Obrazovanje odraslih/Adult Education, ISSN 1512-8784, Broj 1-11 2022., str. 91-108
UDK: 72:378.4]:004.4BIM
DOI: 10.53617/issn2744-2047.2022.22.1-2.91
Pregledni rad/Review paper
Primljeno/Received: 01.12.2022.
Prihvaćeno/Accepted: 30.12.2022.

Hatidža Çapkın[1]

Meeting Professional Development Needs of Architects: Models for Integrating BIM into Education Programs

Abstract: There is a need for innovation in the education and further professional development of architects which will enable them acquire and develop the future-oriented knowledge and skills. In the knowledge society, learning takes place in an array of different contexts and lasts as long as an individual is keen on developing new knowledge or skills. However, initial preparation through university programs is essential for the professionalization of the field and development of professional identity in an individual. Yet, university is traditionally resistant and sceptic to changes, especially those coming from the industry or other market-oriented sectors. This makes university experts search for suitable models of introducing innovations. This paper discusses the models questioned in relation to the introduction of the Building Information Modelling (BIM) in architectural education. It is considered a paradigmatic change in engineering education, which requires specific capacities for its successful implementation in the education programs. Three models are discussed; BIM in education frameworks, stand-alone BIM courses, and BIM in the design studio.

Keywords: education needs, professional development of architects, university programs, Building Information Modeling (BIM)

[1] Hatidža Çapkın, PhD, Researcher, Istanbul Technical University, e-mail: isanovic@itu.edu.tr

Introduction

Avant-garde theorists of architectural education consider current education to be in serious crisis, requiring radical changes and paradigmatically new approaches (Buchanan 2012a; Findeli 2001). Much of architectural education is largely based on traditional models, according to which architecture is regarded as an artistic discipline. Current educational models have been widely criticized for its insufficient sensitivity for social and environmental changes, new technologies, and specifically for changes in the architectural practice and construction industry in general (Nicol & Pilling 2005). The methods and tools it uses, the role models it follows and the knowledge it offers, are based on the educational models of the past era (Tvederbrink, Jelić 2021). As such, academic architecture education belongs more to the modern rather than the postmodern educational paradigm.

The influential voices in contemporary architectural research call for a fundamental rethinking of the underlying theories and methods of architectural education and emphasize the need for new educational models that will meet the requirements of the emerging context of 21st century architecture (Buchanan 2012b; Chong et al. 2010; Findeli 2001; Foqué 2010). Moreover, many practicing architects from the world's leading architectural firms such as Patrik Schumacher (ZHA), William and Christopher Sharples (SHoP), Reinier de Graaf (OMA), Winy Maas (MVRDV), are also criticizing today's architectural education. Schumaher (2019), the principal of Zaha Hadid Architects, explicitly expresses concerns about its relevance, as he considers that "the current architecture education is disconnected from the profession and it doesn't pursue societal realities or needs as expressed in real (public or private) client briefs" (Schumacher 2019). The architect specifically emphasized the global crisis in which architecture is found today, which cannot be fixed by universities alone as it reflects the fragmentation and disorientation of the discipline.

What is BIM (Building Information Modeling)?

BIM is a digital model-based technology linked with a database of project information which is led by the idea to reintegrate design, construction, and project management, reducing project delivery time and overall costs. It represents a large innovation in architecture, engineering, construction and operation (AECO) industry with significant upside potential, but it also represents, as most innovations do, a disruption to established culture and associated modes of practice and education. Nowadays, tending towards the adoption of digital technologies and building information modeling (BIM), architectural education is going through transformation. The inclusion of BIM in architecture, as well as engineering and construction into academic curricula has gathered significant pace over recent years. The growing importance and utilization of BIM in contemporary practice creates a task for educators to rethink the way students are being prepared for it. The introduction of BIM into academic curricula strongly indicates the need for transformation of the traditional educational approaches, reconsidering the practice-education relationship and re-arranging the fragmented disciplinary structures in AEC education.

