International Journal of Engineering Education Vol. 35, No. 1(A), pp. 126–141, 2019
Printed in Great Britain
0949-149X/91 $3.00+0.00

Building Information Modeling (BIM) Technology Education for the Needs of Industry in Developing Countries*

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Building Information Modeling (BIM) technology is now globally accepted as a means of creating a knowledge-based construction industry that uses 3D (or more) visualization and simulation techniques to improve business efficiency. However, developing South Asian countries such as Vietnam, Malaysia, and the Philippines have yet to introduce BIM technology, largely due to a lack of appropriately trained professionals. Many countries need to develop the necessary environment and curriculum to teach BIM-related knowledge and skills and thus produce skilled construction professionals capable of implementing this technology. Using a systematic course approach, we developed a BIM course that was specifically designed to address the needs of both those entering the profession and construction companies in developing countries. In addition to understanding the applicability of BIM for construction projects, newly qualified professionals will appreciate the advantages and prospects of Integrated Project Delivery (IPD) systems and BIM technology, as well as the importance of cooperation. The new course will support the development of accomplished professionals with the BIM skills needed by construction companies in today's competitive market.

Keywords: building information modeling; BIM training; systematic course development approach; South Korea

1. Introduction

Almost every aspect of the global construction industry has been impacted by recent trends such as accelerated innovation, sustainable construction, and the application of Building Information Modeling (BIM) in construction to improve efficiency and resolve problems. BIM technology began to gain acceptance in Europe and the US in 2000, with significant improvements in productivity—that is, in the cost, schedule, and quality of design and construction—reported in these regions [1]. BIM emerged from the Object-oriented Building Product Model used to define and express the shapes, functions, and properties of building systems and component models, thereby addressing many of the disadvantages of Computer-Aided Drafting (CAD) [2]. BIM-based automatic processes quickly replaced traditional 2D CAD, paper documents, and Excel sheets in several countries, leading to significant differences in the technical levels of construction automation, BIM-based process, and Integrated Project Delivery (IPD) around the world. Already lagging behind in construction techniques and skills, developing countries were now suffering from an additional technical gap through being late in applying BIM technology. In the case of South Korea, BIM was not introduced until 2008, with a further three to four years required to bridge the gap between BIM theory and practice. Although BIM technology was initially only applied symbolically in representative projects in South Korea, it is now commonplace on construction sites [2–4]. This wider application of BIM to the construction industry is attributable to its applicability: BIM not only includes basic functions such as conflict, interface, and collision detection but can also be applied to such diverse purposes as visualization, fabrication/shop drawings, code reviews, energy simulations, design validation, option analysis(value engineering), forensic analyses, facilities management, cost estimation, construction sequencing, and constructability reviews [3–12]. In addition, BIM supports advanced collaboration processes within construction supply chains more effectively than conventional methods. These advantages are closely related to lean construction, green principles and integrated project delivery [13–15].

While the wide applicability and advantages of BIM promote the active spread of this technology in the construction industry, many construction companies seeking to implement BIM face a major

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* Accepted 12 September 2018.

obstacle in the lack of BIM experts in Korea [10, 16, 17]. In addition to competitive employees equipped with BIM knowledge and skills, BIM information and skills training programs are critical success factors (CSF) for effective BIM application [18–21]. Indeed, Ozorhon and Karahan (2017) note that the availability of qualified staff and employee training are the most important CSFs for the implementation of BIM in developing countries, which tend to fall behind developed countries due to their outdated construction infrastructure and lower productivity [22]. Cook (2004) has argued that the lack of professionals skilled in both the construction and IT sectors has delayed the wider application of BIM. Similarly [23], Young et al. (2008) suggest that the lack of adequate training and education is a critical factor preventing BIM from being widely implemented in construction projects [24]. Validating these arguments, leading countries in the global construction market such as the US, Japan, and Europe were quick to promote BIM implementations by establishing training systems for BIM experts and are now benefitting from these initiatives [25].

South Korea and Japan, both of which are powerhouses in the IT industry, the development of new business opportunities in the marketing area and a better client service are recognized as the most remarkable advantages of BIM applications. Interestingly, 42% of non-BIM users predicted that BIM would play an essential role in the construction industry within five years [26]. Because South Korea was slow to introduce BIM technology, the main focus of the early stage of its implementation has been to secure a sufficient number of BIM experts working in the nation's construction industry. The majority of the initial investment was therefore dedicated to BIM training and a good BIM Expertise Level has now been achieved (Beginner 34%, Moderate 37%, Advanced 15%, and Expert 13%) [26]. However, simple descriptive or theoretical BIM training has only a limited impact. Indeed, most training courses in construction projects are designed to be delivered as one-way lectures and thus do not provide students with sufficient opportunities to apply theoretical knowledge or acquire practical knowledge and skills [25]. Unfortunately, although such lecture-centered approaches are known to be ineffective [21, 27–31], the majority of BIM training programs in private/public and higher education institutes in South Korea continue to utilize them to convey simple theoretical knowledge and basic tutorials for simple practical exercises [25].

The construction industry in South Korea—which includes architecture, engineering, and construction (AEC)—clearly needs to prioritize BIM education and training to improve the business value of its BIM operations. These education and training programs must overcome the basic programs offered by higher education institutions if they are to meet the needs of the industrial sector so BIM can be utilized directly and effectively in real projects [32]. In developing countries, which tend to fall behind developed countries in every area of the construction industry, including techniques, systems, policy, culture, and manpower, recruiting BIM-proficient employees could be a win-win strategy for both individuals and companies. Adopting such innovative measures will improve construction productivity on a national scale.

However, as yet there are few BIM education programs in public/private and higher education institutions in developing countries, and those that do exist tend to provide only an initial introduction. While the construction programs in developed countries provide BIM courses for job applicants from developing countries, BIM curricula that reflect the competitiveness, productivity, and conditions unique to the construction industry of individual countries are still needed. Since the introduction of BIM in 2008, South Korea has experienced massive changes in terms of its systems, policies, technology, and education, with BIM courses that were initially basic or theoretical are now diversifying. This study was thus designed to develop a BIM course that can be directly/indirectly applied to developing countries on the basis of the BIM education in South Korea.

To achieve this goal, the three stages of Tyler's curriculum model were adopted and organized around the identified goals and 22 objects [33]. Given that the primary goal of a curriculum is to cultivate the knowledge and skills of students about to enter the labor market, a curriculum model that establishes systematic and transparent grounds for specific education, training, and assessment systems must be considered when designing a new BIM course [34]. Two major models are used to develop curricula in a systematic and transparent way, namely the product model and the process model. According to Neary (2003), the product model focuses on plan and intention, while the process model highlights activity and effect [35]. Since the new course proposed here will form part of a technical curriculum and the BIM needs of construction companies will coincide with the goals of the job applicants, this study adopted the Tyler model by implementing the following three stages for developing a BIM course: (1) curriculum preparation, (2) curriculum development, and (3) curriculum improvement [33].

