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# A Review of Approaches and Challenges of BIM Education in Construction Management

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**Abstract:** As BIM (building information modeling) became the gold standard of the architecture, construction, and engineering industry, lack of skilled BIM professionals is considered one of the major challenges. It is therefore of significant importance that CM (construction management) programs train future construction professionals in the capabilities and advantages of BIM technology. This paper presents the findings of a comprehensive review of the implementation of BIM education in CM programs and summarizes the process of BIM adoption, existing educational approaches, and identified challenges in the implementation process. The information presented in this paper serves as a guide to CM programs that are new to and in the progress of implementing BIM education.

**Key words:** Construction management, building information modeling, education, approaches, challenges.

## 1. Introduction

Although BIM (building information modeling) has become the trending technology of the AEC (architecture, construction, and engineering) industry, its uses and benefits have not been maximized yet [1]. While some predominant reasons included BIM standards not being adopted across the industry, BIM models not being part of a contract, not enough incentives for the designers to provide complete BIM models, etc., several previous studies have identified the lack of skilled BIM professionals as one major reason [2-5]. To apply BIM technology effectively and efficiently, an AEC practitioner must be cross-trained with both construction knowledge and IT skills [6]. Lack of adequate training has been one of the challenges to move the industry into the BIM era [7, 8].

The increasing adoption combined with the lack of skilled professionals of BIM in the AEC industry has led to an emerging emphasis on BIM education in CM

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(construction management) programs. While BIM education has been implemented in many CM programs, some are still piloting their own approaches in this new content. This paper presents the findings of a comprehensive review of the implementation of BIM education in CM programs and summarizes the process of BIM adoption, existing educational approaches, and identified challenges in the implementation process. The information presented in this paper serves as a guide to CM programs that are new to and in the progress of implementing BIM education.

### 2. From CAD to BIM

2D CAD (computer-aided design) drafting has been traditionally used in CM education to facilitate the curriculum due to its standard use in the AEC industry. As a pedagogical tool, CAD drawings have been used across various subjects including estimating quantity and cost, developing construction sequence and schedule, and analyzing site layout and safety risks [9]. While being widely used as a universal pedagogical tool, it often requires some degree of students' prior experience to interpret 2D CAD drawings. The ability

to interpret CAD drawings mostly depends on students' prior experience since students must perceptually visualize the components of a structure from lines and symbols in a drawing set and mentally combine them into a virtual structure. CM students with little or no previous experience often face challenges and must spend more time interpreting the drawings [10].

Using BIM as a pedagogical tool in CM education can assist students in understanding the complexity of construction projects in both the process and product [11, 12]. In addition, many CM students are aware of BIM as the emerging technology used in the industry and have the expectations of learning the latest and most essential paradigm in a CM program [13]. BIM as a buzzword in the industry, however, often shifts the focus away from its benefits of sharing and simulating information and misleads students to see it as a software program or an acronym for 3D design and modeling [14, 15].

The benefits of BIM in sharing and simulating construction information have often been overlooked in a CM curriculum [14, 15]. Recent research has pointed out that only knowing how to use BIM software to model building systems is not a true understanding of BIM and is in fact far from the expectations of being effective BIM users. Without understanding the fundamental workflow of BIM, CM students will not be able to fully understand and utilize BIM to manage the construction process [4]. To be effective BIM users, students should be able to extract the information needed efficiently from building models to manage the construction process [4]. In addition, due to the rapid development of BIM during the last couple decades, the academia has not agreed on what needs to be included in the CM curriculum [16, 17].

## 3. BIM in CM

# 3.1 BIM Adoption

To better equip students with the capabilities

demanded by the AEC industry, many CM programs have incorporated BIM contents into their curriculum [18]. Various teaching methods and course layout have been used in different CM programs to introduce BIM [19-21]. In general, most CM programs offer BIM in one to three courses and limit its coverage within a single discipline [21, 22]. The implementation strategies include introducing BIM as standalone courses, utilizing cross-discipline BIM courses, adding BIM labs in capstone/project courses, and integrating BIM into existing courses [23].

To better equip students with the capabilities demanded by the AEC industry, many CM programs have introduced BIM into their curriculum [18]. Pavelko and Chasey [24] performed a survey of 59 construction programs that were members of the ASC (Associated Schools of Construction) and were accredited by the ACCE (American Council for Construction Education). The results indicated that 70% of the respondents had BIM covered, and most of them were teaching BIM for 3D coordination (82%), about half for scheduling (4D) (46%), and a third for estimating (5D) (35%) [15, 24].

Becerik-Gerber et al. [25] expanded the pool to 26 CM programs that were accredited by the ABET (Accreditation Board for Engineering and Technology). The findings showed that 60% of the respondents had BIM components in one or two elective courses, and the topics most taught were constructability, scheduling, estimating, design, and visualization [12, 15, 25].