In past two decades, there has been a visible increase of publications in the area of BIM teaching in architectural education and signs that it is becoming a growing field of research. However, there is a lack of agreement among scholars and educators on how should it be done. There is a lack of agreement on whether BIM should be approached in architectural curricula as a tool/skill issue, a new form of design practice or a professional organizational method. As a consequence, the question of how and when to introduce BIM into architectural education remains open and exploring innovative approaches is needed.

BIM as an architect's professional development need

The results of a survey undertaken by RIBA Appointments indicates that architecture schools are not equipping students for the realities of life in practice (Dobson 2014). Another survey conducted by the National Council of Architectural Registration Boards (NCARB 2013) defined the knowledge/skills architecture graduates must possess and the tasks they must be able to perform at the time of licensure. Practitioners listed BIM as the second-highest professional development need.

In addition, licensed architects identified gaps in the business of architecture including construction management, project and practice management. Moreover, Phillip Bernstein, a technology thinker, educator, and architect, also suggests re-aligning the models of practice present in current architectural education. According to his observations two dimensions of being an architect aren't sufficiently developed in education. One is the nature of the practice. What do architects actually do, where do they connect to the overall systems, and what is the future of architecture? Second, the emphasis on design training, just one portion of the architect's responsibilities, tends to warp the student's perspective about the most important thing they're doing and the context in which they operate (Bernstein 2017).

In addition to the gap between practice and education, Nicol and Pilling (2005) suggested other problematic aspects of architectural education which are related to the conception of the design studio, collaboration and teamwork and lifelong and self-learning development. The current conception of design studio mainly emphasizes the issues, roles, methods, tools, and processes from the past century (Clayton 2006). It places much more emphasis on the way design ideas are represented rather than on understanding how they are translated into the actual architecture building. The lack of real-life aspects results in students' proposals focused on 'good looking' design that considers only the one-dimensional context of a building, usually only formal. Thus, many design studio instructors complain about 'visually appealing but unbuildable student projects' (Balfour 2001). In addition, the design studio is still strongly based on drawing as the primary tool for expressing and communicating design ideas. Students are not only taught to make drawings but to think through them as well. In learning by drawing, students learn to dissect building into plans, sections and elevations, all of which contributes to disintegrated thinking about building. Students fail to understand the building as a system of interrelated components and the way they get connected into the whole.

Although architecture building making has always been the act of interdisciplinary contribution from architects, engineers, constructors, and other sub-disciplines, architectural education has never cherished enough the culture of collaboration. The perception of design as the result of one individual creative act is rooted in architecture training and deeply embedded in their practice, knowledge, and tools (Lawson 2006). The abovementioned drawing-based education prioritizes the individual skills of a single designer, a 'solitary genius', rather than the '21st-century collaborator'. In addition, the constant growth of technology poses the requirement for continuous learning and upgrading of our knowledge and skills.

BIM in architectural education

Educators become aware that the role of university education is seen as providing the guidelines on an approach of 'learning how to learn' and teachers become moderators in the learning process, like scaffolding for a new building (Niemi 2009). Architectural education is based around the development of formal skills which are, and always will be, essential for architectural education. As a design tool, the drawing will preserve its important place in the work and thinking of many architects. However, for the competent architects of the future, they need to be expanded and combined with other knowledge and skills.

Over the last few decades, the transformation process of architectural education has already begun in order to make room and adopt new technologies and opportunities they bring for architectural design and building making. The various examples found in research literature demonstrate that academic education is cognizant of the key role that BIM can play in more sustainable, efficient and collaborative practice. The inclusion of BIM in academic architecture, engineering and construction (AEC) programs has gained significant pace over recent years. While there is a visible increase of publications in the area of BIM in academic education and signs that it is becoming a serious area of research, there is a lack of agreement on how should it be done.

