A FRAMEWORK FOR COLLABORATIVE BIM EDUCATION ACROSS THE AEC DISCIPLINES

Jennifer A. Macdonald

University of Technology Sydney, jennifer.macdonald@uts.edu.au

ABSTRACT

The construction industry is beginning to move towards collaborative design practices worldwide, aided by building information modelling (BIM) tools and processes. However, the current shortage of building design professionals trained in BIM remains a barrier to universal adoption of collaborative working practices in the industry. Collaborative working using BIM requires not only the learning of new technologies/software, but also the learning of a new way of working. This means moving from a culture of litigation and fragmentation to one of information sharing, collaboration, and integrated project delivery. Various studies suggest that universities are lagging behind the construction industry in terms of adopting BIM technologies and improved collaborative working practices. Current building design education practice rarely involves collaboration between students training in the architecture, engineering and construction (AEC) professions. In the majority of universities in the US, Europe and Australia, AEC students continue to be educated in separate departments, with little or no integration or collaboration between the disciplines.

The author is currently involved in an Australian Learning and Teaching Council (ALTC) grant-funded project. The aim of this project is to explore methods of improving collaborative design education among students of the architecture, engineering and construction (AEC) disciplines, with the aid of BIM tools. This paper describes the “IMAC” framework that has been developed from this work to assist educators in benchmarking their own curricula and to develop strategies for improvement.

Keywords: Building Information Modelling, BIM, construction education, collaborative working; Framework

INTRODUCTION

The construction industry is moving towards more collaborative working practices worldwide, aided by BIM tools and processes, but various studies indicate that tertiary and professional education is lagging behind (e.g. Becerik-Gerber et al 2011, Allen Consulting Group 2010, Forgues et al 2011). The current shortage of building design professionals trained in BIM remains a barrier to universal adoption of collaborative working practices in the industry. Just as industry must undergo a paradigm shift from its old combative culture to one of integration and information sharing, so must academia. The need for a framework to support adoption of collaborative design and BIM education by Architecture, Engineering and Construction (AEC) schools has been stated previously (Macdonald & Mills, 2011). The author has developed a framework (called the IMAC Framework) with the aid of an ALTC (Australian Learning and Teaching Council) grant. This paper discusses its development and potential applications.

Since engineering and architecture emerged as separate professions from the historic job title of "Master Builder", students of the different AEC disciplines have been educated in isolation from each other. According to Pressman (2007: p3),

> *"Many academic programs still produce students who expect they will spend their careers working as heroic, solitary designers. But integrated practice is sure to stimulate a rethinking of that notion. Pedagogy must focus on teaching not only how to design and detail, but also how to engage with and lead others, and how to collaborate with the professionals they are likely to work with later."*

It is not only students of the separate AEC disciplines that are studying in isolation from each other. Architecture, Engineering and Construction Management departments are generally housed in separate schools or faculties and sometimes even located on separate campuses, such as at the University of South Australia. Sharing teaching across these academic silos is a challenge that must be overcome if we are to produce graduates possessing the key skills in collaborative working using BIM, who will be best placed to drive the industry forward.

WHAT IS BIM AND HOW CAN IT BE USED TO IMPROVE COLLABORATION?

Building Information Modelling (BIM) has no single, widely accepted definition but for the purposes of this paper we will adopt the definition proposed by Eastman, who defines BIM as "a modeling technology and associated set of processes to produce, communicate and analyse building models" (Eastman et al. 2008: p13). These models consist of:

- ***Building components*** – digital components that have *intelligence* (i.e. they have programmable attributes and parametric rules)
- ***Components that include data describing how they behave*** (this allows them to be used for analysis, specifications, and quantity take-offs, for example)
- ***Coordinated data*** – all views of the model are represented in an integrated environment that facilitates and supports coordination and hence all changes made to the model in one view are automatically reflected in other views

In order to build realistic intelligent models it is necessary to assemble the design and construction team at earlier stages in the process compared to traditional practice. The team is creating a virtual representation of the real project and the more information and detail that can be added, the more accurate the model will be. This is leading to changes in the roles of AEC professionals, and is even creating new positions that didn't exist ten years ago, such as the role of BIM manager.

