Integrating building information modelling (BIM) into Engineering education: an exploratory study of industry perceptions using social network data

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Structured abstract

BACKGROUND
Building Information Modelling (BIM) has been widely acknowledged as an emerging technological and procedural shift within the Architecture, Engineering and Construction (AEC) industry. BIM represents a methodology to manage the building design and project data in digital format throughout a building lifecycle. With the implementation of BIM, the design, construction and operation processes can be better streamlined to improve project efficiency. Because of its far-reaching benefits, there is a current push for BIM by governments worldwide, including Australia. However, a significant lack of the understanding of BIM and industry readiness has been identified as a major hindrance; hence, there is a growing demand for tertiary institutions to incorporate BIM into their architecture and engineering curricula to equip new graduates with such knowledge. A number of universities around the world are offering courses for various BIM applications. However, there remain numerous issues associated with the development and delivery of appropriate BIM courses that require careful considerations.

PURPOSE
This study presented in this paper was developed to answer the following question: what are the current issues perceived as critical by BIM professionals on the integration of BIM into universities' engineering curricula?

METHOD
An exploratory analysis was conducted by using a qualitative analysis of the data obtained from a popular online social network platform for professionals – LinkedIn. Data in the form of discussion posts and comments associated with BIM in education were captured from a BIM-specific discussion group using NVivo 10 software. To carry out the analysis, discussion posts and comments were coded to identify important themes emerging from the data. These themes were then examined, interpreted and discussed.

OUTCOMES
The results showed that the themes emerged from the selected discussion posts were concentrated on the recommendations on how BIM can be integrated into a curriculum and the barriers to the integration. The need to teach BIM as a collaborative process rather just a software tool was highlighted, with the difficulty in bridging educational silos identified as one of the main barriers.

CONCLUSIONS
BIM is an innovative concept that can help improve the efficiency of the AEC industry. To successfully integrate BIM into education, the industry perceived that there is the need for universities to be more innovative in developing a collaborative curriculum that requires integration across different educational disciplines. This represents a major challenge to be overcome not only for engineering education, but also other related disciplines within the AEC context.

KEYWORDS
Building Information Modelling, Engineering, Construction.

Introduction

The Architecture, Engineering and Construction (AEC) industry has long been characterised with the lack of efficiency, proneness to disputes and consistently lower-than-expected levels of productivity due to its predominantly fragmented supply chain. Realising this, the industry has attempted to come up with techniques to improve quality, increase productivity and decrease cost of construction projects. One of the most notable examples is the development of Building Information Modelling (BIM). BIM refers to a methodology to manage the building design and project data in digital format throughout a building lifecycle (Succar, 2009); it is considered as a paradigm shift within the industry. BIM is perceived to have the potential to significantly change and improve performance and documentation in the AEC industry by reducing inefficiencies, enhancing productivity, and increasing collaboration and communication (Goedert & Meadati, 2008). With the implementation of BIM, the design, construction and operation processes can be better streamlined to improve project efficiency. BIM is thus generally applied with an aim to achieve decreased project costs, increased productivity and quality, and reduced project delivery time (Azhar, 2011).

Despite the acknowledged benefits of BIM and a number of BIM-capable tools made available on the market for many years, the diffusion of BIM within the AEC industry has been slow, and its adoption has not been to its full potential (Becerik-Gerber & Rice, 2010; Linderoth, 2010). A study conducted by McGraw-Hill (2009) revealed that about half (49%) of the AEC industry in the US used BIM. A more recent study, also by McGraw-Hill (2010), found that in Europe the adoption rate of BIM was even lower at 36%.

In Australia, the need for BIM stemmed from several issues identified by Engineers Australia, most notably, the lack of integration along the supply chain linking various parties and between the project phases. A "National BIM Initiative Blueprint" has been developed by BuildingSMART Australasia to promote the education and uptake of BIM in the Australian AEC industry. It aims to facilitate the Australian Government's adoption of full collaborative BIM for all of its building procurements from 2016. However, Gu and London (2010) revealed that the lack of experience in BIM due to the limited understanding of industry needs and technical requirements represented a major factor delaying the advancement and adoption of BIM related technologies within the Australian AEC industry. Furthermore, recent research by Alabdulqader et al. (2013) identified "inadequate training and education" as one of the main barriers to the adoption BIM within the Australian AEC industry as perceived by the organisations interviewed in the research. This barrier is also consistent with that being faced worldwide.

