
BIM-Enabled Education: a Systematic Literature Review

BIM-Enabled
Education

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261

Abstract

Purpose – Building Information Modelling (BIM) education promises new and exciting opportunities for more integrated learning experiences, multidisciplinary collaboration and greater synthesis between the learning environment and real-world projects. This paper aims to report the findings of a systematic review of the BIM education literature aimed at understanding the current state of the art of BIM-enabled education.

Design/Methodology/Approach – The systematic review methodology adopted borrows from the approach developed and widely deployed in evidence-based practice within the medical research field.

Findings – A total of 330 relevant articles were identified and analysed. Reported instances of BIM-enabled education were identified and analysed. It was found that these can be categorised into two groups: BIM as a learning tool and BIM as a learning environment.

Research Limitations/Implications – This review was limited to the academic literature published in English from 2007 until January 2018.

Practical Implications – BIM as a learning environment represents a new paradigm for AEC education, which emphasises integration, multidisciplinary collaboration, simulation, real life scenarios and application of learning concepts.

Originality/Value – The concept of BIM as a learning environment requires further elaboration, after which it can be used to enhance AEC education.

Keywords Building Information Modelling, BIM education, BIM-enabled education, AEC education, Construction management education, Systematic literature review

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1. Introduction

[Underwood *et al.* \(2013\)](#) conceptualise the development of BIM education in three progressive stages:

- (1) BIM-aware – ensuring that graduates are aware of BIM and the changes it is bringing about;
- (2) BIM-focused – students are instructed how to use BIM in the performance of specific tasks; and
- (3) BIM-enabled – where learning is embedded in the virtual BIM environment and BIM acts as a “vehicle” for learning.

The current research is aimed at exploring the third, “BIM-enabled”, stage which potentially offers opportunities for immersive and integrated learning experiences on the basis of real and up-to-date project models and data from industry. Specifically, the research seeks to address how BIM can be leveraged to improve construction management education. As an initial step, a systematic review of the BIM education literature was undertaken to examine the state-of-the-art of BIM-enabled learning in higher education institutions and in industry and to understand the drivers, challenges and best practices arising from reported experiences to date.

This paper reports initial findings of the literature review. The formal, systematic approach applied is presented in Section 2. A breakdown of the literature captured by the search, an overview of identified cases of BIM-enabled learning and the drivers and challenges associated with them are reported in Section 3. A discussion follows in which the authors’ attempt to interpret and make sense of the findings before the paper is concluded.

2. Research Methodology

The systematic review methodology is associated with evidence-based practice and has been widely applied particularly in the field of healthcare delivery. Since the late-1990s, it has also become the “literature review methodology of choice” for some in the educational research community ([Bearman *et al.* 2012](#)). The review process adopted for this literature review is based on that recommended in [Bearman *et al.* \(2012\)](#).

2.1. Review question(s)

The research objective is to examine the state of the art of BIM-enabled learning from reported experiences to date, and our review questions are as follows:

- (1) *What is the current state of the art of BIM-enabled learning?*
- (2) *What are the issues (drivers, challenges, etc.) that affect BIM-enabled learning?*

2.2. Inclusion and exclusion criteria

The inclusion criteria were defined to include the following:

- all available BIM education articles which describe current practice and
- all available magazine articles to capture industry training examples.

Pre-2007 articles were excluded on the grounds that they would be more than a decade old and, therefore, somewhat out of date. In addition, the year 2007 saw an international upsurge in the interest in BIM with the publication of key BIM standards, so it was considered a sensible start year for the literature search. Only articles in English were considered for the inclusion.

2.3. Search strategy

Major literature databases were selected to ensure good coverage of the available literature and so that peer-reviewed conference papers would be included (as these were anticipated by the authors to be a rich source of case study examples). After initial trial searches, the following databases were selected:

- ASCE Library;
- EBSCOhost Web;
- Scopus; and
- Web of Science Core Collection.