The culture of the construction industry has traditionally been very pugilistic, with minimal trust between parties on projects, aided by an atmosphere of litigation and punitive contracts. This lack of trust does not encourage information sharing and collaboration. Often the professions do not have a deep understanding of the information that each requires at different stages of the project. For example, large architectural models detailed down to the level of sanitary fittings may be sent to engineers for use in wind analysis, when only the basic frame and simplified cladding would be required. Thus time is wasted stripping out and even rebuilding models, when the models could have been set up more efficiently from the start of the process and unnecessary detail excluded prior to model exchange. If students are educated to work collaboratively and to learn the requirements of the other disciplines before they graduate, this level of misunderstanding is likely to be removed in future, and trust improved.

HOW CAN WE ENCOURAGE ADOPTION OF COLLABORATIVE EDUCATION USING BIM?

In the past, academics have resisted teaching technologies such as CAD to students. The author has frequently heard the refrain "we're not teaching students to press buttons" being used among educators who believe that BIM is just another CAD tool. However, this misses the point that BIM is facilitating process, technological, and cultural changes, and its benefits extend far beyond mere visualisation. There is a great opportunity to engage students more effectively and to aid understanding of how buildings are constructed. Hardy, quoted in Deutsch (2011, p202) states:

> *"When I look at the logic of construction means and methods that BIM inherently teaches, I see the potential to educate…"*

Any major change process is likely to encounter resistance. Some of the difficulties for academia in introducing BIM may include:

1. Questions about how to fit new topics into a crowded curriculum.

2. Reluctance to change teaching habits established over many years.

3. For those who may have developed their own niche or expertise, there may be resistance to take on a new subject, about which they are not an expert, or to retrain in an area they are not familiar with.

4. As the technologies supporting BIM evolve at a rapid pace, academics who have been out of industry for some time may feel overwhelmed trying to keep abreast of them.

5. The traditional silos of architecture, engineering and construction schools can be difficult to bridge. As in industry, mistrust of the other professions also exists in academia, and questions can arise as to who is responsible for (and who will pay for) cross-disciplinary courses.

In response to the first question, integrating principles of collaboration and BIM technologies into existing classes throughout the curriculum should reduce the need to develop completely new courses. In order to encourage this curriculum renewal, the professional bodies should update their accreditation criteria to reflect the industry need for graduates skilled in BIM and collaborative working. Accreditation criteria provide the greatest incentive for academic institutions to instigate changes to their curricula.

The author has attended many BIM workshops and conferences over the past few years and it seems that general questions from industry have moved on from "what is BIM and why should we adopt it?" to "we accept that we need to adopt BIM, now how do we go about doing so?" Although AEC academics (with notable exceptions) generally appear to be at the earlier stage of questioning, it is likely that they will also move towards the question of implementation, and the framework described below should provide assistance in this.

THE DEVELOPMENT OF A FRAMEWORK

Construct IT for Business is an industry-led, government supported, centre of excellence promoting innovation and research in the field of IT in construction in the UK. The organisation produced the IT Self-Assessment Tool (Construct IT, 2000), aimed primarily at smaller construction companies, to enable businesses to benchmark their level of IT use and to set targets for improvement. The tool was accompanied by a series of guides to how to carry out these improvements. The author was able to put these guides into practice in a small company very successfully, and decided to adopt the format of the tool and guides as a basis for creating the framework to assist adoption of collaborative design education and BIM into AEC curricula. The education framework also comprises two components: a benchmarking tool and a separate guide to implementation.

METHODOLOGY

The background research informing the development of the framework comprised a literature review, industry internet-based survey and a series of semi-structured interviews conducted by the author both in Australia and worldwide. The results of the literature review have been published previously (Macdonald & Mills, 2011), and indicated that no institution is successfully teaching students of all three AEC disciplines in collaboration. The author conducted a search of available BIM and collaborative design courses advertised at all Australian institutions accredited by the AEC professional bodies. A series of semi-structured interviews were carried out with leading AEC academics at five Australian universities offering all three AEC disciplines. Further interviews were carried out at two US, one Canadian, three UK and two Dutch institutions with experts in the field of BIM and collaborative working. The author was also involved in compiling and analysing a BIM industry survey in 2010, the results of which informed the BIM Economic Study (Allen Consulting Group, 2010). Questions about BIM and collaborative education were included in this survey.

