Challenges of Integrating BIM in Architectural Education

Tuba Kocaturk[1], Arto Kiviniemi[2]
University of Liverpool, School of Architecture, United Kingdom
[1]T.Kocaturk@liverpool.ac.uk, [2]A.Kiviniemi@liverpool.ac.uk

Abstract. *This paper provides a critical overview of some of the fundamental issues regarding the adoption and integration of BIM – both as a method and as a technology – in Architectural education. It aims to establish a common ground for the rationale behind such integration and reflects on the past and present state of the cultural, intellectual, professional and technological context of Architecture. The paper will introduce the core issues to be considered in order to succeed in this challenging and transformational process. It will also introduce a framework for a gradual and progressive adoption of BIM and integrated design in the architectural curriculum.*
Keywords. *Architectural education*; *BIM and integrated design; distributed cognition; integrated design studio.*

INTRODUCTION

The emerging visions for an "Integrated Practice" in building industry, through BIM (Building Information Modelling), carry potential to fundamentally transform the way in which architectural education engages with issues of design knowledge, technology, representations and collaboration (Ambrose et al., 2008). In this article we aim to develop a framework for the integration of BIM into architectural education. We also aim to identify the core issues to be considered in order to succeed in this challenging transformational process.

In UK, the government has set out an ambitious plan to have fully collaborative BIM, with all project and asset information, documentation and data being electronic, on all public sector projects by 2016. The UK programme based on this new BIM strategy is seen as one of the most ambitious and advanced government led programs to embed the use of BIM across all centrally procured public construction projects. Through this Government-led incentive, the construction industry is getting ready to utilize BIM as a stepping stone in order to be more efficient and effective. So how do these ambitions affect architects and architectural education at large? The RIBA believes that architects have a central role to play in ensuring that the construction industry responds to the opportunities offered by BIM in both public and private sectors and has developed a new Plan of Work (launched in May 2013) as an important piece of new guidance for architects and co-professionals [1]. However, there is yet no guidance or a roadmap for architectural schools/institutions as to how they could adapt to the forthcoming challenges in the industry and to educate the future architects accordingly.

There are both complementary and contradictory views as to "if" and "how" BIM – either as a software, or as a process or in any combination – should be integrated into the academia's curriculum structure. Some of the resistance stem from a shared set of concerns which have been outlined by some of the contributors of a recently edited book by Deamer and Bernstein (2011); *1) architectural curricula is already overloaded and there is no room for any more content, 2) The inherent practice-driven approach of BIM methodology is not compatible with the explorative character of design thinking, 3) the structure of the architectural curriculum is not suitable to adopt BIM*. Other factors have also been reported as impeding the successful adoption of BIM in the design curriculum, such as; varying definitions and interpretations of BIM by different professions; issues regarding accreditation, and disproportionate emphasis on "technical skills" (Kiviniemi, 2013).

There are two major areas where BIM will have direct impact on the architectural curriculum. First is its implicit proposition as to how design and project partners should collaborate, and the second is regarding how information (geometric and non-geometric) can be modelled, embedded and shared during the entire project life cycle. However, using a BIM software doesn't automatically guarantee a superior level of collaboration, unless conditions for a successful collaboration are met which is not only through software. Similarly, the ability to virtually model both geometric and non-geometric project information doesn't immediately bring maximum efficiency unless the representations are modelled and shared properly, the information needs in the process are correctly understood, and a robust technical infrastructure and a proper business model to support this process are present. Therefore a view of BIM solely as a software would be a rather superficial and unsustainable approach. The focus should instead be on the principles that the concept of "integrated design and project delivery" was founded on in the first place, so the changes in the curriculum wouldn't become obsolete each time a new BIM technology is developed and introduced.

