

Article

Development of a Project-Based Online Course for BIM Learning

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Abstract: The purpose of this paper was to present a method for developing a project-based online course for building information modeling (BIM) learning. As the development of BIM has gradually increased its influence on the architecture, engineering, and construction (AEC) industries, countries around the world have begun to focus on BIM education and import it into university courses. However, there have been many studies pointing out several problems with the BIM education curriculum. For example, BIM education should not be limited to modeling work, and students do not exactly know the entire BIM workflow. Therefore, this research proposed a project-based online course development method for solving BIM educational issues. The proposed method contains a course development process and guidelines for designing the course. As an example implementation, a five-week Autodesk Revit learning curriculum was developed. Such a curriculum was then utilized in a 32 student class for testing its effectiveness. The results showed that students could understand the BIM process more effectively through the designed project-based course. Additionally, with online video tutorials, students are free to allocate their study time based on their personal needs and adjust their learning progress for better understanding of the course contents.

Keywords: BIM education; project-based course; BIM curriculum; online video tutorial

1. Introduction

The rapid development of information technology (IT) has forced civil engineers to continuously make advances in design methodologies. The advent of building information modeling (BIM) has affected the development of the architecture, engineering, and construction (AEC) industry and traditional 2D drawings have gradually been replaced by 3D models. These changes have created challenges for educators and students, as these changes require a flexible curriculum. Traditional civil engineering courses must incorporate some changes to adapt to current technological trends. At present, some universities around the world have begun to focus on BIM education, including combining BIM with different courses, combining BIM with competitions, or setting up online courses for BIM learning. In other words, the entire BIM process requires the collaboration of experts from a variety of fields. It is important to effectively integrate different areas of expertise into the BIM curriculum.

For BIM education, some studies in the past have pointed out that some course design is not efficient for students to learn BIM. For example, each student has different abilities to absorb the course knowledge and someone may have to spend more time thinking in three-dimensional operations. These reasons may cause a gap in learning outcomes. In addition, BIM makes a reliable digital representation of the building equipment, which is available for facility management, collision checks, cost estimation, material calculations, and facility management. Each component stores important information at different stages and can be applied to energy analysis, stress analysis, and even regulatory review.

Therefore, BIM training should not be limited to the application of tools. It should be regarded as the workflow needed to cultivate BIM-ready graduates in the AEC industry. In recent years, many studies have focused on BIM education. These studies include analyses of the ways in which BIM is learned in different countries around the world, of how students learn BIM efficiently, and of how distance learning or project-based methods can be used to learn BIM. The following subsection will provide a review of BIM technology, the challenges in BIM education, and the state-of-the-art teaching method for BIM education.

1.1. BIM Is More Than Drawing

For today's students, standard BIM is not unfamiliar. Most students have encountered virtual 3D models. Creating and working with a 3D model is very simple and intuitive, and students can master these practices in a few hours [1]. Building information modeling is often considered a modeling tool; however, BIM is an intelligent 3D model-based process for the life cycle of buildings. Furthermore, it is not just a simple 3D model process; it can be used to simulate every aspect of a design's performance [2]. Abbas et al. [3] pointed out that most universities are unaware of the importance of BIM applications and educational strategies. In Pakistan, some enterprises have begun to teach or discuss BIM. However, the current state of BIM education in the AEC industry still requires significant improvement. Macdonald [4] considered that BIM education is not just learning new software, but also learning a new way of working. It is a method that requires collaboration. Huang [5] considered that there are various strategies for introducing BIM. There are still many challenges in the AEC industry or in academia. Previous studies have shown that in the United States, most of the BIM courses offered in many construction management (CM) programs focus on modeling skills and the application of BIM in scheduling and estimation. While these topics appear to be important in the application of BIM, students will not be able to fully understand the BIM process in a construction project without comprehending the fundamental BIM workflow [6]. López-Zaldívar et al. [7] found that the undergraduate students of the Polytechnic University of Madrid encountered several difficulties in BIM education, including the absence of regulations and the lack of development of standard protocols of action. This affected students who are highly interested in learning BIM. Building information modeling education should not be limited to the teaching of how to use BIM applications; rather it should focus on increasing BIM concepts and technologies. The BIM model contains a lot of important information, so all users must know how to handle this data and how to use the incorporated information.

1.2. Changes in BIM Education Are Happening

To enable students to effectively understand the entire BIM process and building cycle in the BIM course, countries around the world have begun to have different teaching methods. Yong et al. [8] mainly contributed to the development of BIM courses and introduced a curriculum that uses a systematic approach with the method consisting of three phases: (1) preparation, (2) development, and (3) improvement. Pikas et al. [9] provided several recommendations for BIM education after analysis of several case studies. These recommendations include the need for continuity in BIM education and the learning benefits of BIM visualization, and they point out that students believe that combining BIM courses with real-life cases can improve their understanding of BIM programs. Tsai [10] applied a peer-review system for the instruction of building information modeling. The system contains guidelines for the instructor to develop the course for the learner to learn and grade others' work. Clevenger et al. [11] introduced three BIM-based cross-curricular education modules that integrate BIM technology into architectural engineering-related education. Forsythe et al. [12] reported a program-wide implementation strategy for the development of teaching supported by BIM at the University of Technology Sydney (UTS) and pointed out that BIM is a model-driven approach. The core principle of the strategy is the promotion of a more integrated teaching model and the linking of different individual subjects. An initiation named "OpeBIM" is being implemented at Helsinki

Metropolia University of Applied Sciences. They plan to revise programs and courses and use BIM to connect existing courses and collaborative learning between different disciplines. In addition, to solve the local industrial development of BIM, the University of Auckland not only plans to offer undergraduate and postgraduate BIM courses but also actively participates in the BIM education department in New Zealand and gradually designs and implements different BIM-related courses [13]. Vilnius Gediminas Technical University (VGTU) and Kaunas University of Technology (KTU), the largest universities of science and technology in Lithuania, combine BIM education in their courses. The VGTU focuses on postgraduate education and KTU focuses on undergraduates. The aim of this master's education is not only to train specialists but also to create and develop standards to guide and coordinate BIM drafting [14]. Lewis et al. [15] described a learning method for BIM energy modeling. The development and implementation of the Revit-based energy modeling (EM) teaching module were designed to familiarize engineering and building students with the process of energy modeling. Building information modeling education is changing, and there have been many cases where countries have begun to focus on BIM education. Educators are trying to develop relevant curriculum strategies and are eager to cultivate BIM professionals.

