Virtual Construction Project Management Environment

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March 2016

AKÓ AOTEAROA
NATIONAL CENTRE FOR TERTIARY TEACHING EXCELLENCE

Unitec
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Contents

Executive summary

The focus of this research project was to develop a virtual Construction Project Management (CPM) environment to enhance the educational outcomes for learners in the discipline of Construction Management. The environment utilised Virtual Design and Construction (VDC) technologies and processes and project-based learning. A virtual model of a building was used as the central course resource to investigate, analyse and simulate the construction project.

Three main challenges were encountered in setting up and managing the environment. These were related to content, delivery and development of the environment. The benefits of the environment were improved student engagement and, through that, good learning outcomes in CPM topics, particularly in Building Information Modelling (BIM) technology for CPM.

The overall project objectives were met. The students found the environment challenging, but very engaging, and considerable improvements in knowledge and skill development were seen in all topic areas during the course. However, fitting all learning outcomes in proved to be too much. This had been signalled during the planning stage of the course and the decision had already been made to reduce slightly the emphasis of the VDC process compared to the VDC technology, and to leave a comparison of traditional and emerging methods outside the course.

The concept has proved to be transferable to other Construction courses, such as Construction Technology and Construction Economics. The findings have been disseminated nationally to other tertiary institutions delivering VDC subjects, and internationally via Australasian Universities' Building Education Association Conference. An international journal paper with a focus on Building Information Model development for educational purposes is in progress and will be published 2016.

Acronyms and terminology

Virtual Design and Construction (VDC)) is the use of multi-disciplinary performance models of design-construction projects, including the product, work processes and organisation of the design-construction-operation team in order to support business objectives.

Building Information Modelling (BIM) is a subset of VDC focusing on the computer-based product design, which supports the processes of VDC.

Building Information Model is a 3-dimensional model of a building or an infrastructure, which contains information to be used for various analysis and simulation purposes. Can be called also a virtual model of the building.

Virtual Construction Project Management Environment is an environment developed in this project which uses Virtual Design and Construction processes and a Building Information Model as the central resource for students to learn the essential skills needed in Construction Project Management.

Background

The current Construction Managers' education delivery model does not support students' acquisition of the most important skills in construction management: interpersonal, time management and problem-solving. In addition, the New Zealand construction industry is facing a fundamental change within the discipline, with the introduction of Building Information Modelling (BIM)/Virtual Design and Construction (VDC). VDC is emerging as a new collaborative way of working in the construction industry. It requires a corresponding fundamental change in teaching and learning methods. To address these issues, this project focused on creating a Virtual Construction Project Management Environment for one key course of Construction Managers. This level 6 course was delivered over the period September-November 2014. The project tested whether students develop and improve both soft skills (interpersonal, time management and problem-solving) and technical skills (processes of planning and basic concepts and processes of VDC). The project also investigated if the environment could be applied to other Construction Managers' courses and across different construction disciplines.

Three objectives were set for the project:
1. To enhance educational outcomes for learners by creating a Virtual Construction Project Management Environment that utilises Virtual Design and Construction (VDC) technologies and processes.
2. To create a concept that can be transferable to a variety of courses in the construction discipline, including Architectural Technology, Construction Economics, Facilities Management etc.
3. To contribute to the development of a more coherent knowledge base of effective teaching and learning in the construction discipline.

Literature review

Literature shows that the most important skills of a Construction Management professional are the ability to communicate and to solve problems (Arts et al, 2006; Jaeger and Adair, 2012). Literature also shows that Construction Management graduates lack practical building technology knowledge building, communication and time management skills, and the ability to solve problems. (Love et al, 2003).

> CPM education has traditionally been a combination of lectures, tutorials, assignments and exams. Isolated, static and individual assessments have limited relevance to project tasks in the industry and also affect student motivation. Instead students should be involved in tasks similar to real world ones, which rehearse their collaboration, communication, creative thinking and problem solving skills. (Puolitaival et al., 2015, p. 2)

BIM/VDC is an emerging area in the New Zealand construction industry. VDC is a collaborative way of working with all construction project stakeholders, which embeds key product and project data into a 3-dimensional computer model of a building. This can be used for effective management of the project and project information throughout the whole project lifecycle – from earliest concept to operation (HM Government, 2012). Therefore VDC can be seen as an effective way to improve productivity and could even be a part of the solution for housing needs in Auckland and for the Christchurch rebuild (Kane, 2012).

