AC 2011-1346: THE POTENTIAL OF BIM TO FACILITATE COLLABORATIVE AEC EDUCATION

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The Potential of BIM to Facilitate Collaborative AEC Education

Introduction

Enlightened companies in the Architecture, Engineering and Construction (AEC) industry are moving towards collaborative working practices, where all design team members are engaged at an earlier stage in the design process, aided by building information modelling (BIM) tools. Whereas the old 2D CAD tools simply replicated manual drawing processes, without adding any value, BIM is a completely new paradigm. It allows professionals to query their designs at an early stage of the design process; to explore different options; to run structural and environmental performance analyses and costings and to detect problems and resolve them before they get to site. However, this way of working cannot be achieved through technology alone. It requires a cultural shift within the industry from that of fragmentation and litigation to collaborative working and information sharing. It also requires some significant change to the way in which future architects, engineers and construction professionals involved in the building industry are educated.

There is a great opportunity for educators to train undergraduates in the AEC professions, including engineers such as structural, civil, building services and electrical engineers, in the use of BIM and the concepts of collaborative design, before they learn about the "old ways" of working in the industry. These new graduates are likely to have a profound effect on the industry and to lead the charge in adopting BIM and developing innovative approaches to working practices. Unfortunately, students of the various AEC disciplines currently tend to be educated separately, often in different Departments and frequently with little interaction. This paper discusses the potential of BIM for improving collaborative AEC education, and proposes a way forward for Universities, based on the outcomes of a series of surveys and interviews with a range of industry and academic stakeholders in the AEC professions, examining current and future practice in this important area.

The need for collaboration in the AEC professions

In the U.S., approximately eight per cent of the total workforce in 2007 was employed in construction and the industry contributed $611 billion, or 4.4 per cent of the gross domestic product (GDP) in that year[1]. Similarly, the construction industry represents approximately six per cent of both Australia's and the UK's GDP[2, 3]. But despite the importance of the construction industry to the developed world, some studies suggest that productivity has declined over the past 30 years and that the construction industry is extremely inefficient compared with other industries.

The adoption of computers and 2D computer-aided design (CAD), far from improving efficiency, has actually coincided with a decrease in documentation quality and productivity and significant losses are accrued in the construction industry due to lack of interoperability between the various sectors and professions involved in it. It is estimated that poor documentation is

contributing an additional 10-15% to typical project costs[4]. The construction industry has also been described as extremely fragmented and lacking integration[5, 6].

In the light of such studies, major changes have been recommended by industry organisations such as the US National Academy of Sciences (2009). Two of the five key activities identified by the Academy for improving the industry were:

1. Widespread deployment and use of interoperable technology applications, also called Building Information Modelling (BIM);
2. Improved job-site efficiency through more effective interfacing of people, processes, materials, equipment and information.[1, p.1]

As a consequence of such recommendations the construction industry worldwide is beginning to move towards collaborative design practices as a means of improving project quality and certainty. This move is being supported by the use of Building Information Modelling (BIM) technologies and processes. BIM requires practitioners to rethink the ways in which they develop designs and manage construction projects and is leading to changes in traditional design team job descriptions. However, the current shortage of graduates trained in collaborative design (and in BIM as a technology to facilitate collaboration), remains a barrier to progress in this area.

Current practice and understanding of BIM amongst AEC faculty

In the majority of universities in US, Europe and Australia, Architecture, Engineering and Construction (AEC) students continue to be educated in separate departments, with little or no integration or collaboration between the disciplines. Often the first time that students from each AEC discipline are exposed to working with design team members from other disciplines is in the workplace after graduation. It is important for graduates to have an understanding of the roles played by other construction professionals and the impact that their design decisions have on projects overall. However, the isolated manner in which they are currently educated does not provide this understanding.