Joannides et al. [18] administrated a survey of 70 construction programs that were ACCE accredited and received 35 responses. The results suggested that 83% had included BIM with the majority (55%) in one to two courses, and the most taught topics were 3D coordination (37%), 4D scheduling (25%), and 5D estimating (20%) [18]. In general, most CM programs offer BIM in one to three courses and limit its coverage within a single discipline [21, 22].

## 3.2 Existing Approaches

Since there is no commonly agreed approach to introduce BIM, many CM programs have been struggling to understand what and how to teach [21, 22]. The various implementation strategies that CM programs have employed to incorporate BIM into the curriculum can be grouped into four categories: standalone courses, cross-discipline courses, capstone/project courses, and integration into existing courses.

Introducing BIM in standalone courses is an effective approach to quickly cover BIM components. Many CM programs introduce BIM in courses such as Digital Graphical Representation, Graphical Communication, and Construction Information Technology [22, 26]. These courses often replace an existing lower level CAD course and thus focus on the specific skills of modeling and basic analysis [5, 18, 20, 21]. This approach has been adopted widely because most CM subjects can benefit more with BIM. and in many cases, CAD is no longer needed. Some CM programs introduce BIM by allowing students to take cross-discipline courses from other programs such as civil engineering workshops and architecture studios [5].

While this approach is efficient at some extent and takes the maximal use of existing resources, these cross-discipline courses often focus towards design and away from CM topics. Implementing BIM in a capstone project allows students to learn the BIM process in various CM subjects throughout the project cycle. However, teaching BIM within a one- or even two-semester capstone project limits the use of BIM in each CM discipline to only a couple of weeks due to time constraint. As a result, students get only a basic understanding of the BIM process and their BIM skills fall short of the expectation to become fluent.

Integrating BIM into existing courses is considered the most practical way to offer BIM [4]. This strategy typically divides BIM contents into smaller and manageable topics, and thus can provide CM students with a rich and rigorous learning environment and consequently better quality of education [4, 21]. It is also generally accepted that BIM integration should be distributed over all years of the CM curriculum instead of only in lower or upper level courses [21].

Sacks and Pikas [21] summarized from an Internet discussion in 2011 that BIM education should focus on the fundamental knowledge in the first two years, such as modeling skills, the parametric concept, and constraints, followed by the implementation of specific BIM functionalities in different CM subjects, such as estimating, scheduling, visualization, coordination, system analysis, etc. In the last few semesters, BIM should be incorporated into the broader picture of construction projects to create a holistic understanding of the use of BIM process in professional practice [21].

### 3.3 BIM Courses

Offering new BIM courses is one popular approach that many CM programs have employed to incorporate BIM contents into their curriculum. One typical solution is to have an introductory BIM course replace an existing lower level CAD course, such as Construction Graphical Communication Construction Information Technology [22, 26]. This is viable because students no longer need CAD drafting once they use BIM since 2D drawings can be generated directly from a 3D BIM model. Due to the course conversion, these introductory BIM courses focus mainly on specific modeling skills [5, 18]. The other solution is to offer a new junior- or senior-level elective BIM course as an addition to the CM curriculum. These elective BIM courses often focus on analysis tools of BIM applications, such 3D coordination, 4D scheduling, and 5D estimating, and use model-based project to demonstrate the use of BIM in various CM subjects [20, 21].

The CM program at Arizona State University offered Introduction to BIM as a 1-credit computer application course to teach the concept of BIM

process and applications of BIM software [14]. The program further offered a 1-credit BIM lab to accompany the CM capstone course Project Management. The BIM lab covered a range of BIM-related CM topics including site logistics visualization, model-based estimating, 4D scheduling, and clash detection using a variety of commercial packages such as Revit, Navisworks, SketchUp, Bluebeam Revu, and DESTINI Profiler. The capstone course itself also incorporated BIM contents on developing a BIM Execution Plan [15].

The CM program at University of Texas at San Antonio offered BIM for Construction Management as a 3-credit elective course for junior and senior students who had completed CM core courses. As the only BIM course in the curriculum, it covered a wide variety of BIM topics including design and visualization, model-based quantity take-off and estimating, and 4D scheduling, clash detection, and constructability. The course contained lecture sessions to introduce BIM concepts, execution plans, implementation, case studies. and software demonstration, and included lab sessions to provide hands-on practice on Revit (Architecture, Structure, MEP), Navisworks, as well as SketchUp and Primavera P6. The course focused on basic modeling skills, understanding of database, as well as trade coordination with different platforms [27].

Some CM programs chose to offer a BIM module or workshops within an existing CM course instead of offering a complete new course as an alternative approach. The CM program at Colorado State University developed a BIM module within a structures course to present the capabilities of BIM software and other analysis programs, including 3D interactive animations, material schedules and quantity takeoff, material and labor cost estimates, and construction sequence [28]. The CM program at California State University, Chico included seven one-hour BIM workshops in the Construction Methods Analysis course and had industry representatives teach various BIM tools, i.e., SketchUp, Revit, Navisworks, and Solibri, on related CM topics including site layout, model analysis, structural steel sequencing, clash detection, and constructability [29].