VDC offers a virtual project environment for all stakeholders. Operating in a VDC environment requires new skills, because of the technology involved, and an understanding of the different design and construction process compared to the conventional approach (McDonald, 2012; Succar, 2013). Conventional two-dimensional and paper-based processes offer few possibilities for proper collaboration. When the project team has the required skill and knowledge set, VDC assists with coordination, communication and collaboration, and improves the accuracy of plans and programmes considerably (Eastman et al, 2011).

> There has been significant discussion in published literature about the strategies that tertiary education should take in order to respond to the change in the industry. Guidelines, frameworks and strategies have been established for curriculum development: Pikas et al. (2013) has developed a BIM education framework for construction engineering and management programmes; Lee et al. (2013) proposed a guideline for integration of BIM in construction education; and Forsythe et al. (2013) discuss a programme wide project-based learning (PjBL) approach, to name a few. Whilst the benefits of the new technology and processes have been recognized, the need to integrate it as part of architectural, engineering and construction (AEC) curricula has been understood, and frameworks for VDC content have been explored, practical solutions of how to set up a course for VDC in a tertiary construction project management (CPM) education setting have not been widely discussed. (Puolitaival et al. 2015, p. 2)

According to Sharma (2012), tertiary institutions in New Zealand do not offer Construction Project Management education in a way that develops the required skill and knowledge sets.

The literature review revealed that there is limited literature on:
1.   international perspectives and practices in VDC pedagogy;
2.   how VDC works as a teaching and learning tool in New Zealand Construction Project Management education;
3.   whether VDC can be used simultaneously:
     a. as a new technology/process in Construction Project Management to be learned and
     b. as a vehicle to learn the soft and technical skills of Construction Project Management;
4.   how student-centred teaching and learning methods work in Construction Project Management education.

This project set out to show the impact of creating and working within a virtual environment on students' learning, and whether the potential uses mentioned above can be applied for multiple purposes. Achieving this 'multipurpose' could maximise the efficiency of teaching and learning, as students would not just learn the technical skills, or processes of planning and programming, but also the soft skills, or core Construction Project Management skills and the basics of the new VDC technology and processes.

Methodology and project design

Timeline

This project started in the middle of Semester 1, 2014 and continued through to middle of Semester 2, 2015. Data was collected in Semester 2, 2014, and analysis and summary reports written in 2015 as well as most of the publications.

Research method

The central research method used in this project was action research. Action research is very common in educational research as it allows the teacher to explore and actively change the teaching and curriculum during the course of the project (Souto-Manning, 2012). This method gives the researcher the opportunity to observe the teaching and learning while being part of the delivery and having impact on the issues researched.

A group of staff worked together to integrate the best practice CPM planning and organisation on-site, and the emerging holistic discipline methodology of VDC. The central element of the delivery was the virtual model of the building project – a three level apartment building with a basement (Figure 1). This was created in collaboration with Housing New Zealand, National Diploma in Architectural Technology students and Department of Construction staff. The project came from Housing New Zealand, the students worked as model authors and the staff supervised the model authoring process. The environment was tested on the 2014 student cohort of 30 participants. The students worked in teams of four on the project assignment using the virtual model created for investigation, analysis and simulation.

Figure 1. Virtual model of the project in Navisworks Manage.

Action research consists of three recurring phases: inquiry, action and reflection. The cycle of phases can be repeated as many times as needed (MacKenzie, Tan, Hoverman & Baldwin, 2012).

The inquiry phase

The 'inquiry phase' of the project started with a literature analysis identifying what the core skills of Construction Managers are and how Virtual Design and Construction has been integrated as part of Construction Project Management education internationally.

The School of Built Environment, University of Technology Sydney (UTS) and Institute of Construction Managers and Economics, Tampere University of Technology (TUT) (Finland) joined the team at this stage as technical advisors. UTS had implemented a VDC curriculum in 2010 and their experience and knowledge was invaluable, particularly when exploring the different options for implementation, but also later in the dissemination phase. A visit to UTS was undertaken to study their model of delivery in detail. This included studying the facilities and other on-site resources used such as hardware, software and BIM models

TUT had just started to integrate VDC into their Construction Managers' education and they were willing to share their experiences as well.