Various universities around the world such as Georgia Tech, MIT, Southern California (USC), Virginia Tech, Harvard, PennState, Texas, Cal Poly, are searching for the best ways to introduce BIM in architecture, as well as engineering and construction academic curricula. The questions of when and how to introduce BIM are approached differently. Barison and Santos (2018) provide the extensive list of authors and universities who have integrated BIM into their curricula as well as a comprehensive overview of common trends in adoption across disciplines (Barison & Santos, 2018). According to their observations, architecture schools were among pioneers showing interest in BIM adoption when it first appeared. However, today, they are among the ones with the least agreement on how to do it.

One of the major reasons for this can be found in the presence of clearly opposite attitudes towards BIM in architectural education. On one side, BIM is seen as a threat to the explorative character of architectural education and the creative development of students. On the other side, it is seen as an opportunity to improve architectural education by helping to resolve some of its existing issues. BIM is also seen as a promoter of a more sophisticated 'design thinking' by allowing explorations of various dimensions of design solutions. According to this view, BIM is an inevitable part of the 21st-century architectural curricula.

Another reason for the still unresolved status of BIM in architectural education comes from the fact that it means different things for different educators. While some see BIM as a tool/skill issue, others consider it as a new form of design practice, or a new professional organizational model (Deamer 2011). Each of these positions leads to very different pedagogical approaches, teaching methods and contents. In addition, BIM is not just a new topic to be added to the existing educational models. Its adoption requires re-considering epistemological, cognitive and pedagogical aspects of education (Kiviniemi 2013). In order to answer the question of how and when to introduce BIM into architectural education requires exploring innovative approaches.

Main approaches to BIM in architectural education

BIM education has been widely explored in the literature over the past two decades. Various authors have discussed BIM curricula models from program to course levels. Barison and Santos (2018) and Abdirad and Dossick (2016) provided a comprehensive analysis and systematic review of research literature on BIM curriculum design in AEC education (Abdirad & Dossick 2016; Barison & Santos, 2018). However, their focus is mainly on construction and engineering curricula. Although both share some common characteristics and contents with architectural curricula, the introduction of BIM in architectural education needs to be considered as a separate case. The design studio centered curricula and the explorative nature are unique for architectural education.

Three dominant approaches to the introduction of BIM into academic architectural curricula can be extracted from research literature:

a) BIM education frameworks

b) Stand-alone BIM courses
c) BIM in the design studio.

BIM education frameworks

They are usually developed on the national level, based on the requirements of a specific country. For example, the UK BIM Academic Forum proposed (BAF) a set of learning outcomes to address strategic, management and technical industry needs to facilitate knowledge, understanding, practical skills and transferable skills (Underwood et al. 2015). BAF also produced a useful BIM teaching impact matrix, which described the following four levels of engagement: absent, aware, infused and embedded. The learning outcomes framework indicates the knowledge required from construction industry practitioners in order to implement BIM level 2 successfully. However, since the framework is aligned with UK BIM standards and policies, it can only be completely followed in the UK and in countries where UK BIM standards have been adopted. In Australia, the "Collaborative Building Design Education using BIM (CodeBIM)" proposed a framework for collaborative building design teaching using BIM entitled as IMAC (Illustration, Manipulation, Application and Collaboration) (Mills, Tran, Parks, & Macdonald 2013). IMAC framework provides a strategy for how BIM education should be provided in AEC education.

Kelly et al. (2015) proposed a reciprocal learning framework where industry best practice, curriculum development, and research activities are coordinated and utilized to address the educational challenges posed by the interdisciplinary nature of BIM. The framework is based on the utilization of real-world local construction projects (as case studies). Academic-industry partnership has enabled the development of industry orientated multi-disciplinary Higher Diploma in BIM. Within this framework, a set of modules was developed: BIM Virtual Modelling Fundamentals, BIM Architecture, BIM Structure, BIM Infrastructure, BIM Mechanical, Electrical and Plumbing, BIM Collaboration and BIM Project.

Coates et al. (2010) suggested the knowledge transfer partnership approach (KTP). KTPs are projects between universities and companies through which academia share knowledge and assist in the development of the industry (Coates, Arayici, & Koskela 2010). Knowledge transfer seeks to organize, create, capture or distribute knowledge and ensure its availability for future users. This concept of knowledge sharing forms the basis of the KTP schema. Using the knowledge gained from the KTP the University can develop course material. Through the KTP the academic supervisors gain industrial experience allowing them to become more knowledgeable tutors.