1.3. State-of-the-Art Teaching Approaches

To fill the gap between the traditional education approach and the newly developed technology, many new teaching methods were developed over the years. Among the new methods, online video tutorials and project-based learning methods are widely utilized nowadays. Video-based learning (VBL) emphasizes active learning as the main learning mode, and learners are free to arrange lessons when they want to learn. Through online videos, knowledge can be presented in many creative ways so that students can truly master the course. The educational quality of the video can be better than human teachers in ensuring consistency. Teachers may be influenced by emotions or the environment while online courses can ensure their video is of high quality before being released. Online video teaching and project-based learning (PBL) each have many advantages. If these methods can be effectively applied in the BIM course, great benefits will be observed. Project-based learning has proven to be an effective learning method that is student-centered and focuses on real-world issues. Project-based learning combines learning with major tasks or issues to engage learners in the problem. It emphasizes learning through complex, meaningful problem scenarios and solving problems through learner self-exploration and collaboration. This approach gives students the ability to learn actively, think critically, and solve problems.

1.3.1. Online Video Tutorials for Education

In recent years, various video-based learning tools have been developed, and many online learning platforms are growing rapidly. Giannakos [16] reviewed the status of and trends in video-based learning research over the past 12 years. Choi and Johnson [17] argue that video-based instruction is more memorable than traditional text teaching. Yousef et al. [18] analyzed the research on VBL published in 2003–2013 and explored the benefits and effectiveness of VBL for education. The Internet is a major technological advancement that has reshaped universities around the world and has been found to be a powerful tool for education. Additionally, the Internet and traditional classroom teaching methods are not mutually exclusive [19]. Distance education is a teaching delivery system that allows students to participate in educational opportunities without being limited by the space of the class. Internet and computer technology seem to have the ability to significantly change the educational landscape [20]. Using an online tutorial as a course has been found by many studies to have many advantages. In fact, through online courses, students can flexibly adjust the teacher's delivery speed and theme selection to match their personal learning speed and interest. Students can replay the course segments and stop the lectures while studying to make sure they understand the content. They can skip some of the topic segments that they have previously learned [21]. Yi et al. [22] analyzed the benefits of using a video course as a supplement to courses. The results show that online video tutorials are a

valuable and effective tool to improve student mastery of problem solving. Wong et al. [23] surveyed the satisfaction of the e-learning approach. The results show that students believe that e-learning methods are useful because they are free to control the speed, time, and location of learning. The design of online course videos affects viewers' learning. Guo et al. [24] analyzed four courses on a massive open online course (MOOC) platform with 6.9 million video viewing data. They found several factors that attracted students to watch videos, including informative talking-head videos, Khan-style tablet drawings, and short videos.

1.3.2. Project-Based BIM Learning

Project-based learning has been increasingly applied in construction and engineering curricula. Some studies have been performed on how to use a project-based approach for learning BIM. Prompt et al. [25] mentioned that for many teams using BIM, adopting BIM is a challenge. The main reason for this is that the individual's ability is insufficient, and through project-based learning this problem can be solved. Rahman et al. [26] pointed out that educational research shows that problem-based learning can help students solve common problems in BIM construction projects. At the same time, a structured process for developing BIM learning modules was proposed to enable educators to create effective problem-based learning modules. Using an ongoing campus project, students from two classes collaborated as groups and played distinct roles, as they would in a real project team. Project-based learning methods enhance students' learning ability and make students understand the knowledge needed for BIM implementation [27]. Another case study looked at learning BIM by implementing a tiny solar house project. This small solar home project offered students a good learning opportunity. Students received comprehensive knowledge of BIM from the inception of design to construction and eventually the occupancy and operation of the house [28]. In another study, teachers from two classes used an integrated approach to design a project focused on sustainable design and BIM. Students collaborated in teams to work on some tasks needed to accomplish predefined sustainable goals for a real building project. Students' critical thinking and problem-solving skills are confirmed to be effectively influenced by project-based learning [29]. Zhang et al. [30] proposed a BIM project execution plan (BIMPEP) process framework for integrating project-based learning and real-world project information. Leite [31] introduced a method based on project learning. This method has been successfully improved and is now welcomed by students. Combining these cases, experiential and project-based learning seems to be a promising option for BIM education. The project-based approach helps students understand the entire BIM cycle.

1.4. Scientific Gap in BIM Educations

Differing from traditional blackboard teaching, teaching methods based on either projects or online videos have been proven by many studies to be an effective learning method. However, teaching methods that combine these two approaches are not common. Therefore, this research aims to develop a new BIM course by combining the two teaching methods' advantages for filling the gap between new technology and the conventional teaching method.

2. Research Objectives

This research aimed to develop an effective BIM learning course by combining online video tutorials and project-based learning (PBL). Currently, implementing BIM technology into construction projects has become common. However, since learning BIM tools require significant hands-on practice and practical experiences, the challenge of helping students learn BIM tools and cultivate BIM experiences before entering the industry still remains unsolved. Therefore, this research proposes a BIM tool learning method which allows students to learn basic modeling skills as well as understand the entire BIM process of a construction project. This study developed a complete course design workflow. The workflow included how to set-up the learning target according to the students' background, how to pick a real construction project, how to arrange the course schedule within a limited period, and how

to prepare appropriate course materials. Additionally, this research provides detailed guidelines for each process in the workflow. By providing the workflow with guidelines, the instructor is expected to be able to develop a BIM learning course that allows students to learn BIM effectively.

3. Methodology

This study proposed a course design method for helping students learn BIM tools efficiently and effectively. Figure 1 illustrates the workflow of the proposed BIM course design method. Three major processes are included in the workflow: information review and project selection; course development and materials preparation; and course review and modification. At the beginning of the workflow, the instructor should review the background information of the enrolled students as well as the teaching target of the course. By doing so, the instructor can then define the learning scope and determine a real project for the course. After selecting an appropriate project, the instructor should set-up weekly milestones for the students and separate each milestone into subsections before preparing any course materials. Lastly, a course syllabus could then be generated. Before implementing the course, the instructor should go through the entire course to make sure the designed course fits the predefined learning scope. The following subsections will provide detailed descriptions for each process.