As the outcome of this study, the "BIM in Construction Management for Job Applicants in

Developing Countries" course was designed specifically for those applying for jobs in construction companies—including both undergraduate students and the unemployed. This course was designed to last for a period of 16 weeks and teach basic BIM principles and skills. It is also intended to provide job applicants that majored in architectural engineering with an opportunity to prepare for a career as an industry leader and innovator. The prerequisite subjects for this curriculum include construction materials, building codes, building construction, construction means and methods, blueprint reading, and information technology. These subjects will help attendees—that is, job applicants—comprehensively understand and apply BIM, as well as being a useful way to organize BIM models from various architectural engineering perspectives.

2. Systematic development of the "BIM in construction management for job applicants of developing countries" course

2.1 Preparation stage of course development

As the new BIM course intends to provide trainees with the requisite principles, knowledge, and skills for achieving given objectives, it needs to be developed based on systematic logic and procedure. A preliminary examination of several areas was necessary in the preparation stage to help trainees build the BIM competency required for and applicable to duties in construction companies. The first stage of the course development therefore considered the following issues in order to identify the educational needs of job applicants:

- Goals, advantages, and obstacles in BIM implementation for the AEC industry.
- Necessity of BIM education in the construction industry, especially for construction management.
- Status of BIM education implemented in existing construction programs for job applicants.
- The relationship between BIM and construction management tasks in construction companies—that is, the importance of BIM in construction management.
- Areas of BIM implementation in construction companies, as well as the BIM knowledge and skills required for new employees.
- Priority of BIM education in companies, which was confirmed by BIM experts.

This study analyzed the BIM courses provided in the construction programs of several public/private education institutions in order to identify and define the goals, advantages, and obstacles associated with BIM implementations in the construction industry, and to establish the goals and objectives of the proposed course. The analysis also clarified the gap between actual BIM courses in diverse organizations and BIM competency requirements in the field. Table 1 presents a list of the BIM-related courses included in the construction programs of 3 universities, 2 public education institutions and 1 private education institution in South Korea. The BIM curriculums in all 3 universities aimed at providing both a comprehensive understanding of BIM theories and practical BIM skills for implementing in real construction projects. The primary contents of the lectures varied somewhat, being taken from the following: parametric modeling, case analysis of IPD/BIM projects, practice of basic BIM modeling, BIM based quantity takeoff, 4D Sequence simulation, and lifecycle information management among others. Students attending University B could participate in a field trip to experience a real world implementation of BIM skills in a construction project. However, none of the university curriculums delivered practical knowledge and skills related to real construction field work because most of the curriculum lecturers, who are professors, have much experience in practical applications of BIM. Their lectures on BIM modeling described in their syllabuses were also very basic and tutorial-focused. The Korean Construction Plant Institute, which is a public education body in South Korea, offers long-term courses on establishing methods for handling BIM data, information exchange and applications of BIM data and information. Their syllabuses aim to provide a working level of BIM knowledge and skills for seeking jobs and consist of practical modeling, data interoperability, MEP, structure, civil engineering, BIM application, and so on, while intensified training regarding the theoretical basis of IPD, VDC, BIM, and construction management(CM) are excluded from their education program. KICTE (the Korean Institute of Construction Technology Education) also provides BIM expert courses for professional personnel who are skilled in BIM software and tools, but almost all the trainers are hands-on workers who little knowledge and expertise of IPD/VDC and construction management of the sort typically acquired at higher education institutions. Hansol academy, which is a private educational institution, includes a 3 step BIM curriculum in their program. From the Beginner course through to their BIM expert 2nd grade certificate course, they provide BIM general theories, case analysis, tutorial, BIM based estimating, digital documentation, application of integrated BIM data, and Navisworks by phase. All of the course content is designed to lead ultimately to BIM expert 2nd grade certification, which is a recognized

Table 1. BIM-related Courses Offered by Universities and Public/Private BIM Education Institutions in South Korea

Sector	Institution	Course name	Purpose of course
Universities	University A	BIM based construction information management	• General understanding of Building Information Modeling. • Operation of BIM for creating and managing data of construction projects. • Two classes a week: information management (one class) and modeling (one class). • Lectures on modeling and information management are segmented, but the BIM application in the industry is insufficiently considered and the courses have limited applicability.
	University B	BIM and IPD	• Architectural object modeling methodology based on BIM/IPD case analysis. • IPD-based project practice. • Field trip during the course encourages trainees to acquire practical knowledge for applying BIM to the field.
	University C	Construction technologies	• Modeling and practice. • Lecture-centered education on BIM trends, utilization and cases, BIM practice is conducted for only three of 13 weeks. • 4D and 5D information management. • Differentiated lectures on BIM-fused technological cases reflecting latest trends.
Public	Korean Construction Plant Institute	Company oriented BIM expert training course	• Long-term education course for BIM data set-up, exchange and use. • Experts from companies join the course to help trainees acquire basic work skills in theoretical and practical classes.
	Korean Institute of Construction Technology Education	Company oriented BIM expert training course	• Systematic training designed to cope with the needs of the industry such as BIM-based drawing, quotation, process management, integrated work and quality management for each stage, as well as IT implementation. • Training of field workers who can use various types of information.
Private	Hansol Academy	Beginner course	• Design process education using Revit Architecture. • Practice-based BIM data construction using site, building and other design components.
		Manager course	• Learning the concept of parametric for building and using BIM data of the design phase. • Learning to examine and utilize drawings and quantity. • Learning to examine design and engineering. • Visualization, interference, process simulation, and working process.
		BIM expert 2nd grade certificate course	• Intended for testing the competency of entry-level workers in architectural engineering. • BIM Model review, collaboration, and documentation. • Step-by-step practice of UI of Revit and Navisworks.

BIM license. Thus, their curriculums are made up of basic modeling skills and application capabilities that are often alien to real BIM projects. Furthermore, almost all the organizations and lecturers concerned do not have an academic background, coming instead from business and practice, so it is unreasonable to expect a high level of theory education from them.

Collectively, the results of the education cases suggest that all of the curriculums managed by public and private institutions have relevant contents that serve their own goals, objectives, and lecturer levels, with no single organization providing a balanced curriculum that provides satisfactory coverage of both BIM theories and practical skills. Therefore, students who complete these courses are likely to be disappointed by their limited BIM competency, and even when they succeed in getting a job, the companies that employ them will need to devote additional resources to re-educate them to work with BIM applications.