The action phase

The 'action phase' commenced with the course delivery and data collection in September 2014. The sample participants were the whole cohort of level 6 students in Unitec's Department of Construction on the Planning and Organisation 2 course in the Construction Managers' major. The sample size was 30 students. Asian students, mostly Chinese and Indian, were the ethnic majority in the course (43 %), 30 % were NZ European, 10 % European, 10 % Pacifica, 7 % Maori, and there was

also one African student. Students were younger than in Construction courses normally, most of them aged between 20 and 30, with a mix of engineering degree graduates, school-leavers and those already working in the construction industry. The students worked in teams on a project assignment – a three level apartment building with a basement. A virtual model of the building was created for this purpose and no 2D documentation was handed out to the students. They used the model provided as a basis to visualise, investigate and analyse, and simulate the project in terms of developing a construction methodology, site utilisation plan and a construction programme.

Data collection methods included:
1. tests to determine students' technical knowledge and skills at the start and end of the course;
2. retention and success statistics, which were compared to statistics from previous years to understand what impact the environment had had;
3. course evaluations to measure student satisfaction and to record their perceptions of the learning environment;
4. course development discussion at the end of the course to find out staffs' perceptions about how teaching practice and the learning environment had changed and how effective the new environment was;
5. lecturer diary to collect:
    a. classroom observations on student engagement;
    b. verbal informal feedback from students;
    c. possible issues in the delivery for students or for the staff.

These data collection methods (triangulation) and the use of a wide advisory team (objectivity) addressed the possible limitations of the research method.

Reflection phase

Smaller cycles of reflection were part of the delivery, but the actual reflection phase commenced after the course was delivered. Data was analysed at the end of 2014/beginning of 2015.

Ethics

The project did not require ethics approval due to the data collection methods used.

Discussion and dissemination

Discussion and dissemination phases followed. All project stakeholders were involved in the discussion phase allowing wide and thorough interrogation and reflection of all aspects of the research. The project team, and international stakeholders, UTS and TUT, were responsible for the dissemination of information internally, externally and internationally.

Project outputs were:
- Guide of practice for developing and managing a Virtual Construction Project Management Environment (see Figure 2).
- Project webpage to record project progress and describe the process and results, including the Guide of practice.
- Project reports as requested by Ako Aotearoa and Unitec.
- Two conference papers for the Australasian Universities Building Education Association Conference, AUBEA 2015.
- Presentation at the Unitec Research Symposium 2014 and 2015.
- Dissemination amongst the cooperating tertiary institutes; Christchurch Polytechnic Institute of Technology; University of Technology, Sydney and Tampere University of Technology, Finland.
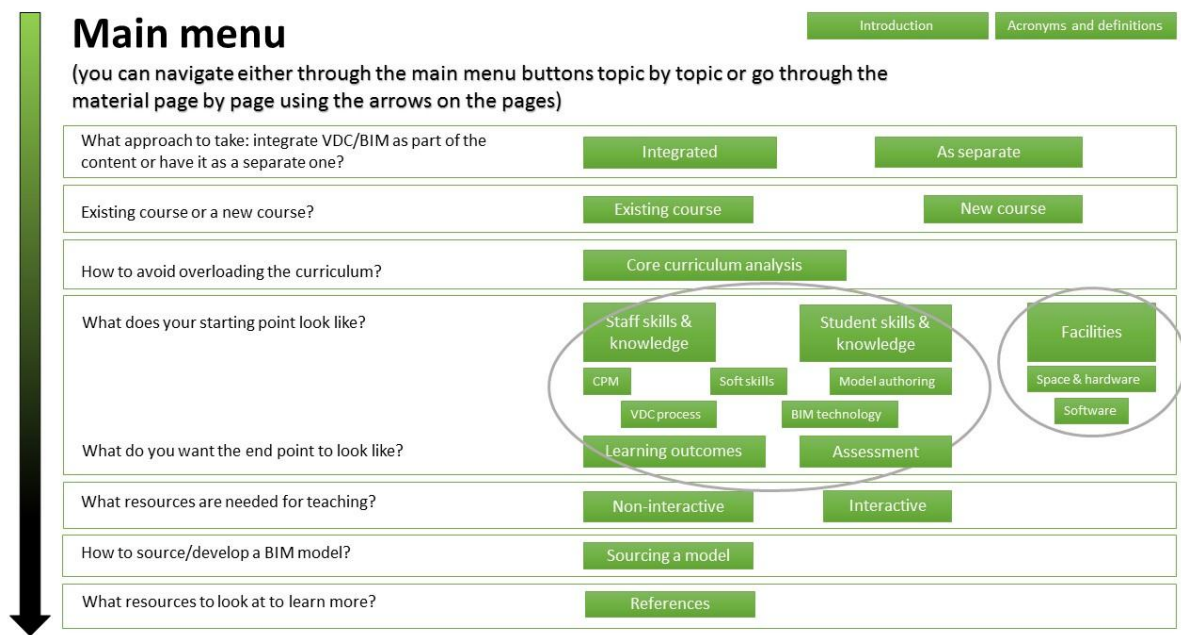
Figure 2. Main menu of the Guide of Practice.