A framework that specifically focuses on architectural education was proposed by Kocaturk and Kivinemi (2013). The main premise of this framework is that BIM impacts two major realms of architectural curricula: representation and modeling; and collaborative working. The focus of the first realm is on the ways of modeling, embedding and sharing geometric and non-geometric information during the entire project life cycle. The second one is proposing ways of collaboration between design and project partners. Accordingly, they proposed two core modules:

- Modeling and representation that focuses on the process of design creation, development, coordination, communication and negotiation through building models.
- Collaborative working and co-creation consider the timing of involving each 'disciplinarity' in design and clarifying the role of an architect in a team.

By acknowledging the differences between individual and collaborative teamwork, this module covers cultural, social and technical issues in collective design activity. They suggested that the integration of BIM should be gradual and progressive change rather than the "add and stir" approach. It should be founded on a deep understanding of other disciplines and their contribution to design. "It needs to be connected with the rest of the curriculum, and the new method and technology of BIM should make sense 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" (Kocaturk & Kiviniemi 2013).

Stand-alone BIM courses

The introduction of BIM into the curriculum initially took the form of single courses (Barison & Santos 2018) and represents the most widespread way of introducing BIM into architectural education. This approach is typically practiced by those who believe that the introduction of BIM should be decoupled from design studios, and taught in other courses such as building technology (Aksamija 2017; Ibrahim 2014). Early examples of this group focused on making a transition from teaching CAD to teaching BIM, and exploration of affordances of BIM tools over CAD tools (Denzer & Hedges 2008). As standalone, BIM is introduced in the form of a specific BIM course, or as part of digital graphics representation, building technology, environmental courses, professional practice, the workshop or as part of research courses in master or doctorate programs (Barison & Santos 2018). This approach can involve a single course or a group of multiple courses addressing different topics, such as basic BIM concepts and modeling, parametric design or building lifecycle applications of BIM.

When BIM is taught in just one or two courses, BIM tools are usually taught at the beginning of the programs (freshman or sophomore) and at the end (junior or senior). When BIM is taught in several courses, the BIM model is used as a teaching resource to improve students' understanding by visualizing certain issues. However, according to a recent survey, many programs around the world still focus mostly on software skills (Rooney 2017). The disadvantage of this approach is that offering standalone BIM courses without any follow-ups in other courses do not support students' long-term learning because students rarely find the opportunity to re-use BIM skills in different courses, and they do not retain software skills after learning and using them for a single course. In addition, a standalone BIM course can be disruptive because students experience a learning environment very different from other AEC courses (Wu & Issa 2013).

BIM in the design studio

For a design studio-centered curricula, positioning BIM in relation to design studio in architectural education deserves careful consideration. As in the previous two approaches, there is a variety of attempts to introduce BIM through the design studio. They can be divided into three main groups:

1) An intradisciplinary studio is a form of teaching BIM to students from the same discipline (architecture, engineering, etc.). This approach is typically employed to create, develop and analyze BIM models or even teach more subjective BIM concepts and simulate collaboration in a real project (Ambrose & Fry 2012)
2) An interdisciplinary studio where students from different programs at the same university learn BIM concepts and simulate real collaboration by experiencing practical situations in a design studio (Poerschke, Holland, Messner & Pihlak 2010).
3) Distance collaboration a local or global level is a variation of interdisciplinary collaboration in which students from collocated teams collaborate and get exposed to typical situations and technologies involving remote collaboration. Guidera (2006) proposed a reductionist approach to the integration of software used in professional practice with course activities associated with the design studio.

This prescriptive strategy emphasizes the use of task specific software features to support specific aspects of design project activities and learning outcomes. Computation, specifically computer modeling using BIM software can be effectively introduced at the early stages of the curriculum through the use of a specific and prescriptive approach to software features and commands. It develops an understanding of the conceptual underpinnings of object-based modeling, thus providing a foundation for the use of more advanced applications of BIM later in the design curriculum as well as in the profession.