There has been a resistance in the past among educators to providing training in computer technologies in Universities. Some argue that it is not the university's role to produce "CAD technicians" and that there is no educational value in using 2D CAD to replicate manual drawing processes. These concerns are reasonably justified as noted previously whereby the adoption of computers and 2D CAD has coincided with a decrease in documentation quality and productivity[4]. Similar resistance exists to teaching engineering analysis and design computer applications, on the grounds that university courses should teach theory and that graduates will learn software packages in the workplace.

Many educators still view BIM as yet another CAD program that students should learn in their own time. However, this argument misses the point that BIM is not merely a new CAD tool or computer application: it is a new paradigm and its benefits extend far greater than mere visualisation. From a pedagogical point of view, there is little difference between learning manual drafting techniques and learning 2D CAD. However, BIM provides opportunities to model every part of the design and construction process and can allow multiple design proposals

to be compared and building performance to be modelled. 2D (and even 3D) CAD merely provides a way of documenting information about the building whereas BIM actually represents the building in virtual reality with all the crucial information within it, allowing analyses to be performed with greater speed and accuracy and providing design team professionals with critical information at earlier stages of the design and build process.

To explore the current practice and understanding of BIM and collaborative AEC education amongst AEC faculty, the authors conducted a series of interviews across Australia and Europe in 2010. A total of 11 senior professors in the built environment area from Architecture, Engineering and Construction Management were interviewed: four in Holland, three in UK and four in Australia. In the same year the first author was involved in conducting a large on-line industry survey of AEC professionals and educators across Australia and New Zealand that produced over 400 responses[7]. The full report of the survey may be obtained from the buildingSMART website at www.buildingsmart.org.au

The data collected in both the interviews and online survey suggest that universities are lagging behind the AEC industry in terms of adopting BIM technologies and improved collaborative working practices. In fact the data indicate that there is a chasm developing between schools of engineering and the other building design professionals, in terms of BIM education. Many architectural departments (and some construction management departments) are beginning to teach BIM software applications in isolation. This is perhaps a natural development from teaching 3D CAD to architectural students. However, it appears that the software is still largely being used as a documentation tool. Where departments **were** teaching BIM software, it appeared that the focus was on the technicalities of using the software and exchanging data between applications, rather than what information is required in order to assist the various AEC disciplines to contribute to the process.

> *"At the moment we place a lot of emphasis on exchanging information between applications...on the technicalities of BIM...rather than the theory of BIM"* (Professor of Architecture, Holland)

Some departments of architecture and construction management have developed "collaborative design teams", where architecture students are required to pretend to be another member of the design team:

> *"We form teams of 7-8 [architectural] students. All have to choose a separate discipline. Each is given a tool, for example thermal analysis, and, we hope, of course, that students of other faculties will engage in this but we have a hard time getting the other faculties to participate. So architectural students put on different hats."* (Professor of Architecture, Australia)

A review of current literature indicates that a few US civil engineering departments are beginning to teach BIM to their students, but Australian and European departments are lagging behind. However, no departments appear to be running fully collaborative design courses between students of architecture, construction management and civil engineering.

> *"I think we really need to start building...the collaboration: rather than developing the architectural proposal without the input of the engineers, really getting them involved at the different stages and to understand not only what they need but what they can bring to the process. No one can really master **all** the design disciplines any more - you really have to use the knowledge that other people have."* (Professor of Digital Design, UK)

The new collaborative design approach is leading to changes in traditional design-team job descriptions, with a blending of roles occurring. Far from this leading to the demise of the current building professions, it is the authors' opinion that BIM will enhance their roles. As the Professor quoted above notes, it is no longer possible for the architect to be a Master Builder responsible for every part of the design process. As buildings become more and more complex, specialised input is required at earlier stages of the design process, and this can be facilitated by BIM. In the *Report on Integrated* Practice published by the American Institute of Architects (AIA) in 2006 one contributor described their view of the future as follows:

> *"the utopian future...we're trying to prepare our students to lead…is the architect not necessarily as master builder, but potentially something more like the Kieran Timberlake model of the architect as a kind of central figure, a connector. I think the architect will need to be someone who can be the advocate for design, and for design thinking. The architect will need to be someone who can think laterally and simultaneously, and begin to help others make decisions that make sense. So ideally there is a role for the architect that's different from the role of any other experts who are coming in, or clients who are coming in, or users, or whoever else is adding to this future design process."*[8]