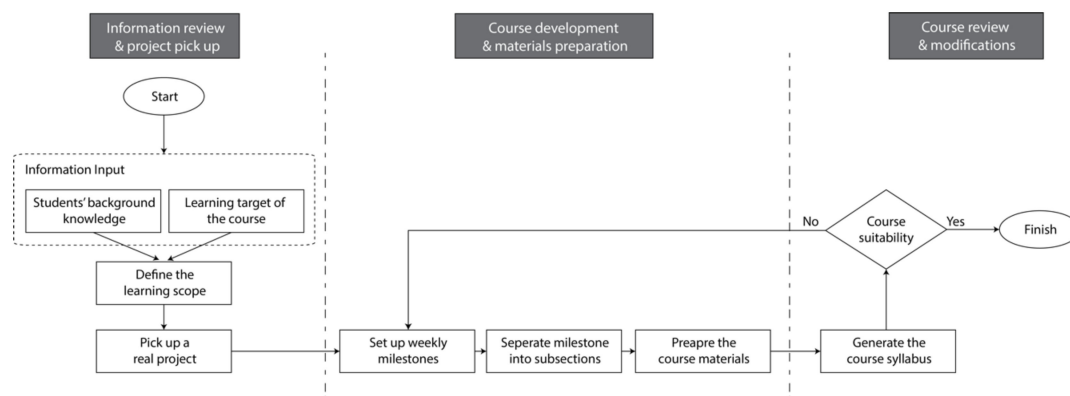


Figure 1. The course design workflow.

3.1. Information Review and Project Selection

In the first process, the instructor needs to define the learning scope and select a real project for the course. In this process, the instructor should gather the background knowledge of the students who will enroll in the course. The background knowledge of the enrolled students may have a significant influence on the learning scope of the course. For instance, if the students are all new to BIM and do not have any experience in using BIM tools, then the instructor needs to limit the learning scope to the basic operations of BIM and build simple 3D models that do not require skillful operation for project completion. Alternatively, if students have taken other basic BIM courses and have already gained some experience with BIM tools, then the instructor can focus on more challenging projects and does not need to cover all BIM operations in detail in the course.

Besides students' background knowledge information, the learning target of the course should also be taken into consideration in the first process. As a project-based course, selecting a suitable project can help students learn and gain experience, which is more practical. The instructor should select a different project, such as a building or bridge, or else a mechanical, electrical, or plumbing (MEP) system, according to the different learning targets. For instance, if the learning target is to use BIM in bridge structural design, then the instructor should select a real bridge construction project so that students can learn the detailed process during the course.

3.2. Course Development and Materials Preparation

The second process is to develop the course content based on the selected project and the learning scope. As shown in Figure 1, the instructor should first set-up the weekly milestones. The weekly milestones can help both the instructor and students to understand what they need to teach or learn in every class. Secondly, each milestone should be separated into several subsections. The instructor should then use each subsection as a unit for preparing the course materials. The following subsection will provide detailed descriptions on the weekly milestone setup, subsection separation, and materials preparation.

3.2.1. Weekly Milestone Setup

Appropriate weekly milestones can help students learn the BIM process systematically. To help students learn how to operate BIM tools and gain more practical experience, it is important for the instructor to set up the milestone by following the actual construction process. Many software-learning courses develop learning tutorials or instructions function by function. Those tutorials could help the student learn every function of the software in detail. However, since the construction process always contains thousands of building components along with many modeling details, using the function-by-function tutorials may prevent the student from efficiently learning the BIM tool. Furthermore, the absence of an actual implementation experience may also prevent the student from using what they learned for further applications. Therefore, for a project-based BIM tool course, it is suggested that the instructor set-up the weekly milestone according to the processes of the real construction project.

For instance, Kang and his teaching team [32] offer an online 3D Computer-Aided Design (CAD) course on Coursera. In the course, a building is selected as the course project. The team divided the course into eight weekly milestones according to the building construction process (Table 1). Since the course was designed as an online course, the teaching team set preview and review milestones at the beginning and the end of the course. After the course preview, the students familiarize themselves with the fundamental concepts of 3D modeling. Then, the building project was separated into the building structure, staircases, windows, and interior decoration processes.

Table 1. A weekly milestone setup example from Coursera [32].

Week	Milestone
Week 1	Initiation: Prepare for the class
Week 2	Basis of 3D modeling: Learn basic concepts and start modeling
Week 3	Building Structure: Create columns, walls, beams, and slabs
Week 4	Staircases: Create staircases and railings
Week 5	Windows: Create detailed components
Week 6	Modify and Place Component: Place components into building model
Week 7	Model Assembling and Materials: Complete this building model
Week 8	Closure: Review and preview

3.2.2. Milestone Subsection Separation

After setting-up the weekly milestones, the instructor should separate each milestone into discrete subsections. Separating milestones into subsections can help both the instructor and the students have short-term project goals. For instance, if a milestone is set as constructing the building structure, then the subsections can be to create the column models, beam models, or slab models.

Having subsections can help the instructor to develop course materials with appropriate contents and difficulties, thus allowing students to systematically learn both BIM tool operations and the construction process. When setting the subsections, the instructor should consider the course contents and course complexity simultaneously. At the beginning of the course, each milestone can have more subsections with reduced complexity since students may need time to familiarize themselves with the

tool. As the course progresses, the number of subsections can be gradually reduced, and the complexity of each subsection can be increased.

To help the instructor develop appropriate subsections, this research proposed a content-complexity curve (C-C curve). Figure 2 illustrates the proposed C-C curve. In the early stage of the project, the complexity of the subsections should be low yet a larger amount of course content should be presented. As the project progresses, the complexity of the subsections can be increased gradually with the content in each subsection gradually reduced. Students can thus learn more basic operation skills at the beginning and use those skills to address increasingly complex problems in the later stages of the project.

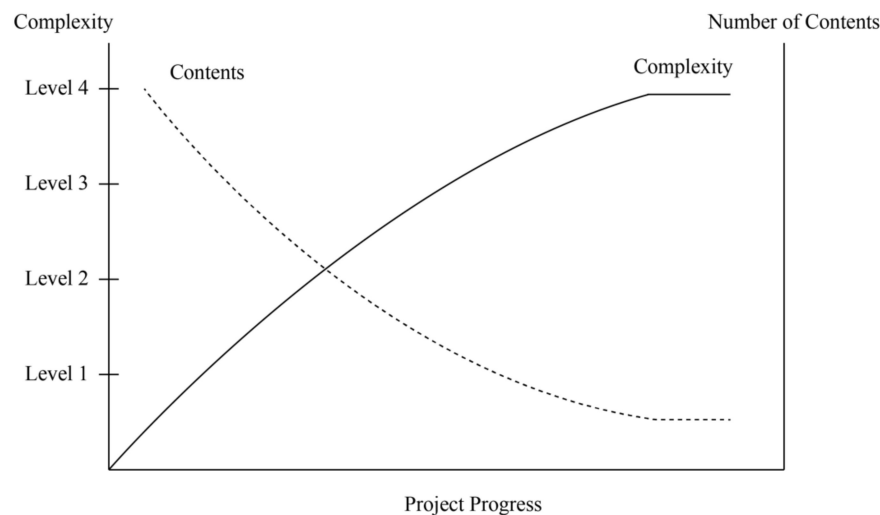


Figure 2. Content-complexity (C-C) curve for subsection separation.

