BIM AND PARAMETRIC DESIGN AS GAME CHANGERS

Exploring their effects on practice culture and epistemology

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Abstract. This paper explores the effects of Building Information Modeling (BIM) and Parametric Design on the distribution of roles and responsibility in architectural practice. It will do so in consideration of the epistemological changes associated to new skill-sets young graduates bring into practice and their positioning among experienced professionals on project teams. On one hand the paper will scrutinise how the use of BIM and Parametric design influences design and delivery of projects, their impacts on practice culture, and the associated role-distribution on project teams. On the other hand the paper will discuss to what extent academic institutions can or should respond to the challenges and the opportunities inherent to these changes in practice. A number of responses to the challenges and opportunities will be presented by the author for further consideration by others.

Keywords. Parametric Design; BIM; Epistemology; Practice; Academic Curriculum; Teaching.

1. Introduction

The effects of BIM and Parametric Design on contemporary practice do not always seem to be well understood by the tertiary architectural education sector. Current developments within professional service firms who adopt innovative technology for the design and delivery of their projects occur at a rapid pace. It is therefore difficult for some academic institutions to grasp the veracity of these changes and to distinguish between major paradigm shifts, and changes that merely represent a 'phase' that doesn't affect the way institutions inform their curriculum.
There is evidence to suggest that the construction industry as a whole experiences a dramatic transformation at this point in time (Onuma, 2006) (Terzidis, 2007) (Mitchell, 2009). The impact of BIM and Parametric Design on contemporary architectural practice is extensive and it provokes questions about a response by academia. Which activities in architecture are most profoundly affected by the current technological changes? How do these transformations relate to skill acquisition of young professionals? What are possible epistemological pathways in tertiary education to address the challenges inherent to the transformation in practice? How can/does one weave yet another set of topics into already overcrowded curriculum?

This paper addresses the above questions (among others) by drawing from historical references and research to subsequently investigate the current changes to the epistemological context of BIM and Parametric Design in practice. In order to grasp the extent of the transformation on contemporary practice, the author gathered responses from about thirty leading architecture and multidisciplinary practices in Australia who utilise parametric techniques for their design exploration and who apply BIM on their projects.

The findings from this investigation will equally benefit those dealing with human resourcing and management in practice, as well as educators who are keen to understand how current developments in practice may influence their teaching methodology.

2. Precedence

The debate about the relation between computational design, its introduction to the academic curriculum, and its relevance in practice has been ongoing since early experimentations and applications in the field. Maver et al. (1979) contextualise the introduction of computationally supported design (decision making) into the architectural profession in the early and mid-1970s, providing examples of the inclusion of CAAD into the architectural education as part of design studio teaching.

Mitchell (1984) summarises the epistemological and practice-related development of CAAD in reference to its experimental beginnings in the 60s, and 70s. By the early 80s, computer hardware started to become affordable, but CAAD software required substantial investment; architecture as a business started to become more capital than labour intensive for the first time. Mitchell (1984) calls for rigour to be applied by academic institutions in formalising the foundations of CAAD education arguing that it is not an issue of technology, but it is one of architecture.

In the review of literature, it becomes apparent that the dawn of the personal computer (PC) era, hand in hand with commercially affordable ‘main-
stream’ CAAD drafting and visualisation tools did not always reinforce the role of the computer as a design aid (Ayrle, 1991). The proliferation of the PC in the architecture studio rather led to increased efficiency of the delivery process while replicating manual drafting processes (Coyne, 1991).