The following Boolean phrase of keyword combinations was used in advanced searches to match “Anywhere in document” (i.e. all text and all fields):

“Education” OR “Training” OR “Learning”) AND (“Building Information Modelling” OR “Building Information Modelling” OR “Virtual Design and Construction”)

The intention was to cast a wide net to capture everything relating to BIM education in the search but to exclude articles about BIM but not education. The advanced search functions also enabled the search results to be limited to articles in English from no earlier than 2007.

2.4. Screening

The screening process followed the steps:

- (1) Database search returns were listed in order of relevance.
- (2) Each article title and, if necessary, abstract were checked to establish relevance.
- (3) Relevant articles were then saved to a database-specific folder using a reference management program (Mendeley Desktop version 1.17.13).
- (4) The total numbers of relevant articles and their type were recorded.

2.5. Results of the search

Search results are presented in the “Findings” section.

2.6. Data extraction

A primarily qualitative, content analysis approach to data extraction was adopted as the focus of the study relates to understanding the complex context of BIM education implementation and the data extracted from multiple research articles require organisation into themes and categories by the analyst to be understood. In addition, certain quantitative metrics are also of interest in this study. The data extraction approach might therefore be described as a mixed methods approach and, to expedite the analyses, NVivo (v.12) software was used, which enabled convenient coding of content to different themes and the organisation of descriptive metrics for each reported case of BIM education.

2.7. Quality / rigour evaluation

The majority of articles identified in the search as relevant are peer reviewed conference and journal articles which suggest a fairly uniform level of rigour in their results. However, the source articles collected also include books, book sections and trade magazine articles and these suggest a different (and lower) level of rigour. To the extent that this influences findings, it has been taken into consideration.

2.8. *Synthesis*

For this research, the content of each article was read and sections of the text considered by the analyst to be pertinent to a theme or subtheme relevant to the research were coded accordingly. From the multiple themes, subthemes and the content coded to them, an overall understanding of the issue under study was elaborated.

2.9. *Reporting findings*

The findings of the systematic review are reported below.

3. Findings

3.1. *Search results*

The following tables sum up the databases included in this literature study (Table 1), number of articles (Table 2) and the main sources of articles (Table 3).

3.2. *Identified examples of BIM-enabled learning*

Ninety two of the articles captured included some description of specific cases of BIM education or BIM training in industry. (Other articles reported surveys of existing BIM education and industry needs for BIM education, curriculum development studies and theoretical or conceptual treatments of BIM education.) Of these 92 cases, 17 were considered to represent BIM-enabled learning with the remainder being considered ‘BIM-focused’. In making this distinction, the authors’ interpreted the Underwood et al. (2013) categorisation as follows:

- In “BIM-focused” education – the emphasis is on learning to use BIM
- In “BIM-enabled” education – BIM use facilitates learning.

Table 1.
Returns From
Database Searches

Number of Articles	ASCE Library	EBSCOhost Web	Scopus	Web of Science	Overall (duplicates removed)
returned by search deemed relevant	613 67	3730 63	1673 210	174 108	N/A 330

Table 2.
Number of Articles
By Year of
Publication

Year	Articles
2007	6
2008	13
2009	6
2010	23
2011	21
2012	41
2013	39
2014	40
2015	47
2016	55
2017	35
2018	4

Source	No. of articles
<i>Conference proceedings – by conference series</i>	
ASEE (2008-2017)	42
AEI (2008-2017)	13
Construction Research Congress (2009-2016)	11
<i>Journals</i>	
Journal of Professional Issues in Engineering Education and Practice	19
Journal of Information Technology in Construction	9
International Journal of Construction Education and Research	8
Automation in Construction	7
Journal of Computing in Civil Engineering	7
Journal of Construction Engineering and Management	5
International Journal of Engineering Education	5
<i>Trade Publications</i>	
ENR	4