Besides the C-C curve, this research also developed a complexity guide table for defining the BIM course complexity. To develop such a guide table, this study utilized a four-level complexity framework for a BIM course proposed by Barison and Santos [33]. Table 2 describes the four complexity levels for the BIM courses. For the first level of complexity, the course should contain the basic components of BIM models with simple geometries, such as beams, columns, and walls. The modeling components with parametric design, such as windows, doors, and equipment, will be categorized as a second-level course. The third level includes BIM model applications such as collision check and 2D plots. The highest level is BIM integration. Further integrations, such as quantity table exporting and land terrain integration, would be categorized as the highest level.

Table 2. Four complexity levels of building information modeling (BIM) courses.

Level	Description	BIM Specialist	BIM Course Categories
1	Ability to master basic engineering views and learn how to adjust the parameters of BIM components.	Primary BIM modeler	BIM basic components (columns, beams, floors, walls)
2	Advanced engineering view capabilities and how to create components.	Intermediate BIM modeler	BIM components with parametric design (doors, windows, equipment)
3	Good engineering view and floor plan drawing ability.	Primary BIM engineer	BIM model application (collision check, 2D plot)
4	Solve complex BIM problems and BIM model applications.	Intermediate BIM engineer	BIM integration (quantity table, land terrain integration)

3.2.3. Prepare the Course Materials

The last step of the course development and material preparation is to prepare the course material according to the pre-defined subsections. Appropriate course materials can help students to learn independently and even provide motivation for learning. As a project-based online course, the course materials contain three major parts: face-to-face lecture, online materials, and auxiliary information (Figure 3).

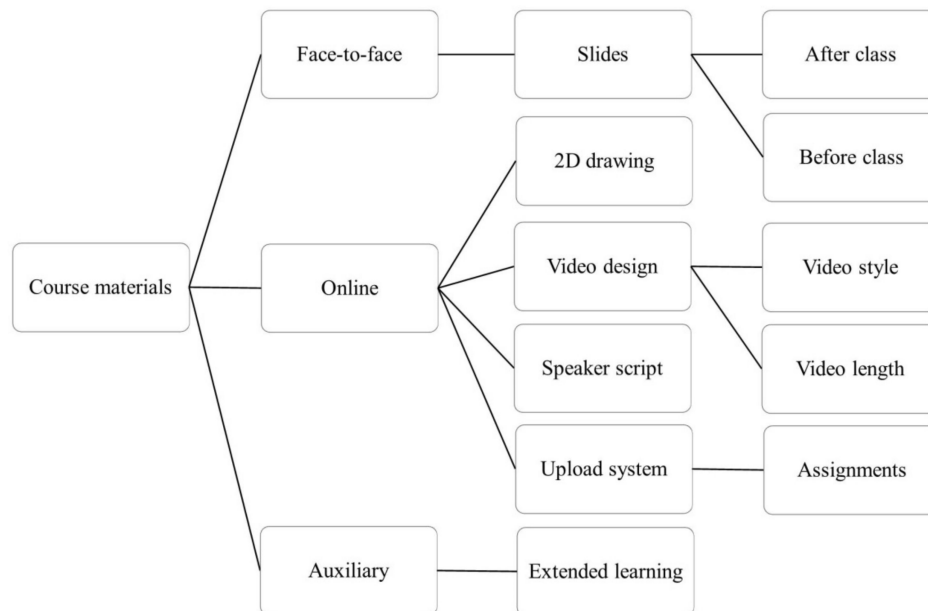


Figure 3. Classification of course materials.

For the face-to-face lecture, the instructor may need to prepare slides for introducing basic knowledge of BIM technology. With the slides, students can understand the main concept behind every operation they perform. Besides slides presented in front of the class, it is suggested that in the slides, the instructor emphasizes possible or common mistakes for the students. Additionally, the instructor can also place the work of the student's peers from the previous subsection in the slides as a demonstration so that students will be able to learn from each other.

The online materials consist of 2D drawings and videos (with a script for the speaker) uploaded via an upload system. The instructor should prepare the 2D drawings of the selected project. The 2D drawings should have a complete architectural plan, structural plan, elevation and section views, and details of the doors and windows to enable the learner to understand the structure and details of the entire BIM model. The video design depends on the style and length of the video. As a video for teaching, the video style should be simple and clear, and the length of the video should not be too long, as lengthy videos may make students lose their patience for learning. The speaker's video script is also important for both the instructor and students when preparing the online materials. A well-designed script can improve the instructor's speaking ability and thus the ability of students to acquire the content clearly. An online upload system also plays an essential role in the online course. The instructor needs to prepare an online platform that allows students to transfer files, watch videos, obtain important announcements, etc. To save effort in developing a new platform, the instructor is suggested to use popular MOOC platforms, such as Coursera, EdX, etc., as their system.

The last part of the course materials is auxiliary information. As a project-based BIM course, students are required to have high self-learning abilities and motivations. This is because BIM tool operations will have significant differences in different projects. The large varieties of BIM tool operations would present challenges for the instructor in providing sufficient and detailed information for students. Therefore, it is important for the instructor to provide extended learning materials for

students to learn on their own. The extended learning materials can be textbooks, literature or real case demonstrations.

3.3. Course Review and Modification

The final stage of the course design is to review and modify the entire course. The syllabus generated based on the previous steps may need to be adjusted. There are many ways to determine if teaching content is appropriate for particular learners. For example, one may seek the help of experienced industry engineers to see if there is a big gap in the difficulty of the overall curriculum or arrange for a few learners to actually test the teaching content in advance. A suitable syllabus is produced through constant testing and modification. After determining that there are no problems with the course, the design process for all courses is completed and the course is released.

4. Implementation and Case Study

For implementation and case study, a BIM course was developed based on the proposed method and implemented in the Department of Civil and Construction Engineering at the National Taiwan University of Science and Technology in Taiwan. In the course, Autodesk Revit is used to build a BIM model of the seven-floor residence building selected for the learning project. The following subsections will provide detailed descriptions of the background of the case study, an overview of the selected project, and the course development.