In order to identify the general requirements expected by construction companies regarding the BIM knowledge and skills of students who have completed a construction program, interviews with eight BIM directors or engineers working for different companies were conducted between 2nd April to 6th April, 2018. The companies that participated in the interview were located in Jongno-gu, Seoul (A, B, C, and F); Bundang-gu, Seongnam (D); Yeongsu-gu, Incheon (E); Jung-gu, Seoul (G); and Seocho-gu, Seoul (H). The interviews were semi-structured, and consisted of questions regarding the current status of the companies' BIM implementations, the main BIM subjects in their construction education programs, and the basic knowledge and

Table 2. Company BIM status, implementation, and expectations regarding BIM knowledge and skills of construction graduates (information provided in interviews conducted from 2nd to 6th April, 2018)

Company	A	B	C	D	E	F	G	H	%
Existence of BIM team	x	x	x	x	x	x	-	x	87.5
BIM implementation areas									
1. Design (drawings) quality control using model authoring.	x	x	x	x	x	x	x	x	100
2. Site logistics: site utilization planning.	x	x	x	x	x	x	–	x	87.5
3. 3D Visualization-based communication.	x	x	x	x	x	x	x	x	100
4. Construction system design.	–	x	x	x	x	x	–	x	75.0
5. Scheduling and sequencing planning.	x	x	x	x	x	x	x	x	100
6. Constructability review, Virtual mock-ups, and prototypes.	x	x	x	x	x	x	x	x	100
7. Interference management: spatial trade coordination, MEP, and structural coordination.	x	x	x	x	x	x	x	x	100
8. BIM based safety management (large equipment utilization simulation and temporary work related with safety, etc.).	–	x	x	x	–	x	–	–	50.0
9. Laser scanning for quality control and feedback.	–	x	x	x	–	–	–	x	50.0
10. Energy simulation	–	–	–	x	x	–	–	–	25.0
11. Facility management	–	–	–	x	–	–	–	x	25.0
12. Model-based estimating	–	x	x	x	–	–	–	x	50.0
13. Shop drawings and material procurement	x	x	x	x	x	x	–	x	87.5
14. BIM for field management	–	–	–	x	–	x	–	–	25.0
15. Integrated project delivery system	–	–	–	x	–	–	–	–	12.5
16. Marketing	-	x	-	x	-	-	-	x	37.5
Knowledge and skills required of construction graduates									
1. General concepts and knowledge of BIM technology	x	x	x	x	x	x	x	x	100
2. Relationship between general contractors and other stakeholders (owner, subcontractors, designer, etc.).	x	x	x	x	x	x	–	–	75.0
3. Importance of BIM implementation in construction management.	x	x	x	x	x	x	x	x	100
4. BIM project execution planning and BIM standards.	–	–	–	x	–	x	–	–	25.0
5. Areas of implementation in the construction processes, including visualization, communication, clash detection, and constructability review.	x	x	x	x	x	x	x	x	100
6. Potential integration between BIM and quantity takeoff, cost estimating, scheduling, and material procurement.	x	x	x	x	x	x	x	x	100
7. Application of BIM in property and facility management.	–	–	–	x	–	–	–	–	12.5
8. Future development and potential of BIM in construction including IPD, energy simulation, and sustainability.	–	x	–	x	x	–	–	–	37.5
BIM software									
1. Revit Architecture and MEP	x	x	–	x	–	–	x	x	62.5
2. Navisworks	x	x	x	x	x	x	x	x	100
3. Google SketchUp	–	–	–	–	x	–	–	–	12.5
BIM knowledge and job search									
1. Requisite skill-sets		x		x	x				37.5
2. Preferable needed skill-sets	x		x			x	x	x	62.5
3. No impact/unrequired skill-sets									0.0

Company "G" has no BIM team, but 2 BIM experts are employed in their organization.

skills they expected of job applicants (Table 2). Interviewee responses showed that all the companies actively utilize BIM as an important tool for design (drawing), quality control using model authoring, site utilization planning, 3D visualization-based communication, construction system design, scheduling and sequencing planning, constructability review, interference management for MEP (mechanical, electrical, and plumbing) and structural coordination shop drawings, and material procurement. However, BIM-based safety management, laser scanning for quality control and feedback, energy simulation, facility management, model-based estimating, BIM in the field, and integrated project delivery systems and marketing were areas where they did not implement BIM or did

Table 3. Important areas of BIM-related tasks according to participating construction companies (information provided in interviews conducted from 9th to 13th April, 2018)

BIM-related tasks	Minimum	Maximum	Mean	SD
Spatial trade coordination–MEP coordination	5	5	5.00	0.000
Visualization	4	5	4.75	0.463
Communication	3	5	4.63	0.744
Design quality control using model authoring	3	5	4.50	0.756
Constructability review	3	5	4.38	0.744
4D simulation-Scheduling and sequence planning	3	5	4.38	0.744
Shop drawing and materials procurement	3	5	4.00	0.756
Construction system design	2	5	3.88	0.991
Site logistics	2	5	3.75	1.035
Model-based estimating	2	5	3.63	1.061
Marketing	2	4	3.50	0.756
BIM in field management	1	5	3.38	1.408
BIM-based safety management	1	5	3.25	1.282
Facility management	1	5	2.75	1.389
Integrated project-delivery system	1	5	2.63	1.302
Laser scanning	1	4	2.25	1.282
Energy simulation	1	3	2.00	0.926

so only in a limited way. Most of the companies expected job applicants to have BIM knowledge and skills in the following subjects: general concepts and knowledge of BIM technology, the relationship between general contractors and other stakeholders, importance of BIM implementation in construction management, areas of implementation in various construction processes (including visualization, communication, clash detection, and constructability review), and potential integration between BIM and quantity takeoff, cost estimation, scheduling, and material procurement. Every respondent said that BIM-related knowledge and skills are preferred, but not compulsory.

This study also conducted a further survey from 9th April to 13th April, 2018 to measure the relative importance of BIM execution items considered important by construction companies, the BIM knowledge and skills of applicants, and the BIM software types required. Based on Oppenheim's approach and the analysis of the earlier unstructured interviews with BIM experts and engineers, the questionnaire was designed and disseminated to the BIM directors and engineers of ten additional construction companies through an online survey tool [36]. Data were collected in terms of a five-point Likert scale. The analysis revealed that the ten construction companies actively used BIM as an important instrument for spatial trade coordination, visualization, communication, design quality control, constructability review, 4D simulation, shop drawing and material procurement, construction system design, and site logistics (Table 3). However, they did not actively apply BIM to such areas as model-based estimating, marketing, BIM in field management, BIM-based safety management, facility management, integrated project-delivery system, laser scanning, and energy simulation. This is interesting, because BIM model based estimating is one of the most effective BIM items. To

Table 4. Importance of BIM knowledge and skills required for construction graduates

Knowledge and skills	Minimum	Maximum	Mean	SD
General concepts and knowledge of BIM technology	3	5	4.63	0.744
Areas of implementation in the construction processes—including visualization, communication, clash detection, and constructability review	2	5	4.50	1.069
Relationship between general contractors/construction management and other stakeholders	3	5	4.38	0.744
BIM project execution planning and BIM standards	2	5	4.25	1.035
Software compatibility	3	5	4.13	0.835
BIM software skills	3	5	3.75	0.707
BIM and sustainability integration	2	5	3.63	1.061
BIM for integrated project delivery	2	4	3.25	0.886
BIM for facility management	2	4	2.88	0.641

Table 5. Importance of BIM knowledge and skills required for construction graduates

BIM-related software	Minimum	Maximum	Mean	SD
Navisworks	3	5	4.50	0.756
Revit Architecture and MEP	2	5	4.25	1.035
Google SketchUp	3	5	4.13	0.835
Auto CAD	2	5	4.00	1.069
Archi CAD	2	5	3.63	0.744
Bentley System	1	5	3.38	0.744

extract the exact quantity of building materials required and the associated cost for real construction project, systems such as the Work Breakdown Structure (WBS), Cost Breakdown Structure (CBS) and Object Breakdown Structure (OBS) should be established beforehand. However, almost none of the construction companies in South Korea have either a cost breakdown structure or BIM-based estimating experts in their organization. Likewise, even though the remaining BIM items (marketing, field management, safety management, facility management, integrated project delivery system, laser scanning, and energy simulation) should be performed by experts who have specialized knowledge about both BIM and their own engineering field, few if any who meet this requirement are working in South Korea.