In addition, the need for formal BIM education was highlighted in a survey study conducted in the US with industry participants by Auburn University (Azhar et al., 2008). The research found that approximately 75% of survey participants consider employment candidates with BIM skills to have an advantage over those who lack BIM knowledge. Properly structured BIM courses would provide industry-required knowledge to prepare students for successful careers in the AEC industry. Therefore, the aim of the research presented in this paper was to shed light on the salient issues associated with integration of BIM into higher education, as perceived by industry practitioners. In the following section, previous research studies relevant to BIM education within the construction education context are reviewed. Following this, the research method employed is explained and the results presented. The paper concludes with the discussion on the results and the implications for the integration of BIM into engineering education.

BIM in Engineering education

The need to incorporate BIM into university teaching to equip engineering graduates with adequate understanding of BIM concepts and BIM skills has been identified as one means to help achieve the successful uptake of BIM within the AEC industry. In fact, a number of universities have already attempted to incorporate BIM into their construction/civil

engineering curriculum. For example, at the Technion-Israel Institute of Technology, Sacks and Barak (2010) reported the inclusion of BIM in the first year course entitled "Communicating Engineering Information". For this course, BIM is used as a key element to form part of the communication skills, rather than as a course by itself. The course has five main content modules: introduction, engineering graphics, BIM concepts, the language of engineering drawings, and BIM training. Kim (2012) implemented a BIM-based teaching approach in a construction management course offered at the Department of Civil Engineering and Construction Engineering Management, California State University, Long Beach. Unlike that reported by Sacks and Barak (2010), this approach views BIM as an integrated learning tool for an effective visualisation teaching approach in construction education. It begins with the understanding of physical models for residential buildings, then proceeds to the generation of 2D drawings using traditional CAD programs before finally moving on to the development of a 3D BIM model and using it for taking off the material quantities.

The above inconsistency in the integration of BIM into engineering education is also reported in a study by Becerik-Gerber et al. (2011). Becerik-Gerber and colleagues conducted a survey with 101 U.S. AEC programs focusing on BIM and sustainability and reviewed how educational innovations (e.g. multidisciplinary collaboration, industry collaborations) are incorporated to develop core competencies in the two subject areas. The authors found disparities in the reviewed programs and suggested the need to realign the current methods to best develop the core knowledge and diverse competencies of engineering students.

In addition, it has been reported that the incorporation of BIM into civil/construction engineering education has faced with many challenges, as follows (Sacks & Pikas, 2013; Sabongi, 2009; Wong et al., 2011):

- BIM demands new teaching methods;
- There is a lack of BIM-specific materials and textbooks as well as other educational resources for students;
- Modelling requires expert construction knowledge that is not easily understood by students, especially when they lack work experience;
- It is difficult to educate the teachers due to rapidly evolving technology;
- BIM is resource intensive (software is expensive);
- BIM is problematic for people with weak general IT skills;
- There is no room in the existing curriculum for additional classes;
- Integrating different areas of the curriculum to realise the multidisciplinary aspect of BIM is problematic; and
- There is a lack of accreditation standards and requirements to guide the implementation of BIM within a curriculum.

The above challenges indicate some fundamental issues that most universities are confronting when attempting to integrate BIM into their engineering curricula. Most of these issues are associated with the internal constraints that exist in different institutions, which suggest the need for them to innovate should they wish to pursue the development of a BIM-integrated curriculum.

It is worth highlighting that the inconsistency in how BIM is integrated into engineering education may be attributed to the last challenge identified above – the lack of accreditation standards and professional requirements to guide the development of BIM-integrated curricula. Perhaps, this issue reflects the existing gap between the industry and academia which merits further studies.

While numerous challenges, issues and needs faced by the academia in integrating BIM into engineering education are well documented, they are not well understood from the industry practitioners' points of view. In order to bridge the gap mentioned above, Becerik-Gerber et al. (2011) argued that future research is required to answer the following questions:

- In which categories is the industry ahead of academia or vice versa in terms of BIM adoption?
- What are the skills that the industry requires from students?
- What are the key barriers?

Given the above research need, the present study was aimed to improve the understanding on how industry practitioners perceive the issues surrounding the integration of BIM into engineering education.