This was echoed in one of the interviews with a UK professor who stated:

> *"I think that the core thing [that is required] is really to get the idea of collaboration and the understanding of the needs and processes and what should be done at the different stages [of building design]. One thing actually that is really important is to think about decision support. So thinking about producing the key information for the decision makers so that they can really understand what they decide."* (Professor of Digital Design, UK)

The professors interviewed and all of the academic respondents to the online survey were unanimous in their view that universities are not currently meeting the needs of industry in terms of collaborative building design and BIM education. The construction industry appears to agree, as the Australian Built Environment Industry Innovation Council wrote to all the Deans of Australian Built Environment Faculties in June 2010 to enquire as *"to what extent the universities are embracing new technologies such as BIM and equipping our future professionals with cutting edge experience."*[9]

Future work

The authors are currently involved in a joint project funded by the Australian Learning and Teaching Council for 2011-12 on *Collaborative building design education using Building Information Modelling*, involving a partnership between three Australian universities, which

aims to develop fully multi-disciplinary project courses, using BIM. The project will produce curriculum development tools to assist in implementing collaborative design courses using BIM in all Australian departments of Architecture, Engineering and Construction. Over the course of the project, the authors aim to address several key questions for AEC educators implementing collaborative BIM courses.

One of these key questions is: How soon should BIM be introduced? Eastman et al state that "students are able to grasp the concepts and become productive using BIM tools more quickly than they were with CAD tools."[10, p. 300] However, BIM tools require a greater knowledge of how buildings/structures are put together, due to greater accuracy and the range of object parameters required to be entered. This is supported in the AIA report that states:

> "*The level of expertise required to intelligently design with BIM is significant, and serious consideration must be given to how it can be taught...the potential effect of BIM on the design process is unprecedented in the ease in which it can translate directly into built form, can be equally viewed as exciting or alarming. Never has a representation tool been so demanding of its user, the competent BIM operator must have an understanding of the tool, a sound knowledge of materials and construction methods, and an appreciation for professional practice."*[8]

From workplace observations Vandezande[11] noted that "senior [architects at his practice] with less computer experience, but greater knowledge of design and constructability, seem to fare better with these [BIM] tools than some of the younger designers". However, if BIM is introduced only in students' final years, as part of a multi-disciplinary project, they will be expected to become instant experts in the software at the same time as learning multi-disciplinary design. The authors therefore plan to introduce the concepts of BIM and associated software tools at earlier stages of the curriculum.

Another hurdle to be overcome, in terms of introducing any new technology at University level, is that faculty members do not always remain up-to-date with technical software applications used in industry. This may be alleviated with closer integration between industry and academia. Many of the institutions surveyed by the authors are keen to develop strong industry links and already have visiting tutors and lecturers from industry, and this could extend to the teaching of BIM processes and technologies.

The authors aim to determine the most effective curriculum strategies that should be adopted to improve collaboration between students and staff in the various AEC disciplines and at what point in their programs these should commence. They also aim to determine what pedagogies are the most appropriate and effective for inter-disciplinary collaborative learning in AEC. Woo[12] comments that "there is no accepted instruction strategy for teaching BIM in AEC-related curricula" so the development of such a strategy will be an important outcome of the project.

Conclusion

It is clear that the adoption of BIM is gaining momentum in the construction industry worldwide but universities are lagging behind in producing graduates skilled in collaborative building

design practice and BIM. For BIM to be fully effective and to yield promised productivity savings, a major cultural shift is required in the industry from that of fragmentation and poor standards of data exchange to one of integration, collaboration and information sharing. This shift will also have to occur within educational establishments including engineering departments. The authors aim to produce curriculum tools to enable adoption of collaborative design courses utilising BIM best practice, which will be available to all AEC departments at the conclusion of the project.

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