THE PROPOSED FRAMEWORK – "IMAC"

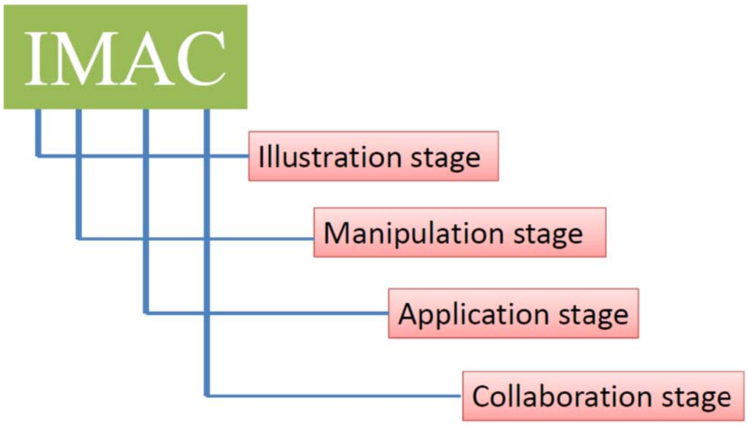

Fig 1: The four stages making up the *IMAC* framework

The top level of the framework is broken into four stages, relating to different levels of achievement. These stages are; Illustration, Manipulation, Application and Collaboration (IMAC). The stages have been mapped to various levels on the taxonomy of learning proposed by Bloom et al (1956). Bloom's taxonomy is divided into three domains: cognitive, affective, and psychomotor. Typical educational goals concerned with recollection or recognition of knowledge and development of intellectual skills fall under Bloom's cognitive domain. Krathwohl et al (1964) further developed the taxonomy into the affective domain, which concerns internalisation of knowledge, i.e. changes in interest, attitudes and values. As the IMAC framework aims to assist development of both technical (I.T and discipline-specific) and interpersonal (collaborative and teamwork) skills, it straddles the cognitive and affective domains.

The framework does not dictate in which academic year each stage should be introduced. Students from the different AEC disciplines study courses of varying lengths and some skills are introduced earlier in some courses than others. For example, students of architecture tend to be introduced to modelling tools from first year whereas students of structural engineering might only be introduced to them in third year. It may also be possible to progress between stages within one academic year.

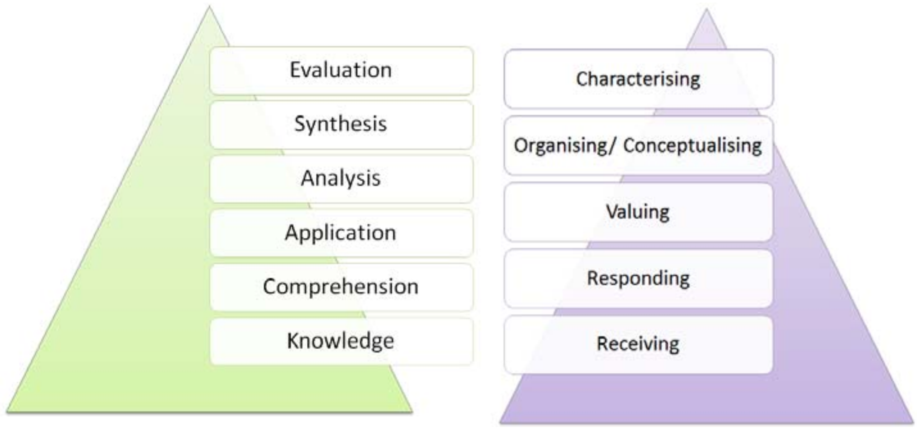

Fig 2: Bloom's Taxonomy of Learning: Cognitive Domain (left) and Affective Domain (right) *Sources: Bloom et al (1956) and Krathwohl et al (1964)*

The framework also considers suitable delivery methods at each stage, aiming to achieve deeper levels of learning as students progress through their education. Koltich and Dean (1999), describe two paradigms of teaching; the transmission model and the engaged critical model. The latter emphasises the need for students to engage with what they are studying and thus develop a deeper level of understanding, and promotes the use of teaching methods such as problem based learning. The philosopher Seneca the Younger is generally credited with the statement "by teaching we learn" and anecdotal evidence suggests that teaching others is one of the best methods of gaining deeper knowledge about a subject. The Learning Pyramid, attributed to the National Teaching Laboratory, has been quoted often in educational literature, though as Magennis & Farrell (2005) point out, the original research source supporting the percentages of retained learning cannot be traced. However, Magennis & Farrell (ibid) conducted research that generally corroborates the order of activities in the pyramid, in terms of the amount of learning that is retained following each type of activity (Fig 3). As practice by doing and teach others/immediate use of learning are the activities shown to provide the deepest levels of learning, the IMAC framework aims to promote them as preferred delivery methods.