Clayton et al. (2010) introduced the Studio 21 approach that takes advantage of twenty-first-century information tools. The study compared conventional and BIM approaches (Studio 20 and 21) in the design studio (Clayton, Ozener, Haliburton, & Farias 2010). Results show that Studio 21 approach radically changes the design process in terms of time devoted to particular tasks, definitions of schemes, and decision warrants. Furthermore, Studio 21 can produce designs with higher performance by enabling the designer to rely upon objective 25 measures of performance rather than tacit knowledge. It can be taught more quickly as it relies less on the slow acquisition of tacit knowledge through experience and more on explicit knowledge that can be transferred in a classroom setting or through written documents. In Studio 21, decisions are based on objective, even quantified measures of performance that derive from simulations and analytical calculations. The designer chooses a scheme among several alternatives based on the examination of the performance.

One of the most representative and successful examples of interdisciplinary BIM studios are collaborative BIM studios at Penn State (Poerschke et al. 2010). BIM began to be taught in the interdisciplinary design studio which brought together students from six different AEC programs and was developed on various levels where students were taught to use BIM technology not only for design integration and analysis but also Integrated Project Delivery (IPD) processes for collaboration (Solnosky, Parfitt, & Holland 2013). In addition, they are characterized by interdisciplinary collaborative design teams; practitioner/ client involvement which exposes students to real-world practitioners and client expectations. This gives the students a unique opportunity to learn from and interact with practitioners as well as to be exposed to a real client; design benchmarking – as the students develop their own designs, they are required to benchmark their work against the real project design in terms of function, cost, schedule, site logistics, and energy consumption. In a collaborative BIM studio, students learn the lexicon of their allied fields. It is not essential to know how to calculate the variables; what is crucial is the knowledge of what the controlling factors are and how their designs might optimize that variable. Pihlak and Deamer et al (2011) reported a study of three integrated studios where they observed design exploration and how it adjusts to BIM protocols (Poerschke et al. 2010). They noted that collaboration is productive when architects are strong and confident about their field, and when engineers are flexible to fit into the creative process. Their specific focus was on design collaboration, formal possibilities, and engineering integration into design.

Key findings of this study show that minimizing conflict between team members from different disciplines leads to decreased innovation in design.

Furthermore, Teams that made too much compromise offered less than optimal solutions. In addition, design emphasis gets lost in the field where design is loaded with numbers, time and money. Within these approaches, BIM was introduced both in undergraduate and graduate courses, each having its advantages and disadvantages. (Nakapan 2015; Yan 2010).

In integrated studios at the undergraduate level, there are many pre-BIM design fundamentals that need to be covered such as form, composition, spatial hierarchy, architectural vocabulary, and grammar. In contrast, Denzer and Hedges (2008) demonstrated that BIM provides significant advantages even at the undergraduate level (Denzer & Hedges 2008). These are: fostering integrated thinking about architecture, structure and mechanical systems; considering materiality and construction at earlier stages of design than the conventional model; 'shifts the curve to the right' – the proportion of time dedicated to developed design increased when compared to schematic design. While in the conventional model, students commonly work only in the schematic level, not even considering detailed design, working with BIM allows students to easily deal with questions related to developed design. This also encourages students to pursue more complex designs. However, according to Aksamija (2017), integration of BIM with design studio classes (after mastering the basics and understanding software capabilities) is highly recommended, since this allows students to advance their knowledge and skills.

Further challenges and obstacles in architectural education

The development of successful education depends on more than just curricula development. Supporting curricula development needs knowledgeable tutors, a body of research and reference material and the appropriate environment in which to learn. BIM has put the learning challenge in front of educators and students equally. As BIM has recently gained popularity among architecture educators, many teachers do not have the required level of knowledge, expertise or design project experience to teach BIM. Most teachers are experts in 2D drafting, some in 3D modeling, but relatively a few in BIM (Kiviniemi 2013).