265

Table 3.
Top Sources
of Articles

3.3. Drivers of BIM-enabled learning

The cases reviewed reveal drivers motivating these BIM-enabled education and training initiatives. BIM education in all forms is clearly important from an industry demand and graduate employment perspective (Bozoglu, 2016). The notion of a transition from an old, traditional educational regime to a new BIM-enabled one is reflected by many authors. Forgues and Becerik-Gerber (2013) note that the change brought about by BIM entails moving away from dividing projects between specialist areas and toward integrating work and information flows for whole projects. In doing so, traditional professional practice, power and influence relations are redefined. As university faculties reflect the professional divisions and structures of the traditional construction industry, they struggle to adapt to this change while they are under considerable pressure to rethink the education of built environment professionals and to contribute to the development of the new ways of working (Forgues and Becerik-Gerber, 2013). In parallel, Ambrose (2012) notes the move away from abstraction as embedded in traditional design education towards simulation on the basis of a virtual building model.

Boeykins *et al.* (2013) refer to BIM as representing an “educational methodology”, which students can benefit from experiencing. Advantages of this new, BIM-enabled educational methodology noted in the cases include

- The BIM environment enables students to apply the abstract concepts that they have learned (Forsythe *et al.* 2013) and this has been shown to improve students’ understanding of engineering concepts (Pikas *et al.* 2013).
- BIM provides opportunities for 3D visualisations and interactive, non-verbal simulations which enable the communication of complex ideas across different disciplines and cultural-linguistic groups (Clevenger *et al.* 2012). These have been demonstrated to enhance student understanding (Pikas *et al.* 2013) and student performance (Barham *et al.* 2011).
- BIM provides an excellent tool for data management and a framework for data rich information models, which enhance learning experiences (Irizarry *et al.* 2012). This enables convenient access to information and allows the formation of BIM-based “knowledge repositories” for learning (Barham *et al.* 2011).
- BIM enables the simulation of more realistic (and of real) project conditions for education (Peterson *et al.* 2011; Boeykins *et al.* 2013).

BIM is both driving the emerging need for greater interdisciplinary communication and teamwork and also directly providing opportunities for developing competencies in multidisciplinary collaboration (Becerik-Gerber *et al.* 2012; Bozoglu, 2016).

3.4. Challenges of BIM-enabled learning

Numerous challenges were found to be common to both the BIM-enabled and BIM-focused learning cases and these include:

- *Accreditation* – e.g. different standards for graduates from different disciplines with respect to interdisciplinary collaboration competencies (Chiuini *et al.* 2013);
- *Assessment* – e.g. the difficulty of fully and equally engaging all students in collaborative work (Comiskey *et al.* 2017);
- *Classrooms and technical equipment* – e.g. classrooms not being suitably designed or equipped for collaborative work (Becerik-Gerber *et al.* 2012);
- *Example projects* – e.g. students being overwhelmed by the technical complexity of real projects (Becerik-Gerber *et al.* 2012);
- *Interoperability problems* – between different software packages and even between different versions of the same software (Boeykins *et al.* 2013);
- *Skills* – BIM-related skills differ widely between both individual students (Comiskey *et al.* 2017) and between students of different disciplines (Chiuini *et al.* 2013). For faculty members to become proficient and stay current with BIM software represents a particular challenge (Clevenger *et al.* 2012);
- *Teamwork and collaboration* – e.g. difficulties coordinating and motivating the participation of students and faculty in multidisciplinary collaborations (Boeykins *et al.* 2013);
- *Technical support* – e.g. universities are often under-resourced in terms of providing the necessary technical support to BIM-related educational initiatives (Becerik-Gerber *et al.* 2012);
- *Time* – this is a central problem on numerous levels: e.g. finding time within educational programmes to include BIM-related education and as no additional time can be added to programmes, determining what consequently gets left out (Denzer and Hedges, 2008); Coordinating time between programmes for multidisciplinary collaboration, particularly in the case of remote teams located in different time zones (Dossick *et al.* 2014). The time commitments of faculty to become familiar with BIM software (Denzer and Hedges, 2008);
- *Uncertainty over what to teach* – e.g. as a consequence of rapid developments of BIM in industry (Becerik-Gerber *et al.* 2012); and
- *Workload* – e.g. students finding the workload of BIM-related education to be greater than that normally demanded for the same credits (Forgues and Becerik-Gerber, 2013).

