructionarium Programme and the Peri Construction Exercise does not make sense, since one is practical construction and one is design for constructors. Nevertheless, Construction Management is taught in a quite different ways from the various Universities throughout Europe. Both Constructionarium and Peri Exercise require students to make decisions as engineers, and to use engineering foresight. Construction management issues thread through each of these engineering challenges, but can be judged (assessed) differently. Thus it could be advisable to establish some Joint Educational Programmes (addressed to Graduate or Post Graduate Students) to allow the students to learn to cope with different ways of thinking and legal systems: to permit better understanding of how to make decisions in different engineering contexts and different engineering countries.

The imperative for such understanding grows. For instance, in 2011, the British Cabinet Office issued a Government Construction Strategy (2) that purports that a fully collaborative 3D environment must be needed, so that all Players and Stakeholders involved in a Project are working on a shared platform with reduced transaction costs and less opportunity for error. This will be a phased process working closely with industry groups, in order to allow time for industry to prepare for the development of new standards and for training. Moreover, Government will require fully collaborative 3D Building Information Modelling (with all project and asset information, documentation and data being electronic) as a minimum by 2016.

Imperial College London will take into account such a goal, through a step-by-step introduction of 3D BIM-Based Models. In June 2011, a first attempt, involving Università degli Studi di Brescia and Virginia Tech, was made to introduce the Building Information Modelling (and Management)-Based Automatic Recognition of the Progressed Works. Some students from the Università degli Studi di Brescia, who are preparing a MSc Thesis in Architectural Engineering about BIM(M), Laser Scanning, Augmented Reality and Automatic Tracking and Monitoring, worked with students from Imperial on their Constructionarium. The Italian students coached Imperial students on the collection of picture data from their construction project. The picture data was fed by the Italian students to 4D Models. This meant that they could superimpose on the photographs an image of what progress should have been made on the site if the Constructionarium project was on schedule. It generates a virtual-reconstructed scene using software models from Virginia Tech University in USA: the scene is generated using structural drawings and time plans (intended construction) compared against the pictures taken on the Construction Site (actual construction).

There would appear to be real benefits from introducing students, on exercises such as the Peri Exercise and the Constructionarium, to the use of Building Information Management tools, techniques, thinking, resources, assessments and evaluation. The Peri Exercise, with its design and resource focus, presents students with the type of task where they learn to persuade a jury (client) of the merits of their work in competition (tendering situation). Applying BIM principles will be essential: from 2016, the British Government will not give work to anyone who is not able to show that their designs are done with BIM management underpinning it and able to be used when the design is taken forward for construction.

Likewise, BIM can actually be seen in action on a Constructionarium site, but only if students have been taught about its purpose and how to make use of it. On a construction site, technology becomes an issue. That raises logistical and resource questions for the organizers of Constructionarium and it may be that each university will have to find its own resources for BIM to be seen in action on site. Currently, it is probably limited to quite old-fashioned approaches to bringing together the record-keeping and project management software on site. But the work done with Brescia University and Virginia Tech shows that undergraduate students can become quite excited about the possibilities of technology on a construction site. Indeed, for students who include computational methods and computing amongst the 'theory' subjects that they do, and who are interested in applied technology, the introduction of BIM into the Constructionarium practical exercise may raise its status. A 'wired up' approach to management on a construction site is in keeping with the 'go-anywhere' approach to information technology and breaks down the division between studio-office work by consultants and on-site management work by senior engineers working for contractors.

Further, the 4-D experiments conducted by Brescia students with Imperial students shows that advanced technology for BIM will enable all levels of workers to see or be shown their actual work against intended targets. Where the Peri Exercise challenges students to be able to foresee the requirements of construction and design for them, BIM could permit them to make visual models and introduce another form of communication to their client. For Constructionarium, a project manager (student team leader) would be able to show his/her (inexperienced) team-workers their progress. They would be able to show the specialist licensed operatives and their client (and supervising teachers) their progress against intended target and make explicit the scale of the challenge in front of them for the next day(s).

An outcome of both the Peri Exercise and the Constructionarium is increased confidence in the students, not least because they have engaged in intense, critical engineering thinking and submitted it for the judgement of a client/jury. From such experiences, students develop understanding, insight, and sow seeds for an identity as an engineer who can make engineering decisions. The use of BIM as part of that decision-making engineering thinking seems a logical development for the future of both of these practical exercises.

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