# BIM for Construction Education: Initial Findings from a Literature Review

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## Abstract

**Purpose** – BIM education for construction professionals has tended to lag industry developments. This investigation initiates doctoral research into the use of BIM for construction education. The purpose of this study is to gain an understanding of existing examples of BIM education, their characteristics, the challenges faced in their implementation and any clear trends to focus the doctoral research effort.

**Design/Methodology/Approach** – A systematic search of peer-reviewed BIM education literature was carried out. From the articles captured, 51 specific cases of BIM education were identified and analysed.

**Findings** – Most cases are from the USA with a more global spread from 2013. A tendency towards interdisciplinary collaboration was apparent though single discipline courses remain important. BIM software in education is dominated by Autodesk products. Most cases were found to be BIM-focused with few examples of BIM-enabled education. This was consistent with the most significant BIM education challenges that were found to relate to the skill levels of students, time and the availability of technical support.

**Research Limitations/Implications** – This is an initial study. It is based on only 51 cases of BIM education, which were partially described in peer reviewed conference and journal papers available in international databases.

**Practical Implications** – The investigation has shed some light on existing examples of BIM education and these are useful in designing BIM education initiatives as well as directing further research efforts.

**Originality/Value** – The study offers an original perspective on global BIM education. It also represents the commencement of doctoral research.

**Keywords** Building Information Modelling, BIM, BIM education, Construction education, Education, Literature review

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## 1. Introduction

There has been widespread adoption of BIM in the construction industry, but this adoption has been constrained by a lack of adequately educated and trained construction professionals (Ahn *et al.*, 2013; Beceric-Gerber *et al.*, 2011) and their education has tended to lag industry BIM developments (Forgues & Beceric-Gerber, 2013; Lee *et al.* 2013). There is a consequent and widely recognised need for the incorporation of BIM education into university-level architecture, engineering and construction (AEC) programmes to address this (e.g. Bozoglu, 2016). Indeed, the incorporation of BIM into the university curriculum is seen as offering opportunities to improve AEC education more generally and overcome some of the current problems it faces (Arnett and Quadrato, 2012; Forsythe *et al.* 2013)

In this context, this research is a first step to initiate doctoral research into BIM education and the use of BIM for construction education in higher education institutions (HEIs). Its purpose is to identify existing examples of BIM education from the literature and gain an understanding of their characteristics, the challenges faced in their implementation and any clear trends in the state of the art in order to focus the doctoral research effort.

A systematic search of the academic literature was carried out to identify peer-reviewed journal and conference papers on BIM education. Cases of BIM education for AEC students in HEIs reported in these papers were then identified and analysed. The literature search criteria and analysis process are described in Section 2. Section 3 presents the main findings from the analysis of the cases identified and these are discussed in Section 4 before conclusions and implications for further research are drawn.

## 2. Research Methodology

### *2.1. Systematic search to identify the source literature*

The systematic literature search procedure followed that recommended by Bearman *et al.* (2012). The search inclusion criteria were defined to include all available peer-reviewed BIM education articles that describe current practice. Pre-2007 articles were excluded on the grounds that the year 2007 saw an international upsurge in BIM interest with the publication of key BIM standards such as CoBIM, and GSA 2007, so it was considered a sensible start year for the literature search. Only articles in English were considered for inclusion.

The following major literature databases were selected after initial trial searches to ensure good coverage of the available literature and particularly that peer-reviewed conference papers would be included:

- ASCE Library
- EBSCOhost Web
- Scopus
- Web of Science Core Collection

The Boolean phrase ("Education" OR "Training" OR "Learning") AND ("Building Information Modeling" OR "Building Information Modelling" OR "Virtual Design and Construction") was used in advanced searches to match "Anywhere in document" (i.e. all text and all fields).

The intention was to cast a wide net in order to capture everything relating to BIM education in the search but not including articles about BIM which had nothing to do with education.