These results provided a valuable guide in organizing the content of the BIM course proposed in this study. BIM experts and engineers thought that job applicants should learn the following subjects during their construction programs: (1) general concepts and knowledge of BIM technology; (2) areas of implementation in the various construction processes (including visualization, communication, clash detection, and constructability review); (3) the relationship between general contractor/construction management and other stakeholders; (4) BIM project execution planning and BIM standards; and (5) software compatibility. However, they did not consider BIM software skills, BIM and sustainability integration, BIM and integrated project delivery, or BIM for property and facility management as essential (Table 4).

Another survey was performed to identify the importance of BIM software packages such as Navisworks, Revit Architecture and MEP, and Google Sketchup, all of which job applicants considered more important than ArchiCAD or the Bentley system (Table 5). Spatial trade coordination

Table 6. Characterization of the "BIM in Construction Management for Job Applicants" course

Course name	BIM in construction management for job applicants in developing countries
Target	Job applicants enrolled in a construction program in a developing country.
Prerequisites	University core curriculum completed. Fundamental construction courses required—i.e., construction means and methods, contracting, and building science; construction materials, building structure, building code; electrical and mechanical construction; construction planning, quantity take-off/cost estimation and scheduling; blueprint reading; information technology and so on. Upper-level course for junior or senior students
Course description	"BIM in Construction Management for Job Applicants in Developing Countries" aims to teach BIM to job applicants participating in construction programs with the aim of being employed by construction companies in developing countries. The curriculum of this course includes basic theory and application of BIM in real construction processes. More specifically, trainees learn visualization, quantity take-off, analysis, and other BIM skills. They also practice the examination of the interference between multiple work types—such as building-structure, structure-MEP, and MEP-MEP—and consider constructability by using 4D process simulation. More theoretical BIM implementation strategies are also taught. Such aspects of BIM knowledge and skills aim to improve the productivity of construction projects and help trainees understand collaboration strategies among diverse stakeholders.
Major constructs and considerations	A systematic approach to developing/designing the course was utilized, as follows: • Curriculum development theory; • Trends or needs in current construction education; and • Construction industry input. Process-based curriculum; i.e., activity-based learning (Tyler model) Case-based curriculum Learner-centered instruction Collaborative learning and continuous feedback

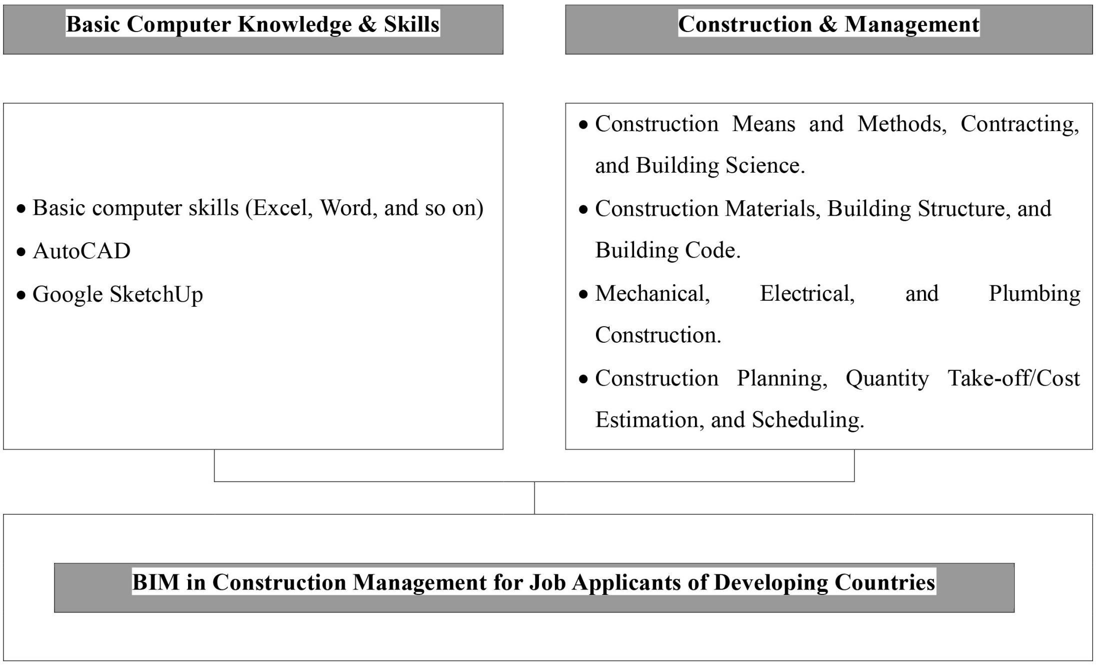

Fig. 1. Framework of the "BIM in Construction Management for Job Applicants of Developing Countries" course.

(clash detection) was identified as an essential area utilizing BIM. Navisworks provides the most effective method of merging multiple models into a single integrated project model for spatial trade coordination and clash detection. The package also serves as a tool for the review, analysis, simulation, and coordination of project information, making it one of the most important tools for communication between participants during the construction phase. Finally, Revit and Google Sketchup aid users with the 3D implementation of buildings and components (objects), and are also useful tools for visualization, communication, site logistics, and constructability review. In the preparation stage of developing the BIM course, a literature review was conducted to analyze the current status of BIM implementation in the construction industry, BIM education, and BIM-related courses provided in South Korean construction programs. Unstructured interviews with BIM experts and engineers were then carried out to identify the preferable BIM-related tasks in construction companies, as well as the BIM knowledge, skills, and software required by job applicants. The data thus collected were used to construct the goals, objectives, subjects, lecture types, and assessment contents of BIM education—as discussed in the following section.

2.2 Development stage of BIM course development: overview

The BIM course development stage consisted of five sub-steps. First, a basic framework was developed, including the outline and an introduction to the BIM course. Second, the goals and objectives were identified based on the BIM courses in higher and public/private education institutions, papers dealing with BIM and its applications in the construction industry, and data collected from the aforementioned surveys. Third, an appropriate learning topic was determined by considering the goals and objectives constructed in a systematic approach. Fourth, adequate instructional strategies and assessment plans were established from the pedagogical perspective. Here, the main focus was to match the learning topic with the learning objectives. Fifth, a course syllabus and a 16 week schedule were determined.