The CM program at University of North Carolina at Charlotte proposed a workflow for a BIM course in a CM curriculum. The workflow suggested that the course should be a senior-level course for students who had completed CM core courses such as estimating, scheduling, and project management. The proposed workflow contained five BIM components, namely 3D modeling, cost estimating, scheduling and project administration, control, and documents, and covered the two major BIM packages, Autodesk Revit (Architecture, Structure, MEP) and Navisworks, and Vico Virtual Construction Software Suite (Constructor, Estimator, Cost Manager, 5D Presenter) [30].

In general, while introducing BIM in new courses is an effective method to quickly cover BIM components, these new courses often focus on specific modeling skills and analysis tools of BIM applications, such 4D scheduling and 5D estimating. To effectively utilize BIM tools to manage the construction process, fully understanding the BIM workflow in a construction project is of equal importance to CM students [4]. Some existing BIM courses ignored the BIM workflow and as a result, CM students had seen BIM simply as 3D design and modeling or just as a software program without recognizing its benefits in sharing and simulating construction information [14, 15].

# 4. Challenges

Although there are various strategies to introduce BIM, to have BIM fully implemented in CM curriculum, many challenges still exist within the CM programs, the academia, and the AEC industry. Most of the challenges are from the faculty, students, and resources of CM programs:

- (1) Lack of available faculty to teach BIM [12, 15, 25]. Due to the high demand of BIM experts in the AEC industry, CM programs may not be able to hire competent new faculty who have been specifically and extensively trained with BIM in their education or industry experience. To many current CM faculty and particularly senior faculty, BIM is a new technology that requires a large amount of time to get familiar and then proficient. It takes even more faculty time to make curriculum changes to incorporate BIM components [25]. For many teaching-focused CM programs, the number of full-time faculty is often small, and they usually work full-load with teaching and advising. It is particularly difficult for them to develop and teach additional topics on BIM.
- (2) Lack of student interest or willingness to learn BIM [14, 15, 21, 31-35]. BIM has a very steep learning curve compared to the traditional CAD drafting [1] and it is also rather challenging for students to self-learn without guidance [30]. Students with previous exposure to CAD may experience difficulties in the transition and students without a clear understanding of building systems and construction methods may encounter a variety of problems in using BIM [1, 14].
- (3) No room for new BIM courses in the curriculum [12, 15, 21, 35]. The curriculum in most CM programs is already a complete system. When new faculty is unavailable and current faculty is full-loaded, there will be neither the need nor any room to add additional courses on BIM. In addition, almost all students can find enough number of CM courses to enroll in order to meet the degree requirements, which leads to neglecting the necessity of adding new BIM courses to the curriculum [25].
- (4) Lack of faculty interest or willingness to teach BIM [4, 15, 21, 25, 29, 33]. CM faculty may be unwilling to incorporate BIM into the existing curriculum since the current course provides sufficient materials and the attempt to change requires much

effort and many resources [33]. In addition, the proficient use of BIM takes repetition and practice, which is difficult to achieve in the current lecture-lab settings due to time constraints [29]. On some BIM topics, it takes so much time to cover the technical skills that there is very little time remaining for their applications in practice [34].

Other challenges of implementing BIM in CM curriculum come from the CM academia and the AEC industry.

- (5) No requirements of BIM in ACCE or ABET accreditation criteria have been identified as another challenge from the CM academia [12, 15, 25]. Most CM programs are accredited through ACCE or ABET and their curriculum strictly follows the accreditation criteria. Both agencies have not specifically indicated having a BIM course as an accreditation requirement [25]. Currently, most CM programs apply BIM components in the category of computer applications or information technology of the accreditation criteria since BIM topics utilize a variety of computer programs [14]. Without formal accreditation requirements, some CM programs just lack the motivation and incentive to incorporate BIM into the curriculum.
- (6) Although the demand of BIM professionals is high in the AEC industry, unclear and inconsistent expectation of BIM skills on CM graduates has been considered a challenge that prevents some CM programs from introducing BIM to the curriculum [21].

In addition, lack of textbooks, tutorials, or models to teach BIM [12, 14, 15, 21, 31] was also identified as a main issue when BIM was first introduced into CM programs a decade ago. After over 10 years of development, this is no longer a challenge since various textbooks and tutorials have been authored and many AEC firms have shared their projects and models with CM programs interested in introducing BIM to the curriculum.

## 5. Conclusions

As BIM has become the gold standard of the AEC industry, lack of skilled BIM professionals has been identified as one major reason among many others including BIM standards not being adopted across the industry, BIM models not being part of a contract, not enough incentives for the designers to provide complete BIM models, etc. [2-5]. It is therefore of significant importance that CM programs train future construction professionals in the capabilities and advantages of BIM technology [1, 28]. This paper presents the findings of a comprehensive review of the implementation of BIM education in CM programs and summarizes the process of BIM adoption, existing educational approaches, and identified challenges in implementation process. The information presented in this paper serves as a guide to CM programs that are new to and in the progress of implementing BIM education.

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