Methodology

Approach

A qualitative approach was employed in this research to explore and analyse important themes uncovered from textual data collected from internet social media. Internet social media provide a communication platform that facilitates the development, sharing and exchanging of online conversations around topics of interest, where participation is not necessarily limited by geographical or social factors (Highfield, 2012). According to Asur and Huberman (2010), its ease of use, speed and reach enable social media to transform public discourse in society and set trends in topics ranging from the environment and politics to technology and the entertainment industry. The sheer volume and variety of the information that propagates through large user communities presents a great opportunity for harnessing the data to study, analyse or predict a specific phenomenon (Asur & Huberman, 2010).

Data collection

The LinkedIn social network platform was chosen as the source for data collection in this research due to its primary focus on professional networking. In particular, LinkedIn has a feature that allows members to create and join the discussion groups of their interests. A search on LinkedIn showed numerous discussion groups related specifically to BIM. This research, however, focused solely on the "BIM Experts" group, which is one of the largest BIM-related discussion groups on LinkedIn, consisting of about 20,000 members (at the time of writing this paper). This discussion group was also used in a recent research conducted by Sacks and Pikas (2013) to obtain initial feedback on the development of BIM curriculum in construction engineering and management education. It was also used by Panuwatwanich and Peansupap (2013) to investigate the diffusion of BIM within the AEC industry.

According to the group's statistics, the majority of the members are senior professionals in the fields of architecture and construction with locations in the UK and USA. The group has active discussions, generating more than a hundred posts and comments weekly. It thus provides an adequate source of data for examining a variety of issues related to BIM adoption and utilisation.

A qualitative analysis approach was employed in this research to analyse discussion threads retrieved from the BIM Experts group for themes and concepts relevant to the diffusion of BIM. To gather textual data of the discussion posts and comments from the group, a feature in the qualitative analysis software NVivo 10, NCapture, was utilised. By using NCapture, discussion threads can be downloaded directly from LinkedIn into the NVivo software. This feature, however, has a limitation in the number of discussions comments that the software can download. Hence, it is not possible to obtain all the posts and comments stored in the discussion group. For this reason, it was decided that only the discussion posts that are specifically related to the integration of BIM within the university education context, together with their associated comments, would be considered for the analysis. To achieve this, a search was conducted on the discussion group using a combination of keywords including "university", "education", "curriculum" and "teaching". Through manual selection, only 20 posts with topics clearly relevant to BIM curriculum and the teaching of BIM in university education with considerable follow-up comments were included in the analysis. There were 146 group members contributing to these posts, which altogether generated 730 comments. The selected posts were generated between the middle of 2011 and early 2013. About half

of these posts consisted of discussions that spanned over at least a week to up to nine months. The remaining posts mainly lasted for 2-6 days.

Data analysis

As mentioned previously, NVivo 10 was used to perform a qualitative analysis in order to extract important issues relevant to the integration of BIM into engineering education as perceived by the industry practitioners. NVivo facilitates the collection and organisation of textual data and can be used to help perform a text analysis through such functions as word queries and coding. To carry out the analysis, all the 20 selected posts and associated comments were captured directly from LinkedIn website and imported to NVivo using the NCapture feature. Coding was then performed to extract important concepts. For each post, all follow-up comments were analysed whereby specific statements or paragraphs were assigned (coded) into relevant concepts (or "nodes" in NVivo term). A screenshot of a coding activity is shown in Figure 1. These concepts were then compiled and evaluated to develop insights into important issues that can be used to inform the integration of BIM into engineering education.
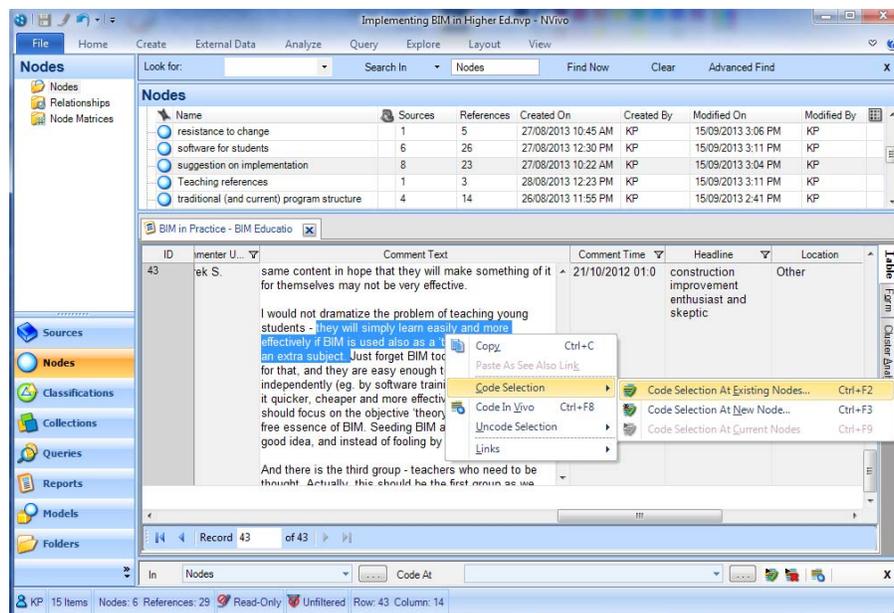