4.1. Background of the Case Study

The course's name is BIM Theory and Practice. This three-unit elective course runs on Fridays from 09:00 to 12:00. The students were primarily third- and fourth-year students at the university and had no knowledge of BIM. Three learning goals were developed based on the student's prior knowledge: (i) teaching the basics of BIM technology; (ii) teaching the basic concepts and operational logic of BIM modeling; and (iii) developing students' ability to deal with project-related issues. In addition to introducing Revit, the course also introduces many BIM applications of Autodesk software (Autodesk, San Rafael, CA, USA), including Dynamo, Navisworks, InRoads, etc. The BIM course is not just a single teaching mode using only online video teaching; guest lecturers are also invited from the professional and software industries.

The 86.6% of the students' time is spent on online video learning with one computer per student in this class. The students are asked to complete a project through these teaching videos within five weeks. The student's weekly assignment is to complete the project progress for the week. The remaining class time is used to illustrate the course highlights and the common mistakes students make. Course professors and teaching assistants play a role in solving student problems in the course and focus on the student's learning status through weekly assignments.

4.2. Overview of the Selected Project

The course project selected for this BIM class is a 7-floor residence from the Skill Evaluation Center in Taiwan, as shown in Figure 4. The structure of this building contains basic components such as columns, beams, plates, and walls, as well as styling balconies, parapet walls, foundations, etc. In addition to the structure, it also contains infrastructure, doors, windows, furniture, kitchen equipment, sloping roof shapes, garages, etc. Students are able to fully practice all of the basic BIM components with this fairly complete residential project. The completed project model will be applied to the follow-up course of collision checking, animation configuration, and planning/scheduling.

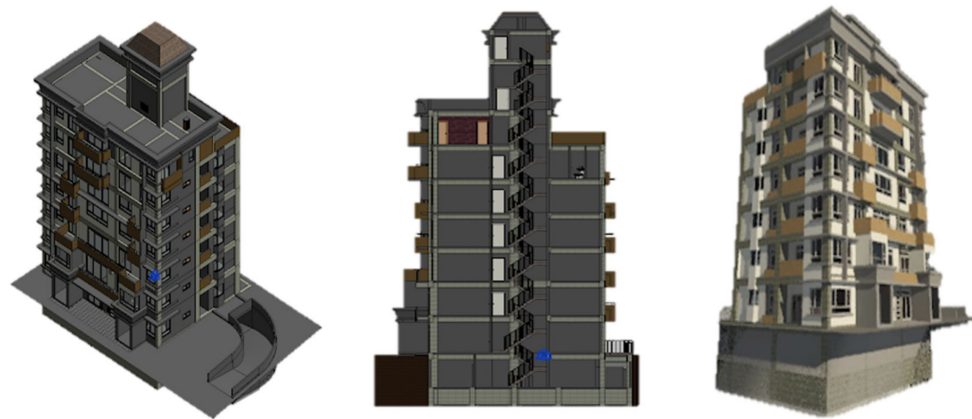


Figure 4. Building information modeling (BIM) residential project.

4.3. Course Development

4.3.1. Weekly Milestone

The Revit course was divided into five weekly milestones according to the building' construction process. Weekly milestones help students set a clear learning goal. As shown in Table 3, the first week represents the student's first contact with the Revit software, so the main content is to introduce the basic concepts of BIM and basic modeling operations. At the same time, the first week also represents the beginning of the project progress, starting from the foundation of the residential building. In the second week, the modeling difficulty increases. After students have the basic concepts of modeling, they begin to touch advanced components such as doors, windows, and some equipment, and try to complete the entire floor. The progress of the project at this time comes to the first floor from the basement.

Table 3. Weekly milestones of the developed course.

Week	Milestone
Week 1	Start BIM and basic modeling: BIM concept and foundation, basement main structure modeling
Week 2	Advanced BIM components: Advanced components and complete the first floor of the building
Week 3	Special BIM components (1): Complete the second floor of the building & parking entrance
Week 4	Special BIM components (2): Create Roof and complete all building models
Week 5	BIM integration: Application and output of BIM component data

In the third week, students are asked to build difficult models such as the GlassFiber Reinforced Cement (GRC) boards and the parking entrance. Students must have good visualization skills to complete the model successfully. In addition, many components can be reused when the project progress reaches the intermediate residential floor. Therefore, students must have the ability to apply models in order to model efficiently. The fourth week focuses on the drawing of the roof model, which also means that the entire project is nearly complete at this point. During this week, students are asked to complete all the models. In the last week, the BIM model data is applied to different requirements. For example, the model can be exported to Navisworks for animation or exported to Infraworks for landscape integration. With the completion of the five-week step-by-step course, a residential building is simultaneously completely modeled.

4.3.2. Separate Milestone into Subsections

After setting the weekly milestones, we separated each milestone into subsections based on the detailed project process. Since the entire residential project may contain thousands of model components and require different modeling skills, we used the four-levels of BIM course complexity to segment the vast content of the course in this class. As shown in Figure 5, each of the four-levels of

BIM course complexity are related to the progress of the project. Each level has a different complexity and will be described in more detail below.

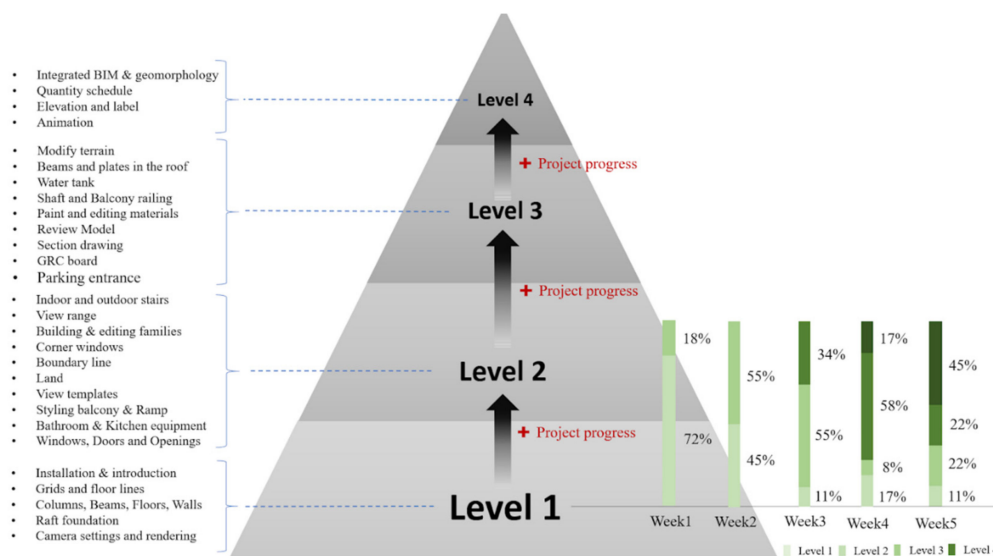


Figure 5. Four-levels of BIM course complexity at the National Taiwan University of Science and Technology.