In the mid to late 80s, a number of commentators debated whether and how to introduce CAAD into academic curricula (Stevens and Radford, 1988) (Sliwinski, 1996), but by the early 1990s, the aspect of visualisation seemed to dominate the focus in the propagation of computational skills from young graduates entering practice (Dawson and Burry, 1996) (Af Klercker, 1996). What followed was an ever increasing interest in geometrical experimentation and topological exploration based on manifestation of scientific theories (Terzidis, 2007) or the exploration of what is possible leaning towards exuberance and digital virtuosity (Colletti, 2010). With ever more sophisticated 3D modelling and geometry manipulation tools available, young graduates with solid ‘3D skills’ would be able to impress more senior peers with photorealistic renders and/or with complex morphological representations of abstract design concepts. The ability to conceive experimental shapes computationally was often not matched with a deeper understanding of the underlying construction or fabrication processes to translate from virtual to the built form (Johnson and Laepple, 2003). Only a select number of high-profile design and engineering firms mastered the transition from conceiving projects with non-standard geometry digitally, to actually building them. In parallel, a number of universities invested substantial funds for rapid prototyping and digital fabrication equipment (Cuff and Snoonian, 2001).

3. The Progression of Parametric Design and BIM

Applying rule-based techniques within CAAD via parametric design or scripting has formed part of academic research and practice over the previous 30+ years. Commentators highlight the alignment of parametric techniques with conceptual thinking and intuitive design exploration applied by architects (Kvan 1985, Aish 1991). Whereas the adoption of scripting for design still seems to occupy an outsider role in architecture (Burry, 2011), parametric design methods increasingly get integrated into technical, as well as design-focused subjects in architectural education. As a result, young graduates now introduce parametric design to mainstream practice, as a method that is (in most cases) novel to their working context.

This development signifies that for the first time in history the architectural profession young graduates introduce significant technological innovation into practice that goes beyond the mere representational aspect of design. The proliferation of parametric tools such as Bentley’s Generative Compo-
nants™ (GC) or McNeel’s Grasshopper™ was facilitated by a number of factors: Reasonable pricing, easy accessibility, tying into existing CAAD software with a strong use-base, intuitive entry and manipulation of parametric relations linked to geometry, a combination of text-based entry with a symbolic and (3D) graphical views, the setup of a strong user-community with peer-to-peer support, and the extensibility into a broad range of architecture and engineering fields. Furthermore, parametric methods assist the capture of quantitative design data from conceptual design onwards and they enable testing and appropriation of geometric building components (e.g. façade-systems) towards constructability.

Whereas parametric design using tools such as Grasshopper™ or GC™ gets applied predominantly for intuitive design exploration, the process of Building Information Modeling (BIM) commonly gets applied to support the delivery stages of a project by increasing efficiency and reducing waste. BIM is based on parametric principles by nature, but their variations typically relate more to individual objects and assembly. BIM has a strong focus on component-based delivery and coordination across disciplines; it is currently transforming the construction industry towards more life-cycle thinking.

The 2008 Global Financial Crises (GFC) has affected the construction sector on various levels (Thangaraj and Chan, 2012) and, as a side effect, it curbed the enthusiasm for exuberant geometrical experimentation across design practices globally (Mitchell, 2009). Pressure is mounting for architectural and engineering practices to consider project cost performance and the management of the material supply-chain. The entire work-context in the construction industry is undergoing substantial changes due to its ever increasing information-richness. Some commentators argue that architects may find the importance of their role reduced significantly unless they embrace change – with BIM giving them an opportunity to do so (Onuma, 2006) (Friedman, 2006). How can academia respond to such challenges?

According to Cheng (2006), the added challenges inherent to BIM education relate to its exhaustiveness and its unprecedented closeness to actual activities undertaken in practice. The risk is high for BIM education to focus too much on mundane technical activities instead of fostering the ability of critical thinking within students (Cheng, 2006). It is therefore empirical to avoid teaching the ‘ins and outs’ of BIM tools (that are quickly outdated) and to focus on its underlying logic in a wider whole-of life context instead. Ambrose seconds this view, highlighting the disruptive nature of BIM on traditional workflow in practice, calling for a radical reform of teaching methods and the definition of the architectural education curriculum (Ambrose, 2007). Activities related to data and information management should
be considered in particular as additions to educational/training programmes both in academia as well as in practice.