Database search returns were listed in order of relevance. Each article title and, if necessary, abstract were checked to establish relevance / eliminate irrelevant articles. Relevant articles were then saved to a reference management program (Mendeley Desktop version 1.17.13). This enabled the convenient elimination of duplicates (see Table 1).

*2.2. Identification of cases and analysis of their contents*

All of the articles were then screened to determine which of them reported actual cases of education and / or training, and a total of 92 reported cases of education / training were found. Of these, 51 cases referred to the education of students in construction-related disciplines in HEIs and therefore fell within the scope of this investigation with the remaining cases being excluded from further analysis.

Content analysis of the selected articles with their reported cases followed a Grounded Theory approach in that data extracted from the multiple research articles were coded into themes and categories by the analyst as they emerged from the articles' content. This qualitative approach was adopted as the intention was to understand the complexities of BIM education implementation in HEIs (Cresswell, 2014).

In addition, quantitative metrics were also considered to be of interest in this study, for example, with regard to identifying trends and levels of significance of the various issues identified. Overall, the data collection and analysis procedures followed may be described as a mixed methods approach. To expedite the analyses, NVivo Plus (v.12) software was used, which enabled both the convenient coding of the articles' content to different themes and also the organisation of the descriptive metrics (date, subject, student level, location, etc.) for each reported case of BIM education.

## 3. Findings

*3.1. Cases by country and year*

Table 2 shows the distribution of the 51 sample cases by country and the year in which they were reported.

Most of the cases in the sample (32 out of 51) took place in the USA. This may be explained to some extent by the main sources of conference and journal papers which the search found to be the American Society of Engineering Education (ASEE) Conference proceedings (2008–2017) and the ASCE Journal of Professional Issues in Engineering Education and Practice, both from the USA. However, the domination by the USA in this area does seem to be a robust finding that reflects the relatively early uptake of BIM in US industry, development and support for BIM by professional organisations (e.g. the AIA) and federal government agencies (e.g. NIBS and GSA) as well as the active promotion of BIM by industry players and software vendors (e.g. in encouraging and sponsoring BIM competitions – Herrmann *et al.* [2015]).

Although the USA-based cases are distributed quite evenly over the 2007-2017 period, outside the USA, there does seem to be an overall increase in the total number of cases

**Table 1.** Returns from Literature Database Searches

| Articles | ASCE Library | EBSCOhost Web | Scopus | Web of Science | Overall (no duplicates) |
|---|---|---|---|---|---|
| Number of articles returned from search | 613 | 3730 | 1673 | 174 | Not application |
| Relevant articles after screening | 67 | 63 | 210 | 108 | 308 |

| Country | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Australia | 1 | | | | | 1 | 1 | | | | | **3** |
| Belgium | | | | | | | 1 | | | | | **1** |
| Chile | | | | | | | | | | 1 | | **1** |
| China | | | | | | | 1 | | | | | **1** |
| Denmark | | | | | | | | | | | 1 | **1** |
| Germany | | | | | | | | | 1 | | | **1** |
| India | | | | | | | | | 1 | | | **1** |
| Ireland | | | | | | | 1 | | | | | **1** |
| Israel | | | | | | | 1 | | | | | **1** |
| New Zealand | | | | | | | | | | 1 | | **1** |
| Portugal | | | | | | | | | | | 1 | **1** |
| Spain | | | | | | | | | | | 1 | **1** |
| Thailand | | | | | | | | | 1 | | | **1** |
| UAE | | | | | | | | | | | 1 | **1** |
| UK | | | | | | | | 1 | 1 | | 1 | **3** |
| USA | 1 | 4 | 1 | 3 | 1 | 6 | 4 | 1 | 6 | 3 | 2 | **32** |
| **TOTAL** | **2** | **4** | **1** | **3** | **1** | **7** | **9** | **2** | **10** | **5** | **7** | **51** |

**Table 2.** Cases by Country and Year of Reporting

reported from 2013 onwards. Finally, it is notable that Africa is the only continent which does not contribute any cases to the sample.