Figure 1: Screenshot of coding in NVivo

Results and discussions

Demographic information

In total, 20 discussion posts related to BIM in engineering education were included in the analysis. These posts generated 730 comments, with 146 members from 25 countries contributing to the discussions. The majority of the contributors were located in the USA (45%), followed by the UK (16%) and Australia (9%). Other contributors included members from countries from Asia-Pacific (New Zealand, China, India and Malaysia), Europe (Italy, France, Belgium, Finland and Denmark), Middle East (UAE and Israel), South America (Brazil and Argentina) and Africa (South Africa and Nigeria). The majority of the contributors were employed as company managers, principals or directors (34%), followed by experienced professionals (13%) and para-professionals (9%). The members mainly operated within the Construction (37%) and Architecture and Planning (32%) industries. The rest included such industries as computer software and management consulting.

Coding results

Each of the 20 discussion posts including its associated follow-up comments was coded. The coding process involved the examination of texts with the view to determine whether any sections, sentences or paragraphs of the comments can be associated with any particular themes or concepts. These concepts (nodes) can be predetermined (a priori) or can be those that emerge after the coding process (a posteriori). Given the lack of previous studies on the perceptions of industry practitioners regarding the integration of BIM into engineering education, this current study was focused on identifying themes that emerged from the discussions rather than trying to search for specific texts to support predetermined themes/concepts derived from previous studies.

The results from the coding analysis are presented in Table 1. The table shows the themes identified from the discussion posts, as ranked by the number of associated statements or paragraphs assigned to each theme. From the table, it can be seen that the majority of the discussions were about how to teach and integrate BIM into university curricula (i.e. the first three themes). This is followed by issues related to the barriers to incorporating BIM in higher education. The top three themes, dealing mainly with the recommendations and suggestions, are discussed separately below, followed by the remaining themes relevant to the barriers to integrating BIM into higher education.

Table 1: Coding results

Rank	Themes	Reference count
1	What to include in BIM course	58
2	BIM Software for students	26
3	How to integrate BIM in curriculum	23
4	Disagreement over BIM concept	17
5	Traditional (and current) program structures	14
6	Need for strong fundamental knowledge	9
7	Need for industry involvement	5
8	Resistance to change	5
9	Professional accreditation issues	1

What should be included in a BIM course?

The most active discussions were associated with specifically what to include in a BIM course. The comments mainly consisted of how some members learned BIM from their universities and what should be taught according to the experiences of some members. The majority of the members agreed that a BIM course should focus on how the BIM concept can be used to manage the entire process and life cycle of a building system, rather than on teaching specific software tools, as one comment stated:

> *Educating students about BIM is about educating students to become systems managers – creating and reusing digital content from all players in the design to build value chain.*

On the other hand, some members believed that a BIM course also requires the focus on teaching specific software tools. According to one of the commenters:

> *I remember being fresh out and looking for work...what did the advertisements say; Graduate with CAD skills wanted. Teaching technology is a must simply because the industry revolves around it.*

It was also suggested that, if possible, a course should include a good balance of both "BIM as a process" and "BIM as a tool" contents. Other suggestions included the use of project-based learning and industry-based activities to effectively teach BIM.

Which BIM software should be taught to the students?

In the industry, there has been a strong debate over which BIM software tools are the most capable, mainly between ArchiCAD and AutoDesk Revit. The debate seems to have the same effect among the members discussing which is more appropriate for education, with no consensus reached. One suggestion was to use the tool that is widely adopted in the market as it will represent the mainstream demand from the industry.