Four Levels of BIM Course Complexity

Figure 5 illustrated the four-level complexity of the designed BIM course. Level 1 is the initial level. The components classified here can be quickly completed by adjusting the parameters, for example, some basic components of columns, beams, plates, walls, etc. Most of the components here are built-in and students only need to resize them to complete the modeling. In Level 2, modeling is more difficult and requires better engineering visualization capabilities. This level mainly includes the creation of door and window families, balconies, stairs, etc. The biggest difference from the first week to the second week is the requirement that students create components by themselves according to the drawing instructions. Next, some more complex models are included in Level 3, such as parking entrances, GRC boards, and roofs. This level also requires students to turn 3D models into 2D drawings. At Level 3, students are required to have good engineering visualization capabilities and modeling skills to complete the model through sketching. The highest level is Level 4. This mainly includes applications of the BIM model such as geomorphology integration, animation, and model data applications. At this level, students need to have a strong understanding of BIM concepts rather than just modeling skills. Level 4 is designed to help students to be not just a BIM modeler but to be a BIM engineer who can apply model data.

Segmentation Strategy

We use the developed content–complexity curve as the segmentation strategy. The construction project was divided into five major stages. Each course week included one project stage for students to learn the modeling process step by step. Fifty-one videos were developed for the course. In the five-week course, the complexity of the course increases from the first week on, and the progress of the project is added to the planning considerations. Figure 6 shows the relationship between the complexity and project stage of the course. As shown in the figure, in every week, the complexity of the course will start from the first level and gradually increases to higher levels. Figure 7 shows the content–complexity curve of the designed course. Weekly course complexity is inversely proportional to the amount of new BIM knowledge. When the course complexity is the lowest in the first week, the new BIM knowledge is the highest. It is worth noting that the fourth week is the final progress of the

project. The amount of new BIM knowledge is the lowest in this week, as the students are required to focus on the more complex course content.

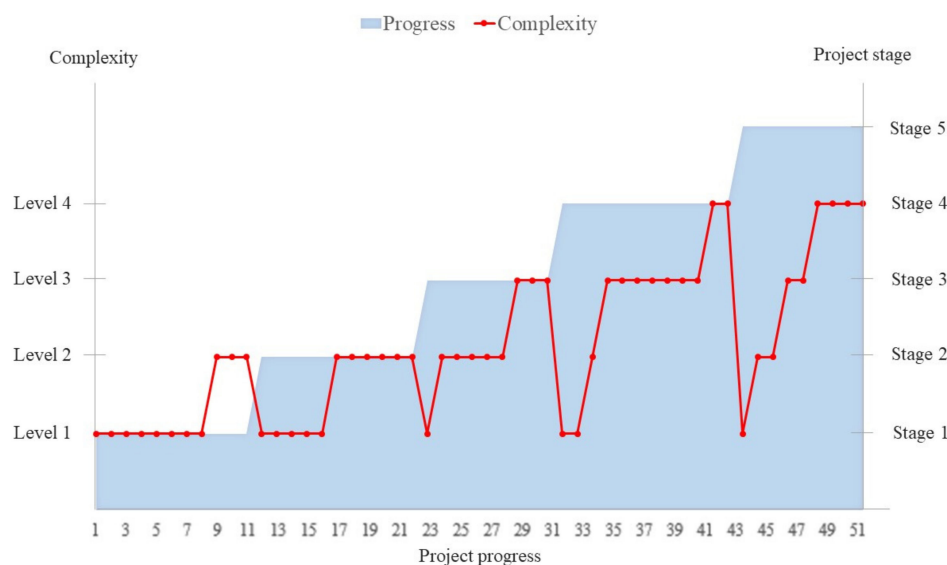


Figure 6. Course complexity and project progress.

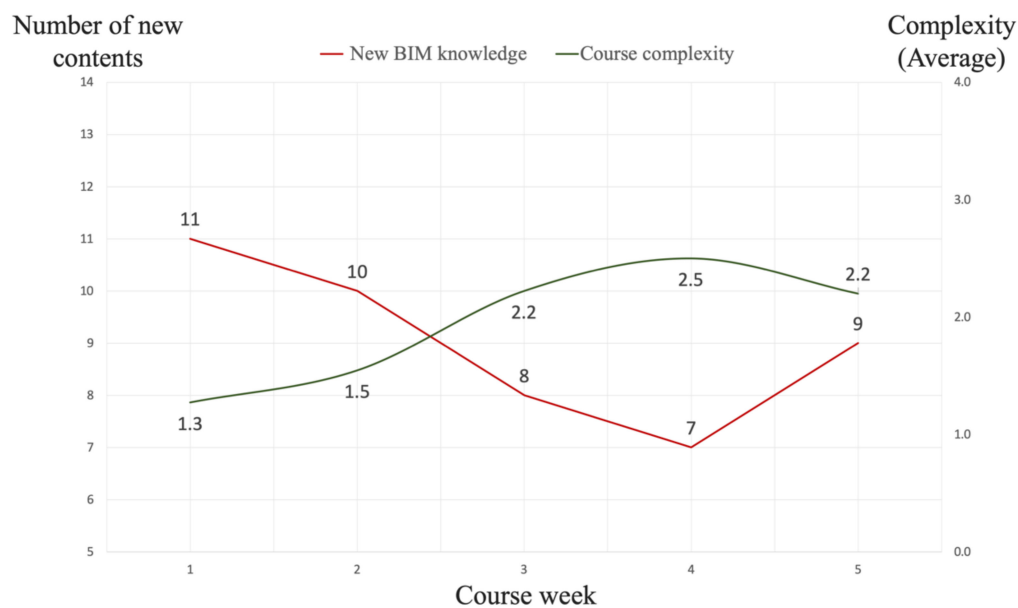


Figure 7. BIM course complexity as compared against new BIM knowledge obtained.