*3.2. Cases by discipline*

The cases were classified according to the disciplines they involved - Architecture, Civil and structural engineering, Construction, MEP Engineering and Other (Figures 1 and 2). The category 'Other' included disparate disciplines which did not fit within the other 4 categories but could not be combined into a single, broader discipline and were not represented in sufficient numbers to warrant separate categories. Examples include: Facilities Management, Environmental Engineering and Industrial Technologies Engineering.

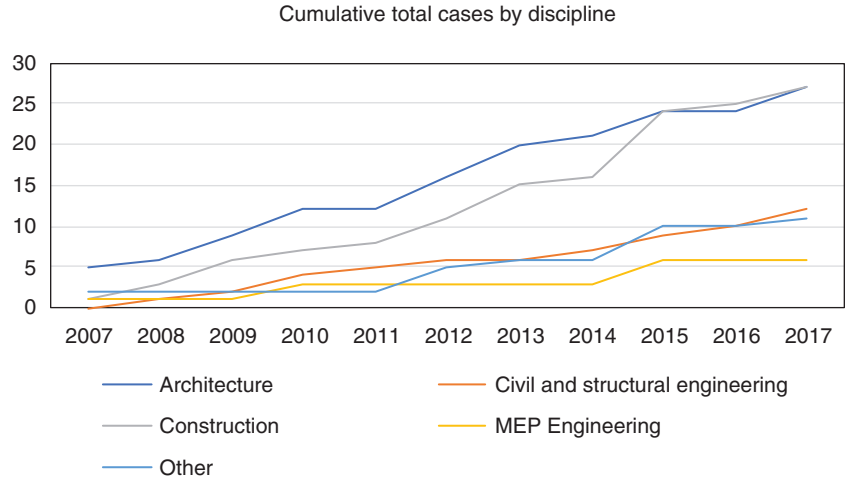


**Figure 1.** Cumulative Distribution of Cases by Discipline Over Time

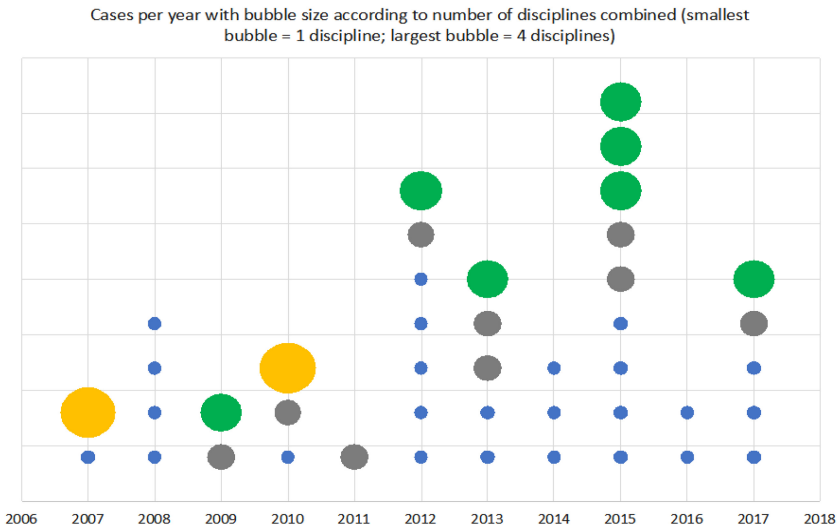


**Figure 2.** Number of Disciplines Combined Per Case Per Year

Slightly less than half of the cases involve more than one discipline. There is no apparent trend towards more combining. Indeed, the most diverse combinations (combining four disciplines) were from 2007 and 2010.

BIM education in AEC courses has proceeded in various modes: by seminars or workshops (Gledson & Dawson, 2017; Gnaur *et al.* 2012), embedding BIM in existing courses (Huang, 2016) and creation of a new single course to accommodate what could not be embedded in existing courses, as in integrated capstone courses (e.g. Ghosh *et al.* 2015).