How to integrate BIM into a curriculum

Unlike the previous issue of what should be taught in a BIM course, the discussions regarding how BIM can be integrated in a curriculum were more to do with the structure and level of the curriculum as well as its relationship with other elements of the wider program. To integrate BIM into the existing curriculum, many members highlighted the need for a multidisciplinary approach to developing a BIM curriculum, as exemplified by a comment below:

> *Since the basics of BIM are about using technology to more effectively collaborate and hand off data sets to alternate use groups, how can that be taught without the integration of multiple educational silos.*

Some members believed that most fundamental courses still need to be maintained with BIM being used as a "teaching method" rather than an extra course. A few members commented that BIM education should be delivered as an apprenticeship, requiring collaboration between industry and trade schools. Others believed that BIM courses should be included as part of a postgraduate level program.

Barriers to integrating BIM into higher education

Apart from the suggestions on how to incorporate BIM in higher education, a number of major barriers were also mentioned under the different themes below.

- "Disagreement over BIM concept" is concerned with the difference in viewpoints regarding whether BIM is a methodological process or a software tool. Such philosophical disagreement is still prevalent among the industry practitioners and it is perceived to have an impact on how a BIM course/curriculum is designed.
- "Traditional program structures" refers to the typical isolated, discipline-specific program structure that exists in most universities. This is viewed as a main barrier because the fundamental concept of BIM hinges upon the whole-life aspect of a building system that requires multidisciplinary effort of all parties involved.
- "Need for strong fundamental knowledge" represents the need for the students to acquire all the important fundamental knowledge before being able to undertake BIM. Given the limited room in most programs, integrating BIM into an existing curriculum will prove a significant challenge.
- "Need for industry involvement" highlights the need to engage expert industry practitioners in the development and delivery of a BIM curriculum.
- "Resistance to change" is concerned with the difficulty in introducing BIM in an already well-established curriculum mentioned above. This includes the difficulty to bridge the "traditional education silos" to deliver a fully collaborative curriculum.
- "Professional accreditation issue" reflects the fact that most professional bodies require the curriculum to satisfy certain learning outcomes necessary for a discipline-specific professional. Hence, there is little opportunity and/or incentive for a university to develop a collaborative curriculum to support the integration of BIM.

Conclusion

Building Information Modelling (BIM) has the potential to improve the efficiency of the AEC industry and its benefits are well recognised and reported in numerous academic and industry publications. However, recent research shows that the adoption of BIM within the AEC industry is still less than anticipated, highlighting the lack of BIM training and education within educational institutions as one main barrier commonly identified across different

studies. With the need for BIM in education, many universities have experimented with integrating BIM into their curricula, particularly in engineering and construction. A number of challenges associated with such initiatives have been reported, with inconsistency found in the delivery approaches across different universities. It has been further recommended that the input from industry practitioners should be sought, examined and incorporated in the development of a BIM-integrated curriculum.

The research presented in this paper was aimed to examine the issues regarding the integration of BIM into engineering education, as perceived by the industry practitioners. Using a qualitative study of social network data obtained from LinkedIn group discussions, a number of insightful recommendations from the industry on how to incorporate BIM into a curriculum were identified. Many of the discussion group members highlighted the need to bridge the educational silos to fully provide a collaborative, multidisciplinary learning environment that truly reflects the nature of BIM. They asserted that the pedagogy of BIM education should focus on teaching BIM as a "process" rather than just a "tool". Moreover, they identified a number of barriers that represent major challenges that both academia and industry need to overcome to successfully incorporate BIM into a curriculum. These challenges are relevant not only to engineering education, but also to other related disciplines within the AEC context.

Limitations and future work

Due to its exploratory nature, this study has a number of main limitations, which are listed below along with the associated recommendations for future research.

- The discussion posts included in this study were limited to only one discussion group and may not be enough to generalise the findings. Future studies that include discussions from other groups are required to determine if the findings are consistent.
- The findings were derived from the comments made by the majority group members from the US and UK. For future studies, these findings need further examination within a specific context using techniques such as questionnaire surveys and focus group. These would help to validate the results and to gain in-depth understanding into critical issues that need to be addressed, with the aim to develop some practical recommendations.
- The themes uncovered in this study were interpreted independently from one another. In fact, possible relationships between these themes did emerge during the analysis, and these need to be further explored to develop a more complete understanding of the issues surrounding the integration of BIM into Engineering Education.

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