In the first sub-step of the development stage, the new course was defined (Table 6), and its framework (Fig. 1) developed by applying the aforementioned systematic course procedure. One of the existing studies defined the target job applicants and framework of the BIM course and presented the course description.

2.3 Development stage of BIM course development: Setting the learning goals

Goals inform the instructors about the desires of the applicants, while presenting the projected knowledge, skill, and behavioral milestones of the course to prospective students. Therefore, setting appropriate learning goals is an essential component in the systematic course development process [37]. The first step in developing a new course is identifying and reviewing the existing BIM-related courses provided by public/private education institutions

Table 7. Learning goals and objectives for the "BIM in Construction Management for Job Applicants in Developing Countries" course

Learning goals	Learning objectives	N	Type
General understanding of BIM knowledge and skills	Concept and basic theory of BIM.	1	Cognitive
	Understanding procurement system and processes of construction projects.	2	Cognitive
	Understanding the latest construction trends for BIM application.	3	Cognitive
	Necessity of BIM implementation in the construction industry.	4	Cognitive
	BIM-related theory and terminology:	5	Cognitive
	IPD, Lean Construction, and BIM;		
	BIM standards, LOD;		
	BIM Project Execution Plan (PxP);		
	Role, function, and availability of BIM Software.		
	History of computer-based modeling—including AutoCAD, 3D computer graphics, Revit, Navisworks, and Bentley—and trends in their application in projects	6	Cognitive
Understanding the application of BIM to construction project	Understanding the integration of IPD systems and lean construction in construction project.	7	Cognitive
	Importance of BIM for construction management.	8	Cognitive
	Understanding BIM implementation cases in the construction industry.	9	Cognitive
	Defining the roles of BIM for each participant of construction project.	10	Cognitive
	Cost-benefit analysis for applying BIM to construction project.	11	Cognitive
Understanding and practice of the application of BIM in construction processes	Comparative analysis between traditional construction processes and BIM-based processes.	12	Cognitive
	Learning BIM implementation areas in construction projects	13	Cognitive
	BIM Authoring skills: Revit, Google Sketchup;		
	Spatial trade coordination: clash detection and interference management;		
	Visualization-based communication;		
	Constructability review: Shop modeling, detailed 4D model, and virtual mock-up;		
	BIM based quantity take-off;		
	Scheduling and sequence planning;		
	Site logistics and material handling;		
	BIM based safety management;		
	Integration BIM model with 3D scanned data for quality management;		
	BIM for field management: field layout software and hardware/Vela/iPad/Cloud/ Bluebeam;		
	As-built and facility management; and		
	Marketing.		
	Importance of the collaboration system among workers on the basis of BIM-integrated modeling environment.	14	Cognitive
	Analysis and evaluation of BIM project execution plan (PxP) and contract system.	15	Affective
	Practice of BIM-based collaboration: team activity.	16	Cognitive
	Project communication and execution of collaboration strategy: role playing.	17	Affective
Practice of BIM software	Practice of BIM authoring tools—including AutoCAD, Revit, and Google Sketchup.	18	Psychomotor
	Integrated modeling of BIM models for each work type: Navisworks.	19	Psychomotor
	Examination of interference between work types and design quality: Navisworks.	20	Psychomotor
	Examination of 4D simulation and optimal process alternative: Navisworks.	21	Psychomotor
	Construction of a detailed shop model and examination of constructability: Navisworks.	22	Psychomotor
	Connecting schedule to and estimating software packages for BIM model: Vico office and Autodesk QTO.	23	Psychomotor
	Understanding and analysis of difficulty levels and difference among various BIM software packages like Revit, Navisworks, Autodesk QTO, Bentley, and Solibri.	24	Cognitive
Future of BIM and applicability	Understanding future trends of BIM technology in the construction industry: fusion with disruptive techniques such as 3D scan, deep learning, AI, augmented reality, etc.	25	Cognitive
	Understanding new opportunities for BIM, IPD, and lean construction.	26	Cognitive
	Understanding new opportunities for applying BIM to the field of sustainability, including facility management, energy modeling, and value engineering.	27	Cognitive
	Active participation in the construction industry by using BIM.	28	Affective

and higher education systems (Table 1). Information regarding BIM-related courses was found by consulting the website of the construction program at each education institute. Professors, lecturers, and others involved were then asked to send copies of the course syllabus. In this way, a comprehensive set of data that included course objectives was obtained (Table 1).

Once the learning goals for the course had been determined, BIM implementation cases from real construction companies and the expectations of the industry for the new BIM course were considered in order to realize the BIM knowledge and skills that would be acquired in the course at a level where they could be applied to real construction processes in a developing country. BIM areas were defined and graded in a manner that emphasized both construction and software (Tables 3–5) and the learning goals and objectives of the new course (Table 6) were developed based on a literature review, goals of BIM courses in construction programs, and the input data collected from industry experts. These learning goals and objectives were defined by applying a pedagogical background consisting of cognitive, affective, and psychomotor domains according to Bloom's taxonomy [38]. In table 7, three domains of pedagogical activities were organized based on this taxonomy and allocated to the appropriate learning goals and objectives [39], as follows:

1. Cognitive domain—i.e., mental skills (knowledge based);
2. Affective domain—i.e., growth in areas of feeling or attitude (emotion based); and
3. Psychomotor domain—i.e., manual or physical skills (action based).

2.4 Development stage for BIM course development: choosing learning topics

Once the learning topics had been determined, two major rules were applied as selection criteria: learning topics must (1) meet each objective defined by learning goals, and (2) be based on learner activities. Moreover, learning topics should consider and reflect career and topic criteria, as well as more social parameters such as knowledge, skill, value, and behavior [37]. After considering various factors, four learning topics comprised of 20 subtopics (Table 8) were identified. The learning topics were allocated in accordance with the learning goals and objectives defined above (Tables 9 and 10).

2.5 Development stage for BIM course development: organizing learning topics

The next stage involved identifying suitable learning content for the learning topics and presenting the course description and instruction strategies. The learning content was expected to:

- Cultivate competencies that directly or indirectly help applicants be assessed positively when seeking jobs.
- Be instantly applicable to duties in the construction company.