The paper will initially identify the rationale behind BIM integration into the Architectural curricula (both as a concept and as a technology) and some of the common misunderstandings which impede its successful adoption. It will then try to explicate some of the fundamental reasons for the resistance against BIM. A critical review of some of the existing educational approaches will be followed with the introduction of a new framework for BIM integration into the architectural education, a discussion regarding some of the pedagogical and cognitive issues, as well as the future of the profession.

DEFINING A COMMON GROUND AND RATIONALE

BIM is widely used as the acronym for 'Building Information Modelling' which is commonly defined using the Construction Project Information Committee definition as: '...digital representation of physical and functional characteristics of a facility creating a shared knowledge resource for information about it forming a reliable basis for decisions during its life cycle, from earliest conception to demolition.' [2].

Before posing the question of "how to", it's essential to revisit an important question: What is the rationale behind using BIM in the first place? Obviously, one would easily argue that the ways in which architectural education will embed BIM into its curriculum - with supporting pedagogies - must be compatible to the rationale behind it and somehow guide this transformational process. The answer to this question is explained in a most recent government documentation as 1) promote greater transparency and collaboration between suppliers and thereby reduce waste (procurement, process and material) through all levels of the supply chain 2) enable intelligent decisions about construction methodology, safer working arrangements, greater energy efficiency leading to carbon reductions and a critical focus on the whole life performance of facilities [3]. In other words, without any specific mention to any specific technology or software, the message is: *how we used to collaborate, make decisions, exchange information, use and organize our time and resources in the past in design and construction sector have been full of inefficiencies causing a lot of waste of time, money, and resources*. *And this needs to change.* This is a statement which each and every person in our sector, including architectural educators and even the biggest BIM sceptics would probably agree with. BIM, in this present time, is "a proposition" as "a possible solution" to tackle some of the major problems of our industry. And just like every proposition, it comes with its own methodology, supported by its own technical infrastructure, implemented as a "technological solution" by various software providers, albeit with variations in their focus and in the support they provide, and with certain bottlenecks.

One of the biggest misunderstandings about BIM and the changes associated with its integration into our work practices is to compare it to the shift from drafting (on tracing paper) to CAD. Firstly, the shift from tracing paper (as 2D drawings) to CAD (as 2D computer files) did not change the outputs that were issued to the industry (Kiviniemi and Fischer 2009). Consequently, it didn't have a major impact on the structure and the hierarchies in the sector, nor required new working methods. However, already the shift from level 0 BIM to level 2 BIM (domain specific, federated models) does indeed pose fundamental changes such as; *Handling and creating information rich models, new ways of working with other stakeholders, re-aligning the disciplinary roles and responsibilities, opportunities for new additional roles for Architects*. Although even the definition of level 3 BIM (fully integrated models) is at the moment somewhat vague, it will introduce new challenges in the future. These changes become great challenges that will relate to training and education of Architects that cannot be solved simply by adding new content and skills to the existing curriculum, but will also necessitate the modification and deletion of some of the existing content.

THE STATUS ANXIETY AND THE ROOTS OF RESISTANCE

The discussions surrounding the "BIM integration into Architectural education" should not be understood in isolation, but in connection with the general changes of the relationship between architectural schools and professional practice since the beginning of the 1990s. For the most part of the 20th century, Architectural education has been looking to cultural studies and literary criticism for its theoretical models, minimizing its operative and technical capacity (Allen, 2012), and thereby created a substantial divide between architectural theory and architectural practice. 1990s marked a big shift from cultural theory to building practice in the academic circles. Theory dominance began to subside as new architecture practices emerged which better suited to meet the challenges issued by globalisation. Today, globalisation, digital technology, environmental change, and increasingly market-driven education economy are already reshaping academia (Ockman and Williamson, 2012). Consequently, there have been changes in the curriculum to address a broader understanding of social, economic, technological and cultural variables in order to design buildings which perform to higher environmental and energy standards. However, still a majority of architectural schools are following the traditional educational models with less engagement with technology and with the larger community of the built-environment that make up the building industry. Having made this distinction, it's also important to note that concerns over BIM integration into the architectural curricula are not only limited to the more conventional schools of architecture. A certain level of scepticism and hesitation exists even among the most technology savvy schools, although they have since long embraced new design methods and technologies in their curriculum and research programmes.