Creating an information-rich virtual model of a building requires much more knowledge than architectural teachers teach. The lack of expertise of teachers can result in poor learning and teaching outcomes. Therefore, the issue of 'who' will deliver BIM-related knowledge represents an important challenge for its introduction in architectural curricula. Further, developing appropriate educational material is another challenge. This is because most of the sources of materials are either from research studies, which are released via publication only, or vendor-oriented material, which is biased towards proprietary BIM tools. In order to overcome this limitation, some universities create their own in-house resources that are used by the students and faculty involved in BIM education. however, this again is not shared among universities massively, and each university has to take a similar effort from scratch.

Putting forward modeling and simulation instead of drawing in learning design represents a significant challenge for architectural education. Modeling and simulation prioritize the building logic and systemic thinking of how things are built, how do they perform, not only how they are represented. Cheng (2006) has warned on the threats and risks of applying BIM without changing the pedagogical model. If BIM is carelessly introduced within the architecture curriculum design thinking its central role in architectural learning could be overshadowed (Cheng 2006). If BIM tools are not introduced properly, they tend to be confused for another CAAD (computer-aided architectural design) tool.

The traditional CAAD tools are usually used within a representational domain and for the exploration of formal possibilities. BIM essentially is a tool that can aid design, but in a different way than the conventional CAAD tools. Architecture programs mostly teach BIM with a focus on design for purposes of visualization and 3D modeling. Students usually get fascinated by the representational capability of the tool and usually ignore the constructional and functional requirements of buildings in their projects. As such, BIM use may negatively impact students' creativity and design solutions may become mere outputs of the functionality of BIM tools instead of emerging from students' creativity. If a student does not understand the underlying principles and what drives their tools, there is a threat to students' disengagement with the tool. In addition, automation of functions and ready-made downloadable libraries possible with BIM can 'disguise' an underdeveloped design by giving it an appearance of resolution making it difficult to distinguish between a conscious design decision and the one automatically created by the BIM software.

BIM introduces the concept of collaboration, which requires the integration of different subject areas. For an educational setting traditionally based on silo logic such as architectural education, this is a challenging task. Moreover, it is difficult to coordinate the schedules, classrooms, and laboratories of all the units involved since this includes many students studying at the same time. 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.

Ususret potrebama za profesionalnim razvojem arhitekata: Modeli integracije BIM-a u obrazovne programe

Sažetak: Izražena je potreba za inoviranjem obrazovanja i stručnog usavršavanja arhitekata, što će im omogućiti sticanje i razvijanje znanja i vještina potrebnih u budućnosti. U društvu znanja, učenje se dešava u mnogim različitim kontekstima i traje sve dok osoba pokazuje volju za razvojem novih znanja i vještina. Ipak, inicijalna priprema kroz univerzitetske programe od suštinske je važnosti za profesionalizaciju područja i razvoj profesionalnog identiteta pojedinaca. Univerzitet tradicionalno pokazuje otpor i nepovjerenje prema promjenama, naročito onima nametnutim od strane industrije i drugih tržišno orijentisanih sektora. To univerzitetske stručnjake stavlja pred potrebu traganja za odgovarajućim modelima uvođenja inovacija. Jedna od tih inovacija, koja se smatra paradigmatskom promjenom u obrazovanju inženjera, jeste uvođenje BIM-a (engl. Building Information Modelling). Ovaj članak diskutira o tri modela uvođenja BIM-a: struktura za BIM u obrazovanju, samostalni predmet BIM i BIM u predmetu Arhitektonsko projektovanje.

Ključne riječi: obrazovne potrebe, profesionalni razvoj arhitekata, univerzitetski programi, Building Information Modelling (BIM)

Bibliography

Abdirad, H., & Dossick, C. S. 2016. BIM curriculum design in architecture, engineering, and construction education: a systematic review. *Journal of Information Technology in Construction (ITcon)*, 21(17), 250-271.