Table 8. Selection of learning topics for the "BIM in Construction Management for Job Applicants in Developing Countries" course

Learning topics	Subtopics	Related objective(s)
Background knowledge of BIM	Definition and significance of BIM	1, 3, 4, and 10
	Historical background of BIM and computer modeling	6, 18, and 19
	Terminology of BIM	5
	Practical approaches to BIM	7
	Issues and opportunities for BIM implementation	3 and 11
BIM in construction	Stakeholders and their roles in BIM	2, 3, and 8
	Collaboration among stakeholders	7 and 8
	BIM applications in construction projects	8, 12, and 13
	BIM standard and implementation plan	15
	Rationale and value of BIM in construction	10, 11, and 14
	Contemporary trend in BIM research and practices	9 and 10
	BIM software for construction	18–22 and 24
	Future trends for BIM and new opportunities in construction	9 and 25–27
Analytic assessment of BIM	Critical analysis of current BIM cases	13
	BIM analysis for construction process	14
	Analysis strategies for BIM	13 and 20–22
Implementation of BIM	BIM practices and process	9 and 13
	Case study related to BIM	9, 10, and 23
	Course projects using BIM	6, 9, 10, 23, and 24
	Internship or practicum field trip	3 and 28

Table 9. Organization of learning content, description, and instructional strategies

Learning content	Description	Instructional strategies
Class orientation	Introduction to syllabus Introduction to homework Group allocation for team activity Explanation about field trip and guest lecture	Instructor's lectures
Instructor's presentation on BIM	BIM issues in constrain GIM assessment BIM concept definition and trend Stakeholders of construction project and introduction of collaboration Value and opportunity of BIM Major causes of BIM issues Studies of BIM implementation in the construction industry and case study	Instructor's lectures Assignment 1 Group discussion 1 Group discussion 2 Assignment 2
Learning about BIM practices and processes	BIM-based project cases and processes BIM standard and the implementation plan in a real process Roles and responsibility of project stakeholders: BIM contract BIM-related issues and concerns in construction project process Areas of BIM application	Instructor's lectures Guest lectures Assignment 3 Assignment 4 Group discussion 3
Learning BIM software–visualization tool	Google Sketchup Revit Navisworks Introduction of ArchiCAD, Autodesk QTO, Bentley, Solibri, and so on.	Instructor's lectures Guest lecture Assignment 4 Assignment 5 Assignment 6
BIM implementation case study	Building element analysis of BIM based on project cases BIM issues in the building production process Development of alternative solutions and pronouncement	Instructor's lecture Guest lectures Group project report Group work and presentation Peer evaluation
Field trip and/or guest lectures	Analysis of BIM implementation cases in construction company BIM application cases and processes in construction projects BIM-related issues and concerns in the construction industry	Guest lectures Group discussion 4 Assignment 7 Field trip report
Future directions of BIM use	BIM application strategy in future construction projects IPD (integrated project delivery) system and lean construction	Assignment 8 Group discussion 5

- Directly reflect BIM applications, trends, and skills in developing countries.
- Directly related to learning goals and objectives.
- Be allocated sufficient time in each lecture to ensure a good balance between theory and practice.
- Provided to students at an appropriate level.
- Ensure every aspect of the educational content assumes prerequisite subjects that trainees from various higher education institutions or universities commonly complete, presenting no unnecessary obstacle to taking the course.

The content of the proposed course has been organized based on various sources, including the curricula of the existing courses, programs, national professionals, major regulatory organizations (AGC, ASC, ASCE, etc.); university textbooks and BIM lecture materials; the content of public/private BIM education institution courses; BIM-related papers; and real world cases of BIM implementation from construction companies. This stage of course development included the appropriate allocation of lecture time to each aspect of the content, as well as presenting the learning sequence in a logical way, allowing trainees to develop their skills as they proceed through the course. The most important strategies and methods are the presentation of lectures, student presentations, trainees' independent study, case surveys, team tasks, field trips, and assignments, as well as individual and team reports (Table 9). The lecturer should provide assignments in each lecture to help students gain an overview of BIM and establish basic BIM-related knowledge. This course has been designed around learner-directed

Table 10. Assessment content for the "BIM in Construction Management for Job Applicants in Developing Countries" course

	Assessment content	Percentage
Assignments	Summarizing practical BIM definitions. Reviewing different journal articles related to BIM implementation in the construction industry. Summarizing BIM practices and process. Developing, modifying, and updating BIM models with Google Sketchup, Revit, and Navisworks. Developing a field trip report. Describing future directions for BIM.	50
Presentations	Group presentations on approaches to implementing BIM analysis and identifying issues in actual BIM models. Group presentations on possible solutions and recommendations for construction operations.	15
Group project reports	Establish a "design BIM model". Spatial coordination and clash detection. Extract visualization model. Documentation practice using BIM data. Edit "design BIM model" to "construction BIM model". Quantity take-off and estimating using BIM data. Establish 4D simulation model for schedule management. As-built model for facility management.	30
Participation	In-class activities and a field trip. Group discussion.	5

lectures, cooperation in team discussions, reports, and presentations.

2.6 Development stage for BIM course development: assessment

Student assessments should consider and reflect their prearranged output as well as ensuring that students have acquired the output in various forms, namely knowledge, skills, and behavioral patterns, so the lecture content must include such forms [37]. Table 10 summarizes the assessment plan for the course. The crucial goals of this assessment are to check whether students have satisfied the minimum set of performance criteria, and identify those who have achieved a higher level of performance.

2.7 Assessment and improvement stage for course development

The proposed BIM course has been constructed using a logical and systematic course development approach. However, the curriculum development itself requires continuous attention to identify and integrate new, advanced, and more efficient methods [40, 41]. Since the proposed BIM course is intended for developing countries that have not yet introduced BIM or are still in the initial stages of implementation, the experience of South Korean instructors or practitioners will be valuable for assessing and improving the application of BIM in these countries. As such, the proposed course was evaluated by and improved according to the advice of an expert group of BIM practitioners. This group consisted of two professors, two instructors from public/private education institutions, and four construction company employees. All these practitioners had experience in training or implementing BIM, and provided very useful information and comments for the new course (Tables 11 and 12).

A draft of the proposed BIM course and the assessment sheet were sent to the expert group. In order to obtain a comprehensive assessment of the course plan, the experts were encouraged to provide descriptive and analytical comments. The assessment items were as follows: the overall framework of the new course, learning goals and objectives, learning topics, instructional strategies, and assessment standards and schedule.

Based on the comments and suggestions obtained, which are listed in Table 12, the draft model of the course plan for "BIM in Construction Management for Job Applicants in Developing Countries" was revised and improved. One of the most important suggestions was that trainees should gain experience with multiple BIM software packages (including ArchiCAD, Autodesk QTO, Bentley, and Solibri) during the course. An interesting point regarding the inclusion of Google Sketchup emerged. Two professors had a negative opinion, claiming that too much emphasis was placed on this software package, while one lecturer and two practitioners recommended its active implementation due to its good visualization performance, regardless of the fact that technically it is not a BIM program. Another suggested that lean construction and IPD (integrated project delivery) be added to the curriculum in relation to BIM.