Hand in hand with the increasing uptake of BIM by multiple professionals across the construction industry, comes the realisation of its disruptive nature towards established means of information exchange in practice (Holzer, 2011). This development raises questions about the consequences multidisciplinary BIM may have on education. McDonald (2012) discusses a framework for collaborative BIM, pointing out that tertiary and professional education is lagging behind developments in practice where stakeholders share information in federated models to produce coordinated sets of documentation across multiple disciplines. It is not the role of academia to pre-enact the working context from practice, but there is sufficient scope for an adjustment of training programmes in order to address BIM competencies across disciplines. A clear understanding of core BIM competencies and how one profession’s information context affects another’s is presented by Succar and Sher (2013).

Some commentators (Friedman, 2006) (Ambrose and Fry, 2012) call for a more radical change to the traditional design studio with strong industry involvement, more focus on team-deliverables and communication thereof, and learning across disciplines. Such an approach would require students to reconsider their focus on the more individual and representational aspects of architectural design, to a more information-centric development of concepts with integrated building performance and constructability feedback.

Burry remains sceptical in how far BIM can offer designers a comprehensive solution for design and delivery of projects (Burry, 2011). In his eyes, the uptake of BIM is mainly driven by business concerns, lacking the ability for digital speculation.

How do decision-makers in contemporary practice, as well as graduates who recently entered architectural and engineering practice respond to the changing context provided by parametric design and BIM? How do they reflect on the epistemological context of tertiary education in the light of technological innovation as it occurs in practice? Where are BIM and parametric design positioned among the key duties young graduates are expected to perform in practice? Where do they acquire the skills that enable them to fulfil those duties, and how long does it take them to become sufficiently skilled in order to be ‘productive’? The author conducted targeted research interviews in order to gain insight about the above questions.
4. Research Interviews and Questionnaire

In search for first-hand feedback from the field, the author ran a series of research interviews, complemented by a questionnaire with approximately 30 leading Australian architecture and engineering firms. All practices invited to partake in the survey are delivering projects using BIM, parametric design methods, or both. In order to avoid a bias towards heavy technology users, respondents to the survey were selected so to represent a mix between technology-focused staff, project architect/engineers with predominant design and management roles, and young graduates with various levels of BIM/parametric design knowledge. Interviewees were asked to articulate their views qualitatively, responding 10 questions related to technology uptake by young graduates in practice, as well as filling in a 14 point questionnaire in order for the author to derive quantitative, measurable outcomes. Industry participation for the questionnaire was high with a response rate of over 90%. This paper summarises the key findings from this targeted industry survey in order to complement the literature review and to understand how much of a ‘game changer’ parametric design and BIM are as perceived by those most affected.

A vast majority of respondents revealed that the technical skill level of young graduates has been increasing strongly over the past 5-10 years (while their detailing skills have dropped). According to those interviewed, the use of BIM was seen as highly relevant in practice whereas parametric design skills were as beneficial addition to the knowledge of young graduates. Interviewees perceive it to be desirable for young professionals to engage with both BIM and parametric design (even though it may not be their career goal). In a highly competitive market with shrinking profit margins for architects, demonstrated skills in parametric design and/or BIM can be the decisive factor for a young graduate to get employed. Figure 1 highlights the combined responses by interviewees when asked about technical skills they look for when recruiting young professionals and recent graduates.

![Figure 1. Survey responses rating required technical skills (1 = irrelevant, 5 = essential).](image-url)
Responses provided point towards the priority of BIM modeling and parametric design over other activities such as 2D CAD drafting, 3D visualisation, or scripting. At the same time, they also illustrate that, as much as BIM modeling capability is expected, other BIM related activities such as coordination, content development and BIM management are not seen as activities young graduates would take over in practice. A related question in the survey revealed that firms look for parametric design skills in young graduates, even though there is little certainty they would get to use them on projects. During the interview respondents pointed out that they were increasingly looking for staff with a good understanding of tool ecologies that assist them in a transition from conceptual modeling to documentation, visualisation and construction. A sound understanding of building construction was seen by some as the ideal prerequisite as it underpins the processes carried out in BIM. Those questioned responded that they would consider a job application preferably if the candidate demonstrates strong interpersonal skills and the ability to work in teams.