Aksamija, A. 2017. BIM in Architectural Education: Teaching Advanced Digital Technologies to Beginner Designers. *The International Journal of Architectonic, Spatial, and Environmental Design*, 11(2), 13-25.

Ambrose, M. A., & Fry, K. M. 2012. Re: Thinking BIM in the Design Studio Beyond Tools… Approaching Ways of Thinking. *CAAD, INNOVATION, PRACTICE: 6th International Conference Proceedings of the Arab Society for Computer Aided Architectural Design*, Manama, Kingdom of Bahrain: The Kingdom University.

Balfour, A. 2001. Architecture and electronic media. *Journal of Architectural Education*, 54(4), 268-271.

Barison, M., & Santos, E. 2018. Advances in BIM Education. In R. F. I. Mutis, and C. C. Menassa eds., *Transforming Engineering Education: Innovative Computer-Mediated Learning Technologies*. Reston ASCE American Society of Civil Engineers, pp. 45-122

Bernstein, P. 2017. Technology and the Future of Design: What's Next?/Interviewer: D. Intelligence. *Design Intelligence Quarterly*, https://www.designfuturescouncil.com/member-portal/dfc-articles/past-quarterly-articles/technology-future-design-whats-next/ (25-10-2022).

Buchanan, P. 2012a. 1989 July: What's wrong with architectural education? Almost everything. *The Architectural Review*. Retrieved from https://www.architectural-review.com/today/1989-july-whats-wrong-witharchitectural-education-almost-everything/8637977.article (01-09-2022).

Buchanan, P. 2012b. The Big Rethink Part 9: Rethinking Architectural Education. The Architectural Review. Retrieved from https://www.architectural-review.com/essays/campaigns/the-big-rethink/thebig-rethink-part-9-rethinking-architectural-education/8636035.article (01-09-2022).

Cheng, R. 2006. Questioning the role of BIM in architectural education. *AECbytes Viewpoint*, 26.

Chong, G. H., Brandt, R., & Martin, W. M. 2010. *Design informed: driving innovation with evidence-based design*. New York: John Wiley & Sons.

Clayton, M., Ozener, O., Haliburton, J., & Farias, F. 2010. Towards Studio 21: Experiments in Design Education Using BIM. Goosens, K. & Agudelo, L. eds. *SIGraDI 2010 Proceedings of the 14th Congress of the Iberoamerican Society of Digital Graphics, SIGraDI,* Bogota, 43-46.

Coates, P., Arayici, Y., & Koskela, L. 2010. Using the knowledge transfer partnership model as a method of transferring BIM and lean process related knowledge between academia and industry: A case study approach. *International Conference of Ecobuild America: Sustainable, High Performance & Technology Solutions for Built Environment.* Washington DC, USA. http://usir.salford.ac.uk/id/eprint/12890/

Deamer, P. 2011. BIM in Academia. In P. Deamer & P. G. Bernstein eds., *BIM in Academia*. US Yale School of Architecture, 9-12.

Denzer, A. & Hedges, K. 2008. From CAD to BIM: Educational strategies for the coming paradigm shift. *AEI 2008: Building Integration Solutions*. https://ascelibrary.org/action/showCitFormats?doi=10.1061%2F41002%28328%296 (15-09-2022).

Dobson, J. 2014. RIBA Appointments: Skills Survey Report 2014. Retrieved from Newcastle Upon Tyne: https://www.architectsjournal.co.uk/Journals/2015/02/02/m/n/i/skills_report__2014.pdf (15-09-2022).

Findeli, A. 2001. Rethinking design education for the 21st century: Theoretical, methodological, and ethical discussion. *Design issues*, 17(1), 5-17.

Foqué, R. 2010. *Building knowledge in architecture*. Antwerp ASP/VUBPRESS/UPA.

Guidera, S. G. 2006. BIM applications in Design Studio An integrative approach Developing Student Skills with Computer Modeling. *Synthetic Landscapes: Proceedings of the 25th Annual Conference of the Association for Computer-Aided Design in Architecture*, Louisville, Kentucky, 12-15 October 2006, pp. 213-227.