Table 11. Experience of BIM experts in academia and the construction industry

Field	Expert		Experience (years)	Position
Academia	Universities	Expert A	10 years	Associate professor
		Expert B	20 years	Professor
	Educational institutes	Expert C	9 years	Instructor
		Expert D	4 years	Instructor
Industry	Expert E		10 years	BIM manager
	Expert F		12 years	BIM manager
	Expert G		15 years	Chief manager
	Expert H		5 years	Assistant manager

Table 12. Input for improving the new "BIM in Construction Management for Job Applicants in Developing Countries" course from BIM experts

Expert	Comments
Expert A (Professor)	Introduce the concept of lean construction and IPD. Theory-centered BIM course is not recommended. Add more cases of industry and practical application techniques to the curriculum. Add necessary knowledge and skills for learning capstone subjects. Add the terms of interoperability or data exchange.
Expert B (Professor)	Introduce other software, including ArchiCAD, Autodesk QTO, Bentley, and Solibri. Do not place as much emphasis on the use of Google Sketchup. Develop BIM practice class based on simple cases of real projects. Explain energy simulation at the different stages of design development and the importance of energy simulation if there is value engineering. Develop affiliated BIM course for each semester/year, not an independent one-semester course.
Expert C (Instructor)	Introduce how BIM can implement applications such as estimating, quantity takeoff, scheduling, clash detection, and so on. Add a team project to set up a BIM execution plan. While Google Sketchup is not officially BIM software, it should be taught because it is a useful visualization tool.
Expert D (Instructor)	Develop BIM use and add curricula for each country. Reorganize the list of content based on the lifecycle of a structure, from preconstruction to operation and maintenance. Add a few additional guest lecturers to cover the content of the course.
Expert E (BIM Manager)	Add a lecture on BIM use and strategy for each type of construction project (building type) to the curriculum. More segmented lectures on BIM that reflect different roles of participants in construction projects.
Expert F (Serveone)	While Google Sketchup is not recognized as BIM software, it is necessary to teach it because of its use as a visualization tool. The maintenance BIM and its use for each building type needs to be further segmented. Emphasize Revit/Navisworks and similar systems for coordination and design review.
Expert G (Posco A&C)	Classify BIM use techniques for production types of project (modular, prefabrication, off-site, etc.). Emphasize Revit/Navisworks and similar systems for coordination and design review.
Expert H (Maidas)	Recommend a joint BIM course between faculty and BIM experts in the construction industry. Add techniques of structure modeling based on list and methodology of structural analysis to curriculum.

The input data included the comments and suggestions obtained during the improvement phase of the course development stage, which were of great help in improving the draft curriculum for the course. For example, the use of software packages such as ArchiCAD, Autodesk QTO, Bentley, and Solibri has been added to the curriculum. The learning contents—entitled "Future directions of BIM use"—were also expanded to include a group discussion regarding lean construction and IPD, further improving the syllabus. In response to the comment warning against an excessive emphasis on BIM theory, and the suggested addition of real cases from the construction industry and practical BIM techniques, we added a BIM standard and implementation plan that involve real processes to the learning contents, entitled "Learning about BIM practices and processes." This additional content was allotted to a guest lecturer in order to provide an opportunity to invite expert practitioners from the industry into the classroom.

3. Discussion

In order to develop this proposed BIM curriculum for implementation in the education systems in developing countries, systematic and step by step course development logic was applied, and the BIM education content and topics derived from case analyses of existing BIM courses at universities and public and private educational institutions. Interviews with BIM experts and construction managers working at construction companies contributed valuable information regarding the practical needs of construction industry and establishing a BIM skills list which can be applied to real construction projects. Based on these inputs, a detailed syllabus and set of assessment criteria were developed and assessed by BIM experts working in academia and industry. After conducting a thorough assessment of the proposed course's Learning Goals and Objectives, Learning Topics, Learning Contents, and Assessment Contents, the course was modified to include several elements they considered important. As a result, the final version of the proposed BIM course provides a balanced curriculum that deals comprehensively with the theories and practices of BIM application.

The new BIM course can be undertaken by both undergraduate students and job applicants who have already finished college. Any undergraduate students who have completed the prerequisite subjects can be enrolled in this course in the first semester of their third year. They will learn basic features of the construction industry, the importance of collaboration among stakeholders, as well as BIM-related knowledge and the skills used in construction projects and management. Accordingly, this course will help students acquire more comprehensive and technical knowledge related to other subjects in construction programs. On the basis of various subjects already learned, graduate job applicants will learn BIM-related knowledge and skills that are actually utilized in the industry, thereby becoming BIM-competent applicants that companies wish to employ.

The proposed BIM course thus helps job applicants become more familiar with BIM and gain an understanding of how BIM technology is implemented in real world construction projects. Moreover, the course provides job applicants with a basic background from which to prepare their future careers as construction managers. Finally, the proposed BIM course helps job applicants obtain both knowledge- and technique-related skills by providing a well-balanced education that integrates theory, practice, knowledge, and skills.

4. Conclusions

The purpose of this study was to develop a new training course—"BIM in Construction Management for Job Applicants in Developing Countries"—to equip construction company job applicants in developing countries with the BIM-related knowledge and skills that they need to satisfy the needs of the industry. To achieve this goal, this study adopted a systematic approach based on Tyler's model. The course developed was based on cases from South Korea, which has already experienced the early stage of introducing BIM, in order to apply it to the education curricula of developing countries that have not yet introduced BIM technology or are only in the initial stage of doing so. In addition to confirming the importance of BIM-related education for construction programs, the preparation stage involved analyzing the current status of BIM-related courses of higher education or private/public education institutions, methods for implementing BIM in real construction projects, and industry expectations regarding the BIM competence of job applicants. Based on the needs for BIM education thus identified, the course was developed by following a systematic course development process that included developing a detailed description of a comprehensive course syllabus and course content.

The major contribution of this study is that it provides a logical guide for construction education programs and instructors seeking to develop a BIM course for a construction curriculum in a developing country. Construction and engineering educators can apply our proposed "BIM in Construction Management for Job Applicants in Developing Countries" based on sound pedagogical principles (described above) to their own education curriculum, as well as teach job applicants the latest technology such as BIM, IPD, and lean construction. Moreover, the proposed course provides a general framework that is applicable to the context of conventional construction programs as it is based on, and can thus utilize, the course content already provided in construction programs in the US, Europe, and South Korea. The BIM course proposed here is an independent education program, and has proven to be a very effective method of integrating BIM into the curricula of construction programs.

However, this course is not the only option when educating job applicants about BIM. There are a wide range of laws/legal systems, cultures, construction industry features, educational environments, and needs of companies in developing countries. Accordingly, further study is needed to develop customized solutions for integrating BIM into the construction curricula of each country.

Also the follow-up study should be performed to assess the proposed course quantitatively, so the authors are preparing to include this new BIM course in our next lecture schedule at Hanyang University. By applying the proposed BIM curriculum in our classrooms, we expect that the BIM course will be standardized and reinforced based on the experiences and needs of the students who participate in the class.

Acknowledgements—This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT & Future Planning (No. 2015R1A5A1037548).