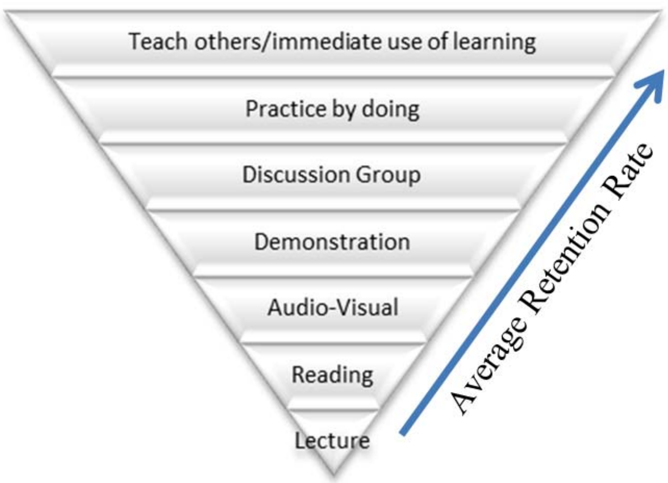

Fig 3: Version of the NTL Learning Pyramid as described in *Magennis & Farrell (2005)*

The four stages of the IMAC framework are described in detail, below.

Illustration Stage (Knowledge/Comprehension and Receiving/Responding)

This is an introductory stage. Building Information Models are used to illustrate key concepts to students and students will typically be taught in their separate disciplines at this stage. Models will have sufficient detail to allow lecturers/tutors to highlight different components/connections to show how buildings are constructed, insulated and waterproofed for example.

Manipulation Stage (Comprehension/Application and Responding/Valuing)

At this stage, students start to interact with and manipulate existing models themselves. They will be required to make simple changes and/or create basic elements within the models in relation to their disciplines. They are also continuing to develop their teamwork and basic IT literacy skills, in addition to developing discipline-specific knowledge.

Application Stage (Application/Analysis and Valuing/Organising)

At this stage, students have acquired basic theoretical knowledge in their disciplines and are starting to apply this knowledge to solve discipline-related problems. For architecture students, they will start to build building information models from scratch and learn how to set the models up for effective inter-disciplinary collaboration. Engineers will start to use tools to analyse models using exports from Building Information Models. Construction managers will develop 4D and 5D schedules, and plan logistics and materials ordering using models from other disciplines. All disciplines will be taught principles of Value Engineering and Sustainable design and how BIM tools can be used to assist these. They will also be introduced to the roles that the other disciplines play in a construction team, and how models are set-up to facilitate information exchange.

Collaboration Stage (Synthesis/Evaluation and Characterising)

At this stage, the students from the different disciplines come together to work on joint projects. Ideally this will involve groups containing a student from each AEC discipline. Learning through teaching others can be encouraged by pairing senior engineering and construction students with junior architecture students, for example. Ideally, real-world problems will be given to the students to solve. To ease students into the process, they can be given partly-finished models to start with, and then be asked to make some changes to these models due to “new project information” arising. The students will also learn about the types of contract that facilitate BIM and collaborative working, and will continue to learn about group dynamics and improving teamwork.

MAPPING EXISTING COURSES AT AUSTRALIAN UNIVERSITIES

The work described in this paper has been supported by an Australian Learning and Teaching Council (ALTC) grant, involving partners from the University of Technology Sydney, the University of South Australia and the University of Newcastle. The benchmarking component of the IMAC framework has been used to benchmark existing courses at the three institutions and to plot targets for future curriculum developments. The framework recognises that the different disciplines will not be aiming to achieve full collaboration in all courses or areas – for example, architecture graduates will be expected to be able to create full BIM models from scratch whereas engineers and construction managers would usually only be expected to be able to manipulate existing models for their own analysis purposes. The framework tool thus suggests different targets (shaded, refer Fig 4) for the different discipline areas, and it is expected that these will be mapped to professional accreditation criteria as these are developed.