4. Discussion of findings

The reported instances of BIM education that were judged to represent BIM-enabled learning as opposed to BIM-aware or BIM-focused learning, can be categorised into two groups:

- (1) BIM as a learning tool – where traditional learning processes are enhanced through the deployment of some aspect(s) of BIM; and

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- (2) BIM as a learning environment – where learning takes place within a BIM context in the sense of BIM providing a common platform for communication and / or where BIM work flow processes are adopted.

4.1. BIM as a learning tool

Pikas *et al.* (2013) note the importance of BIM “as a tool for performing the engineering tasks taught within design, analysis, and management courses”. The simplest form of this is perhaps the use of 3D models for visualisation assistance in learning. Numerous examples of this were captured, e.g. assisting visualisation in Concrete Structures courses (Barnham *et al.* 2011), aiding information understanding in Working Drawings Analysis (Ghosh, 2012) and providing illustrations for safety training in academic and industry settings (Clevenger *et al.* 2012).

Beyond 3D geometric and parametric information for visualisation, BIM provides a means of organising all building-related information into conveniently accessible databases. Irizarry *et al.* (2012) have leveraged this and demonstrate the effectiveness of using “BIM-based knowledge repositories” to enhance numerous courses for Civil Engineering and Construction Management students.

4.2. BIM as a learning environment

The most common form of BIM-enabled learning described in the cases reviewed was the collaborative project. Although these collaborative projects differ in their focus, the extent of the building process they cover and the disciplines that they embrace, they share a common trait in that communication and collaboration is enabled by BIM-based communication environments. The sophistication of the environments described varies from relatively simple, shared common data environments, parametric models and the collaborative features offered by BIM software (e.g. Comiskey *et al.* 2017) to virtual collaboration spaces resembling computer gaming environments with participants represented as avatars (e.g. Dossick *et al.* 2015).

As noted in the Findings section above, the notion of a transition from traditional AEC education to BIM-based AEC education is strongly reflected in the literature and the changes taking place include:

- Decomposition → Integration
- Separate professional roles → Multidisciplinary collaboration
- Abstraction → Simulation
- Simplified, abstract concepts → More complex, closer to reality / real life scenarios
- Learning concepts → Learning concepts and applying them

Multidisciplinary collaboration emerges as a key requirement going forward – a requirement that is both driven by BIM adoption and which can now be conveniently simulated and learned on the basis of BIM.

In this transitional context, we see a clear role for both categories of BIM-enabled learning identified above:

- “BIM as a learning tool” representing primarily *pretransition* BIM-enabled learning possibilities in that elements of BIM are used to teach traditional courses and concepts which are mostly taught, organised and delivered in traditional ways; and
- “BIM as a learning environment” representing the emerging, BIM-based educational paradigm

In the identified examples of “BIM as an environment”, there is an emphasis on collaboration itself and much time and effort is still expended on learning BIM-skills and ways of working because these are still unfamiliar to many students and faculty. Simulation takes place in the sense that real project scenarios are being simulated in the classroom but we do not yet see reported examples of simulation in the sense of multiple simulations to optimise solutions on the project scale. Nor do we find examples of the teaching of fundamental concepts (other than collaboration, communication and the new and BIM work processes) within the BIM environment. These areas of development need further exploration. They offer the potential of leveraging the new environment to develop AEC concepts and knowledge and to deliver greater value.

5. Conclusions

Existing cases of BIM-enabled learning were found to belong to two categories:

- (1) BIM as a learning tool – where traditional learning processes are enhanced through the deployment of some aspect(s) of BIM; and
- (2) BIM as a learning environment – where learning takes place within a BIM context (BIM providing a common platform for communication, BIM work flow processes, etc.)

“BIM as a learning environment” appears to represent a new (post-BIM-transition) educational paradigm in which integration, multidisciplinary collaboration, simulation, real life scenarios and application of learning concepts are at the heart of the learning process.

Further research is called for to describe this BIM learning environment in such a way that it can be usefully created and applied in AEC education.

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