The details of the course are shown in Table 4. The first week of the course covers 72% of Level 1 and 18% of Level 2. Clearly, the first week is introductory, so we specifically designed more sections that are basic for this week. Students can get started with less difficult content in the course and complete the weekly progress of the project. At this stage, the progress of the project was basic and only considered the basement engineering. In the second week of the course, Level 1 and Level 2 content each account for 45% and 55% of the content. After the first week, the basic course content is gradually reduced, and the project progresses to the first floor. In the third week of the course, Level 1, 2, and 3 each account for 11%, 55%, and 34%, respectively, of the course content. The progress of the project reaches the second floor and includes the construction of the parking entrance.

Table 4. Course schedule.

Schedule	Course Topics	Complexity Level
Week 1	01-Introduction of Revit	First
	02-Grids and floor lines	First
	03-Foundation columns	First
	04-Foundation beams	First
	05-Raft foundation and Floor	First
	06-Basement columns and Exterior walls	First
	07-Interior walls of the basement	First
	08-Basement windows, doors, and openings	First
	09-Outdoor stairs in the basement	Second
	10-Indoor stairs and section line	Second
	11-Introducing the view range	Second
Week 2	12-The girders on the first floor	First
	13-Thin beams on the first floor	First
	14-Floor on the first floor	First
	15-Columns and walls on the first floor	First
	16-Handrails and interior walls on the first floor	First
	17-Building Families-Take windows as an example	Second
	18-Edit Families	Second
	19-Doors and windows on the first floor	Second
	20-Corner window in the first floor	Second
	21-Indoor stairs in the first floor	Second
	22-Boundary line and land	Second
Week 3	23-Beams and floor on the second floor	First
	24-Walls, doors, and windows in the second floor	Second
	25-Indoor stairs in the second floor	Second
	26-Styling balcony and ramp	Second
	27-Bathroom and kitchen equipment	Second
	28-Import CAD files	Second
	29-Parking Entrance-1	Third
	30-Parking Entrance-2	Third
	31-Modify terrain	Third
Week 4	32-Beams and floor on the third floor	First
	33-Columns, walls, doors, windows on the third floor	First
	34-Staircase and elevator openings, modify brick walls	Second
	35-Complete the fourth to seventh floor-01	Third
	36-Complete the fourth to seventh floor-02	Third
	37-Beams and plates on the roof	Third
	38-Columns, walls, stairs from the roof to P2 floor	Third
	39-Columns, walls, beams from P2 to P3 floor	Third
	40-Shaft and Balcony railing	Third
	41-Paint and editing materials	Third
	42-GRC styling board	Fourth
	43-Water tank with Inclined plate on the roof	Fourth

Table 4. Cont.

Schedule	Course Topics	Complexity Level
Week 5	44-Camera settings and rendering	First
	45-View templates and drawings	Second
	46-Elevation and label	Second
	47-Section drawing (1)	Third
	48-Section drawing (2)	Third
	49-Review Model-Stairs and Tank Floor	Fourth
	50-Animation	Fourth
	51-Integrated model and geomorphology	Fourth
	52-Quantity table	Fourth

In the fourth week of the course, Level 1, 2, 3, and 4 content each account for 17%, 8%, 58%, and 17%, respectively, of the course content. The project progress in this week includes the residential standard floor and the roof. Students should complete the entire residential project using the course content of the previous four weeks. In the fifth week, Level 4 content occupies 45% of the course content for the week, which makes students learn the most complex content and the course focuses on the application of BIM models, such as reviewing models, animation settings, and quantity tables.

4.3.3. Preparing the Course Materials

After completing the segmentation of the course milestones, we created online videos to implement the BIM teaching. We prepared 52 video tutorials and uploaded them to our BIM teaching website. As shown in Figure 8, a teaching website belonging to this BIM course was designed. The teaching website contains four tabs, with the first being the home page of the website, which is used to introduce the course objectives. The second is the course schedule, which is the most commonly used tab by the students. Learners can get weekly online video information, including weekly schedule, course materials, and homework instructions. The third tab is used to illustrate the scoring mechanism for this course. The last tab is used to place other BIM course sites where students can access other learning resources.

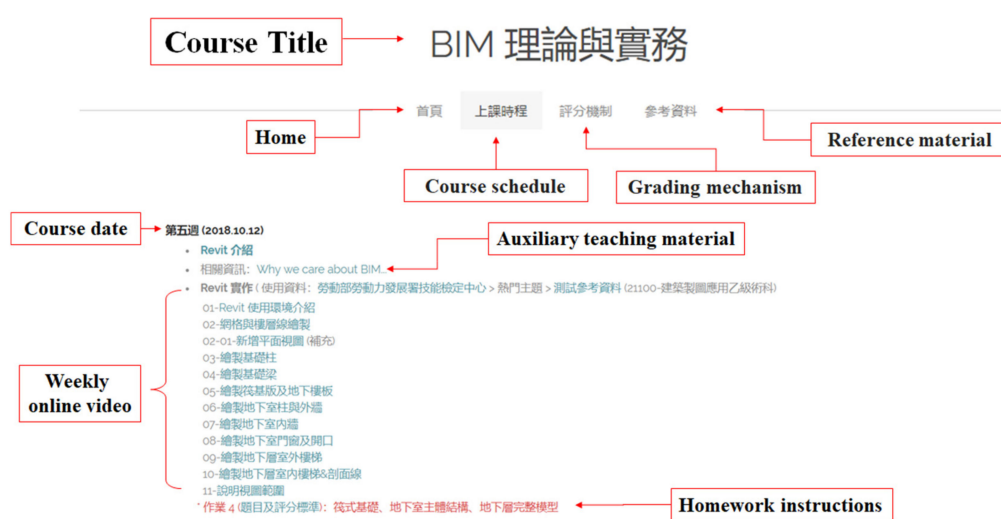


Figure 8. BIM teaching website.

To help learners make effective use of the online video learning, we set the video length to an average of 10 min and the title of each video contains a clear learning goal. Moreover, as shown in

Figure 9, the hand-drawn figures and highlights in the video are used by the speaker to assist in teaching. The learner is free to pause the video and adjust the speed and volume while watching the online video. It is important that when students encounter problems, they can record the time of the video and report it to the course director which makes the problem clearer.