Findings and discussion

Three main challenges were encountered in setting up and managing the Virtual Construction Project Management Environment. These were related to content, delivery and development of the environment. Benefits of the environment were improved student engagement and through that, good learning outcomes in Construction Project Management (CPM) topics and especially in Virtual Design and Construction (VDC) processes and Building Information Modelling (BIM) technology for CPM.

Content

The issue with content concerned finding the balance between the traditional and the emerging methods. Although it would have been valuable for the students to be able to discuss and evaluate, and properly compare the traditional and VDC approaches for deeper learning, this turned out to be too much considering the course duration, level and students' previous exposure to VDC. The choice was made to strongly concentrate on the BIM technology, have a slightly lighter focus on VDC process and to leave traditional methods outside the course scope. On the software side, two new pieces of software were introduced: MS Project and Autodesk Navisworks Manage. In addition, the student needed to navigate in the model with Adobe Acrobat Reader and use SketchUp for construction site layout plans. The students were already familiar with the two latter pieces of software. The biggest learning curve for students was with Navisworks Manage. The students would have preferred to work with Navisworks Manage right from the start in order to get familiar with it instead of using Adobe Acrobat Reader and a 3D PDF. This contradicted the staff idea to use 3D PDF as an easy approach to VDC technology. Students also wanted to have a simpler model to rehearse the use of the software, but unfortunately the tight 7 week delivery model did not allow this. The balance in each course when it comes to soft and technical skills; and traditional and emerging methods, needs to be weighted carefully and a core curriculum analysis is recommended to prevent

information overflow and excessive workloads. A guide has been developed by Karjalainen, Alha & Jutila (2006).

Delivery

The new environment was challenging for both the students and the staff. Students were not expected to have any previous experience with the VDC software, but it was assumed that as second year students, they would have reasonably good skills with basic office programmes such as Microsoft Word, Excel and PowerPoint, and file management skills. In reality their literacy with these programmes varied a lot. For some students, introduction to a new software was relatively easy, while others struggled greatly being barely computer literate at the start. This is also found by Margaryan et al. (2011), who argued that the characterisation of today's learners as digital natives with a high awareness of computer technology is flawed. The learners might be efficient consumers of technology, but not necessarily efficient computer operators.

When it came to the staff, the short preparation time made the course delivery itself challenging. The course was delivered by a team of staff with complementary skills in CPM and VDC. Due to the long project funding application process, and intellectual property issues during the model development stage, the model release was delayed for months from the original plan and the preparation time left for the staff was minimal. Staff did not have enough time to get familiar with the virtual model and especially how the model behaved in the software environment. This resulted in some problems during the delivery, when the staff were not able to fluently navigate through the model and the software in order to introduce them to the students. Staff unfamiliar with the software were interpreting the model incorrectly which resulted in inconsistencies with the instructions given to the students. This caused frustration among the students and an extra session was held to correct the possible misunderstandings among the staff and the students. It was also noticed that when introducing the software, in addition to the lecturers, a tutorial assistant was needed, at least for parts of the course, to assist with the software use in class. This is recommended at least for the first delivery of the course, and also for later courses if the student numbers are bigger than 25 per class.