Civil and structural and MEP engineering courses have witnessed a steady rise in the number of cases reported from 2007 to 2017 although not at the same rate as architecture and construction courses.

BIM education offers opportunities to take advantage of the greater interdisciplinary collaboration inherent in BIM. Numerous studies have suggested a more integrated approach to teaching which aims to bridge the traditional boundaries between AEC industry professions that have been replicated in industry and educational structures (e.g. Forgues & Farah, 2013). Our data reflects this with many of the identified cases exhibiting interdisciplinary collaborative and integrated learning. However, Solnosky *et al.* (2015) suggest that most cases that involve interdisciplinary learning have started from single disciplines then expanded to embrace others.

### *3.3. Software used in the cases*

Subheadings should also be numbered in accordance with their section and the sequence of subheadings.

Software has been grouped into three categories (see Figure 3):

(1) modelling software;
(2) software for model-based viewing, checking, simulations, etc.; and
(3) data sharing and collaboration software.

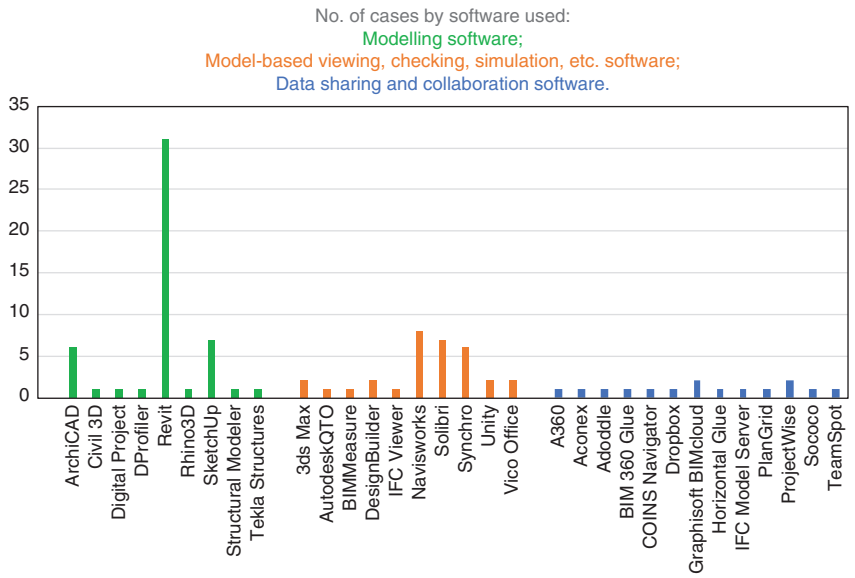


**Figure 3.**
Software Used in the Identified Cases

Revit, SketchUp and ArchiCAD are shown to be prevalent for modelling. Navisworks, Solibri and Synchro dominate for model-based applications and Graphisoft BIMcloud and (Bentley) ProjectWise take the lead in file sharing platforms among the cases considered. It is tentatively suggested that, with the great majority of cases being in the USA, this may tend to emphasise the dominance of Autodesk products (Revit and Navisworks) and other USA-based products in BIM applications.

### *3.4. BIM-enabled versus BIM-focused*

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 peformance 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 identified cases were classified according to these stages (Table 3) with the intention of testing for any obvious trends.

Most of the cases were found to be BIM-focused while only five cases were considered to be BIM-enabled (one reported in 2011, three in 2012 and one in 2015 with all of them from the USA). There were no BIM-aware cases identified. Advances between 2011 and 2015 demonstrate the efforts of faculty to create a more immersive and engaging environment by leveraging BIM applications, tools and products to enhance students' learning. The examples of this BIM-enabled learning were found in Arnett and Quadrato (2012), Ambrose (2012), Clevenger *et al.* (2012, 2015) and Nawari *et al.* (2014).