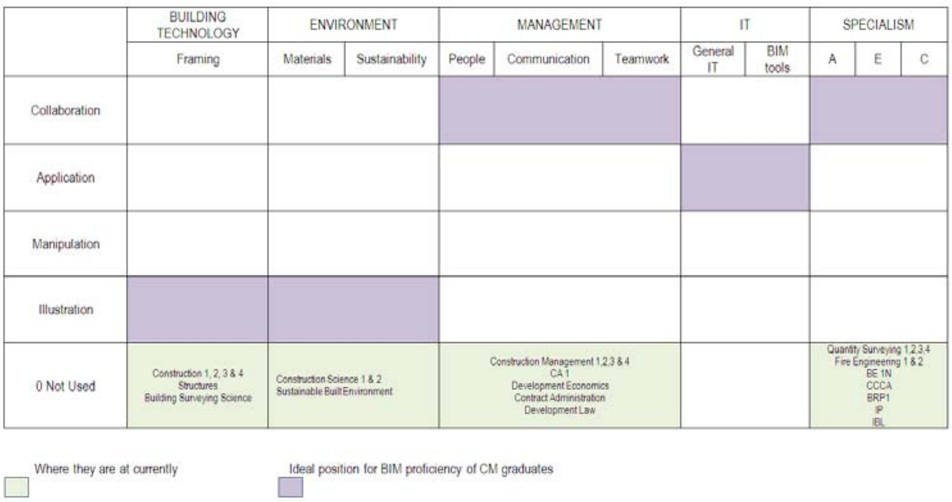

Fig 4 Example of Mapping exercise for a CM course, with suggested targets shaded

CONCLUSION

The mapping exercise is being completed at the three ALTC partnership institutions. The data gathered and the “How to” component of the framework will be used to assist redevelopment of existing courses. The courses will be then be evaluated and the results published by the end of 2013. A website is also being developed to assist AEC educators across Australasia. The author welcomes feedback.

REFERENCES

Allen Consulting Group, (2010): *Productivity in the buildings network: assessing the impacts of Building Information Models*, report to the Built Environment Innovation and Industry Council, Sydney, October 2010

Becerik-Gerber, B., Gerber, D., Ku, K. (2011), ‘The pace of technological innovation in architecture, engineering, and construction education: integrating recent trends into the curricula’, *Journal of Information Technology in Construction* (ITcon), Vol. 16, pp. 411-432

Bloom, B.S., Englehart, M.D., Furst, E.J., Hill, W.H., Krathwohl, D.R. (1956), *The Taxonomy of Educational Objectives, The Classification of Educational Goals, Handbook I: Cognitive Domain*, David McKay Company, New York, N.Y

Deutsch, R. (2011), BIM and Integrated Design: Strategies for Architectural Practice, John Wiley & Sons, Inc., New Jersey

Eastman, C., Teicholz, P., Sacks, R., Liston, K. (2008), BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors, John Wiley & Sons, Inc., New Jersey

Forgues, D., Staub-French, S., Farah, L.M. (2011): ‘Teaching Building Design and Construction Engineering. Are we ready for the paradigm shift?’ *Proc. of the 2nd Annual Conference of the CEEA*, Newfoundland, Canada, June 6-8, 2011

Koltich, E. & Dean, A.V. (1999), ‘Student Ratings of Instruction in the USA: Hidden assumptions and missing conceptions about ‘good’ teaching, *Studies in Higher Education* **24**(1), 27-42

Krathwohl, D.R., Bloom, B.S., Masia, B.B. (1964), The Taxonomy of Educational Objectives: The Classification of Educational Goals, Handbook II: Affective Domain, David McKay Company, New York, N.Y

Macdonald, J.A. & Mills, J.E. (2011), 'The Potential of BIM to Facilitate Collaborative AEC Education', American Society for Engineering Education Annual Conference, Vancouver, Canada, June 2011 in *Proceedings of the 118th ASEE Annual Conference*, American Society of Engineering Education, Vancouver, Canada.

Magennis, S. & Farrell, A. (2005), ‘Teaching and Learning Activities: Expanding the Repertoire to Support Student Learning’, in *Emerging Issues in the Practice of University Learning and Teaching*, O’Neill, G., McMullin, B. (eds), AISHE Dublin

Pressman, A. (2007), “Integrated Practice in Perspective: A New Model for the Architectural Profession”, *Architectural Record*, May 2007, http://archrecord.construction.com/practice/projDelivery/0705proj-3.asp (accessed March 2012)