Although there are a few innovative and successful implementations of BIM in current practice, architectural education has been slow to respond. There are two issues to understand about the existent resistance. One is associated with some of the established values embedded deeply within its professional culture. The other is due to the nature of architectural education as an institution, and the cultural and intellectual capital it entails. Professional education in Architecture doesn't only provide the necessary epistemological and cultural context for architects, but also helps define the social and professional context within which architects work and operate within the construction industry. Although there are distinct variations in the positions different schools of Architecture take, there have always been an unspoken but almost anonymously accepted cultural norms and codes as to how architects associate themselves with the rest of the construction industry and within the society at large (Stevens, 1998).

BIM is not just a new technology. If it was just another CAD, or another piece of technology, architects would have already been the first to adopt and advocate, as we have already been witnessing through the highly creative and innovative use of the recent parametric and computational "digital design software" both in practice and in various Schools of Architecture. BIM has an implicit proposition as to how the sector should/could be realigned, restructured and work together. In other words, it will have wider social and professional implications within the sector, which makes its potential future users more hesitant. And this is probably at the core of one of the least pronounced reasons for resistance against BIM, especially by the educators in architecture, that is; by entering into an unchartered (BIM) territory architects can become a mere player, one of "the others", instead of "the creator, the innovator". BIM is not a fixed or a finished concept or methodology, and technology is continually being updated and developed to meet the industry needs, giving way to the emergence of new concepts and insights on a continuous basis. Another justified reason for the existing anxiety is about how to integrate something that is not yet theoretically nor practically complete into an "educational system" which is historically based on established theoretical and discursive models? There are various concerns that naturally follow this discussion, such as:

- How will the changes affect our accreditation status?
- How will the existing staff adapt to the new skills and knowledge required by this fast moving and industry-led approach?
- Can creative artistic expression co-exist with collaborative practice?
- Can we retain and protect our professional values in a new-found collaborative and democratic pluralism?

A GENERAL REVIEW OF CURRENT EDUCATIONAL EFFORTS OF BIM INTEGRATION

A recent study suggest that universities are lagging behind the AEC industry in terms of adopting BIM technologies and improved collaborative working practices, and that universities are not currently meeting the needs of industry in terms of collaborative building design and BIM education (Macdonald and Mills, 2011). A majority of developments in UK relate to the emergence of new master courses in BIM and Integrated Design as well as CPD courses addressing to different disciplinary groups. This makes sense as they are fast track options and provide concentrated content. They usually address to a multi-disciplinary audience and therefore entail rather generic content. They do not always address the individual disciplinary challenges and often aim to provide "an introduction" to the subject. CPDs and software-vendor led trainings usually provide more discipline specific teaching, and can range from more theoretical to more technical. However, when we look at UG level education, the situation is quite different. There are only very few adventurous institutions where BIM is already a part of their curricula, albeit quite disintegrated from the rest of the more conventional content and methods of delivery. BIM integrated design studios have also become a rather experimental and safe option in the introduction of BIM into the curricula, which are implemented in both UG and PG level studios. In most cases, architecture students work in "collaborative design teams" pretending to be another disciplinary member of the design team. In few cases, students from different disciplinary backgrounds are brought together to collaborate on design/engineering challenges. In both cases, the studio is quite isolated from the rest of the curriculum and the chosen approach doesn't follow any particular institutional and pedagogical agenda. Determining the success criteria for these experiments are also quite challenging due to differences between the maturity levels of students, their varying familiarity with the software used, and the focus of the studio challenge.