Model development

Developing a BIM model as the base of the environment proved to be a challenge as well. Based on previous experience, it was already identified that sourcing a model from industry would not be likely to work due to issues of intellectual property and because an industry model would most likely be too complex, considering the course level and learning outcomes sought. The next option was to have an external contractor to author the model based on 2D documentation already available. The design team of the chosen building was comfortable in handing over the 2D documentation to be used for educational purposes, but uncomfortable in giving the documentation to a third party for any extended model authoring purposes. Ultimately the modelling work was done in-house with Unitec National Diploma in Architectural Technology students as contracted model authors and Department of Construction staff as supervisors. This option was very cost effective and without any IP issues. While it did prove to be very demanding, it was a great educational process for both the staff supervising the modelling work, and the students who did the actual modelling work itself. However, during the development process, not enough attention was given to correct model authoring protocols, which later resulted in some errors when information was extracted from the model. Also it was only understood much later, that during the course delivery, many items on the model were developed to too high a Level of Development (LoD). A simpler model would have enabled students to concentrate on the CPM tasks by using the model, rather than becoming confused by the complexity of the model itself.

The students found the environment very challenging but also engaging. Challenging in that there was some anxiety when it came to coping with the new software and when submitting the assignment. Engaging, in that there was active participation in discussions and activities in the classroom and also evidenced by high attendance numbers and high retention compared to equivalent other courses. Learning outcomes were also achieved, students gained a good understanding of what Virtual Design and Construction is for Construction Project Management. Considerable improvements were seen in all topic areas during the course. This was measured by using formative start and end tests, in addition to the assignment and examination. Some student comments collected through course evaluation:

- " I am happy with the contents of the course as it is very practical."
- "Frustrating at the start but by the end I was very happy with my progression of understanding of BIM."

"This course had lots of work and very tight schedule. Learnt a lot."

Conclusions and recommendations

The first research objective, enhancing educational outcomes, has been achieved during this research. The students found the environment very engaging. This was measured by comparing the retention numbers to equivalent other courses. Considerable improvements were seen in all topic areas during the course. However fitting all soft and technical skills in proved to be too much. The balance in each course when it comes to soft and technical skills; and traditional and emerging methods needs to be weighted carefully.

The second research objective, creating a transferable concept, was fully achieved. The concept has been evaluated and redeveloped, and it can be used in other Construction courses in a variety of subjects. The BIM model has been redeveloped to be more suitable for courses in construction technology (Sem 2 2015) and construction economics (2016) and for second delivery of Planning and Organisation 2. The project and teaching team gained valuable knowledge and skills during the project, which will enable them to develop resources and include VDC and BIM into other courses they teach and coordinate.

The third objective, contributing to a more coherent knowledge base in CPM teaching, has been achieved. Findings have been shared with the three other participating institutes: Christchurch Polytechnic Institute of Technology, University of Technology, Sydney, and Tampere University of Technology, Finland. Further collaboration has been discussed. Two papers have been published and presented at the Australasian Universities Building Education Association (AUBEA) Conference in Sydney, in 8-10 July 2015.

The Virtual CPM environment is an effective way to engage students in learning, not only Construction Management, but also VDC processes and BIM technology, however its use needs to be carefully considered. Considerations include how many new things, and in which depth, students can learn simultaneously, and adjustments should be made to the complexity of the environment accordingly. Because the environment is usually new to both the students and the staff, there needs to be reasonable time for the staff to familiarise themselves with the environment, process and technology, before the course delivery starts, in order that they can offer guidance to the students

as appropriate. Model development is a time consuming process and can easily go wrong if not planned and managed carefully. In addition to the size and type of the building, careful consideration needs to be given to what the appropriate Level of Development of the model items are, and what information the model needs to contain. This is to allow for appropriate analysis and simulation, but also in order to not hinder students' learning by offering too much detail and information which could confuse them. Model authoring protocols need to be followed so that the information can then be extracted from the model with model analysis tools as required.

Discussions with Department of Construction staff on how to incorporate VDC and BIM better as part of the courses are underway. The discussed changes will become effective gradually, allowing time and resources for the development work needed. This change is ongoing until the new technologies and processes become business as usual.

More detailed recommendations and guidance can be found in *Virtual Design and Construction for Construction Management Education - Guide of practice for course level development* (Puolitaival, 2015).

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