References

1. J. S. Lee and J. J. Kim, BIM-Based 4D Simulation to Improve Module Manufacturing Productivity for Sustainable Building Projects, *Sustainability*, **9**(3), 2017, p. 426.
2. R. Sacks, C. M. Eastman and G. Lee, Parametric 3D modeling in building construction with examples from precast concrete, *Automat. Constr*., **13**(3), 2004, pp. 291–312.
3. C. M. Eastman, P. Teicholz, R. Sacks and K. Liston, BIM handbook: A guide to building information modeling for owners, managers, architects, engineers, contractors, and fabricators, *Wiley*, Hoboken, NJ, 2008.
4. Y. H. Ahn, C. S. Cho and N. H. Lee, Building Information Modeling: Systematic course development for undergraduate construction students, *J. Prof. Issues Eng. Educ. Pract*., **149**(4), 2013, pp. 290–300.
5. Associated General Contractors of America (AGC), The contractors' guide to BIM, Arlington, VA., 2005.
6. S. Azhar, Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry, *Leadership Manage. Eng*., **11**(3), 2011, pp. 241–252.
7. S. Azhar, M. Hein and B. Sketo, Building information modeling (BIM): Benefits, risks and challenges, *Proc., Annual Conf. of the Associated Schools of Construction*, Windsor, CO, 2008, pp. 1–11.
8. K. Barlish and K. Sullivan, How to measure the benefits of BIM–A case study approach, *Automat. Constr*., **24**(1), 2012, pp. 149–159.
9. Cooperative Research Center for Construction Innovation, Adopting BIM for facilities management: Solutions for managing the Sydney Opera House, Brisbane, Australia, 2007.
10. N. Gu and K. London, Understanding and facilitating BIM adoption in the AEC industry, *Automat. Constr.*, **19**(8), 2010, pp. 988–999.
11. M. F. Hergunsel, Benefits of building information modeling for construction managers, *M.S. thesis, Worcester Polytechnic Institute*, Worcester, MA., 2011.
12. H. J. Wang, J. P. Zhang, K. W. Chau and M. Anson, 4D dynamic management for construction planning and resource utilization, *Automat. Constr*., **13**(5), 2004, pp. 575–589.
13. Autodesk White Paper, Improving building industry results through integrated project delivery and building information modeling, https://damassets.autodesk.net/content/dam/autodesk/files/bim_and_ipd_whitepaper.pdf, 2008 (March. 14, 2018).
14. D. C. Kent and B. Becerik-Gerber, Understanding construction industry experience and attitudes toward integrated project delivery, *J. Constr. Eng. Manage*., 10.1061/(ASCE)CO.1943-7862.0000188, 2010, pp. 815–825.
15. R. Sacks and R. Barak, Teaching building information modeling as an integral part of freshman year civil engineering education, *J. Prof. Issues Eng. Educ. Pract*., 10.1061/(ASCE)EI.1943-5541.0000003, 2010, pp. 30–38.
16. K. A. Wong, K. F. Wong and A. Nadeem, Building information modelling for tertiary construction education in Hong Kong, *J. Inform. Technol. Constr*., **16**(1), 2011, pp. 467–476.
17. B. Becerik-Gerber, D. J. Gerber and K. Ku, The pace of technological innovation in architectural, engineering, and construction education: Integrating recent trends into the curricula, *J. Inform. Technol. Constr*., **16**(1), 2011, pp. 411–431.
18. B. Baiden, A. Price and A. Dainty, The extent of team integration within construction projects, *Int. J. Project Manage.*, **24**(1), 2006, pp. 13–23.
19. K. F. Chien, Z. H. Wu and S. C. Huang, Identifying and assessing critical risk factors for BIM projects: empirical study, *Autom. Constr.*, **45**(1), 2014, pp. 1–15.
20. S. Lee, J. Yu and D. Jeong, BIM acceptance model in construction organizations, *J. Manage. Eng*., 10.1061/(ASCE)ME.1943-5479.0000252, 2015, p. 04014048.
21. A. Z. Sampaio, The Introduction of the BIM Concept in Civil Engineering Curriculum, *Int. J. Engineering Education*, **31**(1B), 2015, pp. 302–315.
22. 22. B. Ozorhon and U. Karahan, Critical Success Factors of Building Information Modeling Implementation, *J. Manage. Eng*., **33**(3), 2017, p. 04016054
23. C. Cook, Scaling the building information mountain, *AEC Mag*., **17**(3), 2004.
24. N. W. Young, S. A. Jones and H. M. Bernstein, Building information modeling (BIM): Transforming design and construction to achieve greater industry productivity, McGraw-Hill, New York, 2008.
25. W. Wu and R. R. A. Issa, BIM Education and Recruiting: Survey-Based Comparative Analysis of Issues, Perceptions, and Collaboration Opportunities, *J. Prof. Issues Eng. Educ. Pract*., **140**(2), 2014, p. 04013014
26. McGraw Hill Construction, The business value of BIM for Construction in Major Global Markets: How Contractors around the World are Driving Innovation with Building Information Modeling, *McGraw-Hill*, New York, 2014.
27. J. Goedert, Y. Cho, M. Subramaniam, H. Guo and L. Xiao, A framework for virtual interactive construction education (vice), *Autom. Constr*., **20**(1), 2011, pp. 76–87.
28. S. Kubicki and C. Boton, 4D-based teaching of high-rise structural principles, *Proc., CIB W078 2011 Int. Conf.*, International Council for Research and Innovation in Building and Construction, Delft, Netherlands, 2011.
29. C. Clevenger, S. Glick and C. L. del Puerto, Interoperable learning leveraging building information modeling (BIM) in construction education, *Int. J. Constr. Educ. Res*., **8**(2), 2012, pp. 101–118.
30. O. LóPez-Zaldívar, A. Verdú-VáZquez, T. Gil-López and R. V. Lozano-Diez, The Implementation of Building Information Modeling Technology in University Teaching: The Case of the Polytechnic University of Madrid, *Int. J. Engineering Education*, **33**(2A), 2017, pp. 712–722.
31. J. Zhang, H. Li and H. Xie, Exploring the Cognitive Structure and Quality Elements: Building Information Modeling Education in Civil Engineering and Management, *Int. J. Engineering Education*, **32**(4), 2016, pp. 1679–1690.
32. J. Zhang, H. Xie and H. Li, Competency-Based Knowledge Integration of BIM Capstone in Construction Engineering and Management Education, *Int. J. Engineering Education*, **33**(6B), 2017, pp. 2020–2032.
33. R. W. Tyler, Basic principles of curriculum and instruction, *University of Chicago Press*, Chicago, 1949.
34. G. O'Neill, Overview of curriculum models, https://www.ucd.ie/t4cms/UCDTLP00631.pdf, 2010 (March. 18, 2018).
35. M. Neary, Curriculum concepts and research, *Nelson Thornes*, Cheltenham, UK, 2003.
36. A. N. Oppenheim, Questionnaire design, interviewing and attitude measurement, *Continuum International*, New York, 2000.
37. J. McKimm, Curriculum design and development, https://faculty.londondeanery.ac.uk/e-learning/setting-learning-

objectives/Curriculum_design_and_development.pdf, 2007 (March. 11, 2018).
38. B. S. Bloom and R. K. David, Taxonomy of education objectives: The classification of education goals, *Longmans*, New York, 1956.
39. B. S. Bloom, Taxonomy of educational objectives, *Pearson*, Boston, 1984.
40. Y. H. Ahn, A. R. Pearce, H. S. Kwon and J. Wells, The systematic course development process: Building a course in sustainable construction for students in the U.S.A., *J. Green Build.*, **4**(1), 2009, pp. 169–182.
41. P. F. Oliva, Developing the curriculum, *Little, Brown and Company*, Boston, 1982.

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