A recent article examined 3 integrated studios that variously explored designs (design collaboration, formal possibilities, engineering integration into design) and how they adjusted to the protocols of BIM, each providing interesting and contrasting examples (Pihlak et al., 2011). Some of the key findings of this study can be summarized as follows:

1. BIM teams that strived to minimize the conflict produced the least innovative designs,
2. The collaboration across different disciplines seemed to be productive when designers were strong and confident and when the engineers were flexible enough to go along with the non-linear creative process,
3. Too much compromise led to less than optimal design solutions,
4. The design went into the direction of the discipline where there was more confidence,
5. Design emphasis could easily get lost in an expanded field where numbers, time and money are so present.

A FRAMEWORK FOR BIM INTEGRATION INTO ARCHITECTURAL CURRICULUM

BIM is not just a new topic to be added to the existing curriculum, as it currently is being implemented by many schools, being introduced to the students either as "a new technology" in the studio, and/or as a "new topic" in the professional practice modules, mainly towards the end of the Bachelor level education with not much real connection with the rest of the curricula. If the concept of "BIM and integrated design" is to be embedded into Architectural education, this needs to be a gradual and progressive integration, instead of an "add and stir" approach. It needs to be connected with the rest of the curriculum, and we must be able to make sense of this new method and technology in a continuum, and by identifying our frames of references in relation to how things were in the past, how they are now and how they are changing with new tools and working methods. In order to collaborate, we have to be even more confident and competent in our ability as architects and understand the capabilities and potentials of BIM for our own profession and the design team, and influence the direction of BIM as such. We need to understand the viewpoint of the "others" instead of acting like them. Therefore we propose two core modules that need to be delivered already at the undergraduate education (Part 1 in UK Schools) starting from year 1, progressing in complexity and content as the student matures, and with an increasing degree of integration with the design studio; *Modelling and Representation* and *Collaborative Working*.

Modelling and Representation

The intelligent modelling approach, advocated by recent digital design media and BIM technology are fundamentally changing the way architects used to produce and communicate design information. In architectural education, the reproduction of the "drawing" has a special focus. The fundamental change BIM introduces is the separation of the representation and content; information in models can be viewed using different representations for different purposes and audiences. Thus, there is an urgent need to shift the focus from "drawings" to creating "intelligent" models of the design (including the possibility to generate drawings from the model). As Hugh Whitehead eloquently put it, design requires a "federation of models' (Whitehead et al., 2011) at different levels of abstractions at different phases of the design. Thus, a sketch is a model, but with a high degree of abstraction. A physical model, is yet another.

Heavy emphasis on "drawing" has also brought about "layered thinking" in terms of scales. So the level and detail of thinking has almost become restricted to the scale. Although scaled drawings can be produced from BIM models, certain information has to be thought through quite early in the process and embedded into the model. A core module on "modelling and representation" should convey the fundamental understanding of how various tools and techniques help designers model different types of information, on different level of detail in different stages, and the degree to which they influence and affect the design thinking and process. There are other motivations to develop representations as well, for example, "how to sell your ideas", "how to effectively communicate the value in your design", etc. There are different ways of embedding value and information into a design through different levels of abstractions and different types of representations according to "who" you are dealing with and "for what purpose". However this variety has not been sufficiently present (or encouraged for that matter) in Architectural Education. A majority of schools still require a pre-determined set of scaled drawings for the final studio presentations which are prepared usually for the eyes of other designers, whereas in real practice, architects communicate and negotiate information across a much wider community of professionals and clients, who seldom can fully understand traditional drawings. What we are proposing is a shift of emphasis from the final product representation towards the process of design creation, development, coordination, communication and negotiation through representations. In such a discussion, we implicitly define the role we think the architect should play in the future. Does the architect's role end by preparing the right type and format of information, or do we want to coordinate this multi-layer information web?

The student learning in this module should progress from understanding the fundamentals, then developing intelligent models, and then selectively sharing and exchanging information in data-rich models. Students should also be able to understand the underlying concepts of *creative* and *operational modelling* and the degree of abstraction, clarity and precision required in both.