Interviewees agreed that BIM skills are mainly acquired in practice, whereas parametric design skills are rather acquired in academia. There is still room for improvement when it comes to parametric design skills of young graduates. Asked about how well academia is preparing students for a number of activities in practice (see Figure 2), ratings were predominantly contained. Parametric design only ranks third after 3D visualisation and 2D CAD drafting. Respondents highlighted that the range of (technology related) activities take varying time to master. Becoming proficient in CAD drafting or 3D visualisation would take at least 2 years, Parametric Design, Scripting, BIM Modeling and BIM content development would take at least 2-3 years and BIM coordination and management would require more than 3-4 years (reinforcing that these skills are usually acquired via vocational training).

![Figure 2. Survey responses rating how well academia prepares young graduates for a number of technical activities as required in practice (1 = inadequately, 5 = excellent).](image)
One question as part of the survey dealt in particular with the cultural implications of introducing BIM and parametric design into practice. Respondents reported that the disruptive nature of BIM can lead to increased dislocation of senior staff from the methods of design conception, development and production. Interviewees argued that if senior practitioners are set in their traditional delivery methods, using BIM can become detrimental to the projects as they "use new tools, the old way", resulting in a doubling of the effort required by other team members. Another challenge associated to the problem described above occurs when project leaders allow other (less experienced) technical staff to make decisions for what will be delivered, rather than engaging with (and guiding) the BIM model development and associated processes themselves.

Whereas the proliferation of BIM into the working context in practice appears to go hand in hand with a number of challenges, the introduction of parametric design was seen more positively during the interviews. Respondents reported on a decrease in the master-apprentice hierarchy, with young graduates gaining respect for their value-add skills as they help to facilitate novel approaches by senior staff and "inject a practice with innovation".

Asked about the changes to academic curricula they would like to see in order to align education with requirements in practice, interviewees pointed out the need for more focus on interdisciplinary design and coordination; this was followed by more focus on information management. As seen in Figure 3, BIM modeling skills and parametric design only rank third and fourth, followed by a better understanding of the business side of design, performance analysis, conceptual design and visualisation. In terms of parametric design education, young graduates would like to learn more about how it could streamline the design, documentation, and fabrication process.

Figure 3. Survey responses indicating the desired focus practices would you like to see in order to streamline education with requirements in practice (1 = less focus, 5 = more focus).
5. Discussion and Conclusions

There is a clear indication that academic institutions are misguided if they believe that requirements from practice relate predominantly to modeling or the tool knowledge of BIM. As much as these are useful when applying for a job, practice is well aware that the quality of BIM itself depends on a deeper understanding about the construction process of a building. The danger with BIM as applied by inexperienced operators is a false understanding of the construction process based on the pseudo-tectonic implied by tools that mainly cater for architects (or engineers). This sentiment was reflected uniformly by all interviewees who noted the key quality they’d wish to see in a young graduate is an understanding of "how a building is put together". At the same time, interviewees acknowledged the paradoxical nature of this wish. Such an understanding is usually gained vocationally and it is often highly specific to the working context and the types of projects developed in any given practice. What is suggested though by practice is for architectural education to become more multi-disciplinary, with students exposed to the concerns of other disciplines. Students should gain insight in the information flow within the supply chain across multiple disciplines from early conception through to operation. They should be trained to be empowered to orchestrate and manage this information-flow with authority in order to streamline collaboration.

In regard to parametric design, its introduction to the design studio is highly regarded by practices that look for specialist skills in order for the practice to keep up with current technological developments. For young graduates, sound skills in parametric design can assist in future-proofing their career, in particular if they find ways to introduce their talent to projects beyond early form-finding and experimentation.

Both for BIM and parametric design, the key expectations from practice to academic education seems to be foster a student’s ability to think critically, to be open and alert towards new technology, to adapt to quickly changing environments, and to confidently communicate and manage information in a multidisciplinary setting.

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