| Year | Number of cases BIM-focused | BIM-enabled |
|---|---|---|
| 2007 | 2 | |
| 2008 | 4 | |
| 2009 | 2 | |
| 2010 | 3 | |
| 2011 | | 1 |
| 2012 | 4 | 3 |
| 2013 | 9 | |
| 2014 | 2 | |
| 2015 | 9 | 1 |
| 2016 | 5 | |
| 2017 | 6 | |
| **TOTAL** | **46** | **5** |

**Table 3.** Categorisation of Cases as BIM-Focused/ BIM-Enabled

*3.5. Emergent themes from the content analysis - challenges*

Qualitative content analysis was carried out using a Grounded Theory approach. The most obvious emergent theme was that relating to the implementation challenges faced in BIM education (Table 4).

BIM learning undoubtedly requires extra effort on the parts of both the faculty (who have to prepare learning modules, source for industry participants where required or even take up role playing) and the students who, in most cases, have different exposures to technology and practical experiences.

Most of the challenges noted have existing initiatives aimed at their resolution: e.g. interoperability problems – IFC, Open BIM, etc. – but they remain challenges at least for the short to medium term. Also, skills levels among students and staff as well as in industry are clearly improving, considering the progressive increase of BIM learning over the years and this can only help BIM education going forward.

| Challenge description | #sources referencing challenge |
|---|---|
| Skill levels among students | 13 |
| Time / Workload | 13 |
| Technical support | 11 |
| Interoperability problems | 6 |
| What to teach / learning content | 6 |
| Classroom and technical equipment | 5 |
| Educators' resistance to change | 4 |
| Limitations of BIM-based learning (some students prefer traditional teaching) | 3 |
| Difficulties with assessment | 2 |
| Complexity of example projects | 2 |
| Skill levels among educators | 2 |
| Teamwork and collaboration | 2 |
| Accreditation issues | 1 |
| Curriculum constraints / inflexibility | 1 |
| Intellectual property issues (for model owners) | 1 |
| Disagreements over learning content | 1 |
| Universality-cultural, economic and academic differenceson BIM learning | 1 |

**Table 4.** Identified Challenges

## 5. Conclusions

This preliminary study to initiate doctoral research has systematically searched literature to identify cases of BIM education for AEC disciplines in HEIs. Fifty one specific cases were identified and reviewed in order to understand their characteristics, the challenges faced in their implementation and any clear trends in the state-of-the-art so as to focus the doctoral research effort.

We have noted a domination of the US cases and a more global spread of BIM education cases from 2013 onwards. Domination by architecture and construction over engineering disciplines with a tendency towards interdisciplinary collaboration between them though single discipline BIM education courses remain in a slight majority.

A diversity of software programs supports BIM education, but there is domination by Autodesk products, particularly for modelling and, to a lesser extent, for model-based viewing, checking and simulations.

Classification of the identified cases according to progressive stages of BIM education revealed only 5 examples of BIM-enabled education with the remaining 46 cases being considered primarily BIM-focused. This finding suggests the emphasis in HEIs remains on teaching students to "do" BIM rather than leveraging BIM in the teaching of other, fundamental or non-BIM concepts and topics. It is also backed up by our findings on the challenges faced when implementing BIM education which emerged from the qualitative content analysis of the case study articles. The most significant challenges were found to relate to the skill levels of students, the time / workload requirements and availability of technical support – all of which allude to a continued need for BIM-focused education before the full potential of BIM-enabled education can be realised.

In terms of directing further research, the following possibilities for investigations became apparent in the course of this study:

- Pedagogical approaches to BIM education – many of the cases adopted problem-based and project-based methods a detailed classification and comparison would offer further insights.
- Enablers/motivators/challenges of BIM-enabled learning – with increasing empirical evidence becoming available, a more in-depth exploration of the suggested progression to BIM-enabled AEC education is called for.
- Similarly, the increasingly available evidence should be used towards understanding the costs and benefits of BIM education.

Most specifically, the study has inspired a desire for engagement in action research regarding the implementation of a specific BIM-enabled education pilot case.

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