Collaborative Working: Tools, Issues and Methods

The appreciation of the differences in professional, disciplinary and cultural values during collaborative working has become an important concern with an increase in global mobility and global practices. We propose a core module in "Collaborative Working" that explicitly clarifies the role of architects in a larger community of built environment professionals and introduces the various tools, issues and methods that are geared toward varying goals and practices of collaborative working. As the students get more mature, they should be exposed to diverse set of tools, methods and techniques with which they can experiment, compare and appreciate the differences between individual and collaborative working in different design exercises.

A common tendency in BIM integration in architectural education today is the introduction of "multidisciplinary" design studios, as discussed in the previous sections. Although it is useful to mimic the actual design practice by bringing students from different disciplines together (each drawing on their disciplinary knowledge) at certain point in their formal education, the timing of such an interaction is of vital importance and could only be useful if the students have already gained a certain degree of maturity in their own specialization. In order to make this point clear, we refer to Marilyn Stember's paper (1991) where she offers the following overview of different levels of disciplinarity (descriptions are summarized to fit into our context).

- Intradisciplinary: working within the professional boundaries of a single discipline.
- Cross-disciplinary: a design team (or an individual designer) from one discipline is viewing and using concepts of another discipline from the perspective of their (his/her) own.
- Multidisciplinary: people from different disciplines are present and working on the same project, however each one is operating on their own disciplinary knowledge
- Interdisciplinary: a design team (or an individual designer) is integrating knowledge and methods from different disciplines, using a synthesis of approaches.
- Trans-disciplinary: a unified and commonly accepted framework (understanding) beyond any individual disciplinary perspectives of a community of practice

Architectural education needs to address all of these levels of disciplinarity. Design is intrinsically an *interdisciplinary* activity as the design process entails a continuous synthesis and negotiation of different knowledge from different disciplines. However, this requires an awareness of our own disciplinary roles and responsibilities (*intradisciplinarity*). Only with this awareness, we can utilize the knowledge of other disciplines, appreciate the role they play in relation to ours (*cross-disciplinarity*) and be able to draw on our own disciplinary knowledge in a confident way and can make an effective and creative contribution in a *multidisciplinary* context. When these concepts are used as pedagogical approaches, they are all valid and necessary at different stages of architectural education (and training). However each requires a different level of maturity (of students), and a brief (on an appropriate scale) to support the intended outcome of the relevant studio or taught module it's applied in. Similarly, one should also pay attention to the suitability of each method in different context. For example, interdisciplinarity and cross-disciplinarity are more appropriate for creative design, and multidisciplinarity is more appropriate for relatively more mature students. For example pairing architectural students with engineering and construction management students in "integrated BIM studios" in the early years of UG design education would be "pedagogically incorrect" if the students are not yet at a maturity to recognize each discipline's own values, procedures and protocols. Students would still learn useful skills but this would most probably be at the expense of the quality of the design outcomes as design emphasis would most probably be diminished. It would probably make more sense to introduce "intradisciplinary" and "interdisciplinary" studios during early and later years of UG education, respectively, and "multidisciplinary" studios at the PG level, when the learners have the necessary maturity. Trans-disciplinarity is still an undefined territory in design and construction. Some of the concepts advocated by "integrated design" are currently being recognized as trans-disciplinary. However, this should not be seen as a casual blurring of disciplinary boundaries. On the contrary, as emphasized eloquently by Hanif Kara, one of the conditions of a successful "integrated design" is that "each discipline should become more skilled at what they do and, most importantly, respect and value the contribution of each other as a first step towards new working processes" (as cited in Pihlak et al., 2011).