Ibrahim, M. M. 2014. Thinking the BIM Way: Early integration of Building Information Modelling in education. E. M. Thompson ed. *Fusion – Proceedings of the 32nd eCAADe Conference – Volume 2,* 10-12 September 2014, Newcastle upon Tyne, England, UK, 427-435.

Kelly, M., O'Connor, J., Costello, M., & Nicholson, G. 2015. A Collaborative Academia-Industry Approach to Programme-Wide Implementation of Building Information Modelling Processes using a Reciprocal Learning Framework. *CITA BIM Gathering,* Dublin, 2015.

Kiviniemi, A. 2013. Challenges and opportunities in the BIM education–how to include BIM in the future curricula of AEC professionals. *BIM Academic Workshop 2013*.

Kocaturk, T., & Kiviniemi, A. 2013. Challenges of integrating BIM in architectural education. *Building Information Modelling – Volume 2 – Computation and Performance – eCAADe 31,* Delft: Delft University of Technology, pp. 465-474.

Lawson, B. 2006. How Designers Think: The Design Process *Demystified*. Oxford Architectural Press, Elsevier.

Mills, J., Tran, A., Parks, A., & Macdonald, J. 2013. *Collaborative building design education using Building Information Modelling (CodeBIM)*. Sydney: Office for Learning and Teaching. Retrieved from: https://ltr.edu.au/resources/PP10_1745_Mills_Report_2013.pdf (01-09-2022).

Nakapan, W. 2015. Challenge of teaching BIM in the first year of University: Problems encountered and typical misconceptions to avoid when integrating BIM into an Architectural design curriculum. *Proceedings of the 20th International Conference of the Association for* Computer-Aided Architectural Design Research in Asia, Hong Kong: CAADRIA.

NCARB. 2013. *2012 NCARB Practice Analysis of Architecture*. Retrieved from https://www.ncarb.org/sites/default/files/2013PA_BoxSet_AllReports.pdf (01-09-2022)

Nicol, D., & Pilling, S. 2005. *Changing architectural education: Towards a new professionalism*. London and New York: Taylor & Francis.

Niemi, H. 2009. Why from teaching to learning? *European educational research journal*, 8(1), 1-17.

Poerschke, U., Holland, R. J., Messner, J. I., & Pihlak, M. 2010. BIM collaboration across six disciplines. *Proceedings of the International Conference on Computing in Civil and Building Engineering.* W. Tiziani, ed., Nottingham: University of Nottingham. Available online at http://www.engineering.nottingham.ac.uk/icccbe/proceedings/pdf/af288.pdf (01-09-2022).

Rooney, K. 2017. BIM education – global. 2017 update report. *ICIS Integrated Construction.* Retrieved from http://www.icis.org.au/wp-content/uploads/2017/12/BIM-Education-Global-2017-Update-Report-V4.0.pdf (02-09-2022).

Schumacher, P. 2019. Current Architecture Education Is Detached From The Profession, According To Patrik Schumacher/Interviewer: U. K. A. *News. World Architecture* https://worldarchitecture.org/articlelinks/ecfgh/current-architecture-education-is-detached-from-the-professionaccording-to-patrik-schumacher.html (01-09-2022).

Tvedebrink, TDO, Jelić A. 2021. From Research to Practice: Is Rethinking Architectural Education the Remedy? *HERD: Health Environment Research & Design Journal,* 14(1), 71-86.

Underwood, J., Ayoade, O., Khosrowshahi, F., Greenwood, D., Pittard, S., & Garvey, R. 2015. Current position and associated challenges of BIM education in UK higher education. Retrieved from http://usir.salford.ac.uk/id/eprint/35164/ (01-09-2022).

Wu, W., & Issa, R. R. 2013. BIM education for new career options: an initial investigation. *BIM Academic Workshop,* Washington, DC. USA, 11th January.

Yan, W. 2010. Teaching Building Information Modeling at undergraduate and graduate levels. *Future cities: 28th eCAADe Conference Proceedings*, Zurich: ETH Zurich, 97-106.