COGNITIVE IMPLICATIONS

These recent trends in "digital media and BIM integration" in collaborative design studios point out to a common tendency across many schools of architecture; aiding the learner development through both social and technological scaffolds. In this respect, we identify the emergence of a dominant 'tool-aided', 'socially shared', contextual and highly situated forms of cognition commonly referred to in literature by developmental psychologists and learning theorists as "distributed cognition" (Hutchins et al., 1986) and "distributed intelligence" (Pea, 1993). The central idea is that the resources that shape and enable activity are distributed in configuration across people, environments, situations and artefacts (tools). One of the main pedagogical dilemmas today can be grounded on the gap between the distributed and the individual levels of intelligence that students are building through diverse methods of knowledge acquisition and methods of delivery without any explicit recipes of how to build the link between the two. This separation has become even more distinct with the integration of technology and collaborative working methods in the design studio.

Salomon (1993) introduces two kinds of cognitive effects of technologies on intelligence:

- **Effects with** technology is obtained during intellectual partnership with it, and
- **Effects of** technology in terms of the transferable cognitive residue that this partnership leaves behind in the form of better mastery of skills and strategies.

While **effects with** refers to the development of Distributed Cognition, **effects of** is attributed to the development of individual cognition and solo intelligence which are essential for the learner to develop an autonomous response as a residue to interaction with the social and technological scaffolds. Today, the special emphasis on the use of a variety of BIM software and skill building workshops offered by many tool builders provide mainly technical scaffolds to the learner. This disproportionate emphasis placed on the "tools" present a risk of promoting design and collaboration as solely a tool-driven activity, especially for the novice learner, displacing the innermost values of architecture, and as a consequence, weakening and changing the role of designer in the society (Kocaturk et al., 2012). In sum, we propose the development of individual and distributed competencies within the same pedagogical framework.

SUMMARY AND DISCUSSION

The article gave a critical overview of some of the fundamental issues regarding the adoption and integration of BIM – both as a method and as a technology – in Architectural education. It also tried to explicate some of the fundamental reasons for the current resistance while reflecting on the past and present state of the cultural, intellectual, professional and technological context of Architecture. A critical review of some of the existing educational approaches to BIM integration, such as BIM integrated studios, revealed the fact that the current implementations are quite opportunistic, disintegrated from the rest of the curriculum and lack any clear strategic and/or pedagogical agenda. Two major areas have been identified where BIM will have direct impact on the architectural curriculum; 1) modelling and representation, and 2) collaborative working. These areas have been proposed to be added to the architectural curricula as the two new core modules, starting from year 1, and progressing in complexity and content as the students mature, with an increasing degree of integration with the design studio. Some of the critical pedagogical and cognitive issues have been identified according to the extent to which the new technology and working methods will have an impact on the process of learning and development of both individual and distributed cognition.

It is also important to note the changes in the professional services provided and required from the architects, on a global scale. We are experiencing the emergence of additional profiles, new specializations and consultancy services high in demand in building industry. In such expanded modes of practice, one size doesn't fit all. Is it sustainable or even possible to reproduce "architects" with exactly the same profile? New specializations (such as BIM Manager) should be introduced to students as possible (alternative) pathways already during their UG education, which they could later choose to specialize on during their PG studies. This might be influential in harnessing the most out of individual talent and interest (e.g. design, technical skills, business).

Will architectural education just follow BIM as a trend, solely as a beneficiary, or become one of the driving forces in this industry transformation? Do architects really have the chance to renegotiate their status and maybe even regain their master-builder status with BIM – as implied by many – or does BIM further emphasize and legitimise the hybridity of architectural profession? The answer to these questions, for each and every architectural institute in particular, will be the main guide in setting up a plan for their interpretation and integration of BIM in their educational agenda with relevant and necessary technical infrastructure and pedagogical approaches. And there is a good indication that there will be parallel and contrasting approaches across institutions, which ultimately will determine a new plural agenda for the profession. Therefore the underlying challenge is about renegotiating architects' multiple identities and redefining the problematic relationship that has long existed between academia and practice; techniques and aesthetics; science and humanities.

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