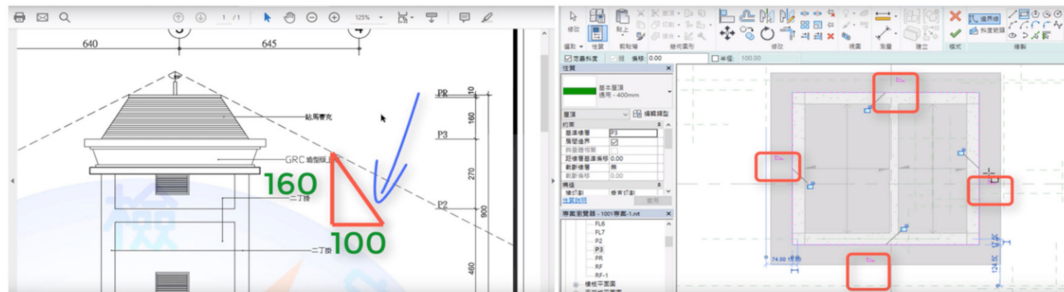


Figure 9. Video highlight examples.

5. Results of the Case Study

This research analyzed students' video-watching behaviors and collected the students' feedback after the course finished for evaluating the effectiveness of the case study. The following sections will describe the results of the video-watching behaviors and student feedbacks respectively.

5.1. Students' Video-Watching Behaviors

An analysis was performed on the relationship between video browsing times and video complexity. As shown in Figure 10, we found that students had significantly increased video browsing times in the first week of the course. This may be because students needed to spend more time exploring Revit in the first week. In addition, the number of video browsing times changed significantly when the complexity of the course changed from low to high, such as at project stages 17, 36, and 45. The change in the number of video browsing times highlights the advantages of online video. When students encounter problems in the course, they can repeat the learning through replaying the video. Conversely, students with good learning outcomes are free to adjust their learning speed.

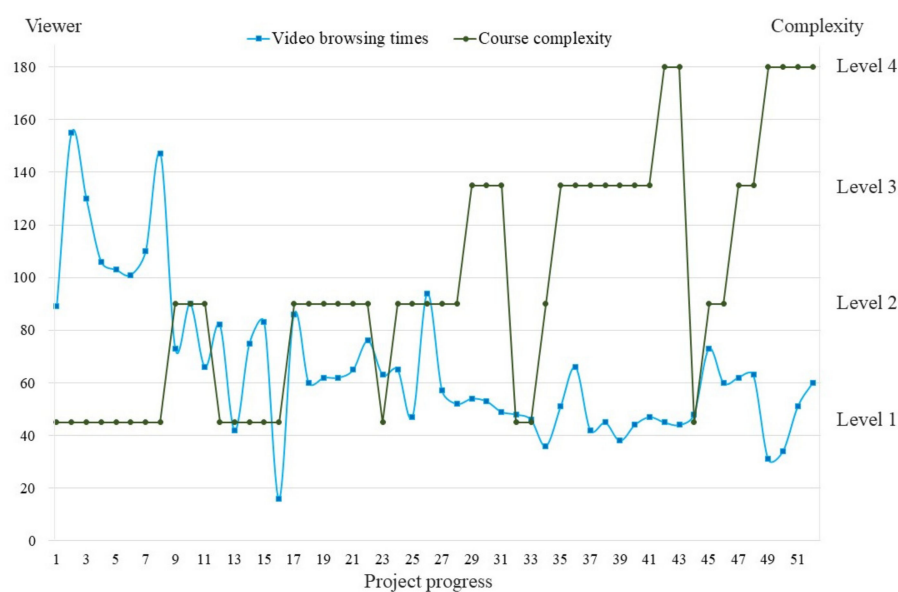


Figure 10. Course video traffic statistics.

5.2. Feedback from Students

To evaluate the benefits of project-based online video tutorials, we collected feedback from students. Students in the class were asked to provide their feedback about having access to the online and project-based BIM course after finishing the course. Twenty-six responses were received. The responses can be divided into four major categories.

1. Combining online videos with BIM teaching was helpful: Nine of the responses indicated that using online videos could be very helpful for their learning. This was because they were able to repeat a specific part of the modeling process when they did not understand something the first time watching. Also, they could watch the videos before going to class and bring their questions to the classroom for further discussions.
2. It was useful to have a project-based course for learning BIM: Four of the 26 responses mentioned that the project-based course could greatly aid them in getting familiar in implementing BIM into a real project. Additionally, having a real project could also help them learn the basics of BIM step by step.
3. It was helpful in not only learning the modeling skills but also the concept of BIM: Six responses stated that after taking the course, they learned not only the skills for building BIM models but also gained an understanding of the concepts behind the modeling process. Having such a course can free them from the traditional thinking in civil engineering and allow them to gain experience in building structures, software integration, civil engineering computing, etc.
4. Motivated the students to learn BIM during the course: Students also mentioned that having this kind of classes can inspire their motivation to learn a new technology. In the traditional class, students would easily get lost in the overall progress if they did not pay full attention to the instructor. It would cause the students a lot of time in follow-up after the class; some students even lose their patience and give up. However, having the detailed instruction in the format of videos could let them preview and review the course content before and after taking the class and help them to stay on the track. Also, the project-based course could help them to gain more knowledge about a real construction project and might provide great help to their other courses.

6. Conclusions

This research proposed a course development method for developing a project-based online BIM tool learning course. Such a method contains three major processes that provide detailed suggestions to the instructor for project selection, course development, and course review. Furthermore, a C-C curve with a four-level BIM complexity table was introduced for helping the instructor prepare the course materials with appropriate content and complexity. For validation, this research implemented the proposed method on developing a BIM tool learning course at the National Taiwan University of Science and Technology. The results of the case study revealed that using a project-based online video teaching method could be helpful for both the instructor and learners. Additionally, with a real project and flexible learning settings, students would have more motivation to learn BIM tools. However, utilizing such a teaching method may somehow decrease the interaction between the instructor and students. Therefore, the instructor may need to put extra effort in toward tracking the learning progress of every student.

Although the results of the case study showed that such a teaching method can have a positive influence on students' learning effectiveness, there are still some limitations of this research. Further studies could conduct a statistical analysis on the impact of students' works. Secondly, since this was the first time for the authors to offer this BIM course, there were no students who had been taught using other teaching methods for comparison. Therefore, the future work of this research is to continuously implement the proposed method into BIM teaching and compare the results with other teaching approaches.

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References

1. Fridrich, J.; Kubecka, K. BIM—The process of modern civil engineering in higher education. *Procedia Soc.* **2014**, *141*, 763–767. [[CrossRef](#)]
2. He, R.; Wang, X.; Du, K.; Bao, B.; Shang, J.; Lv, H. The primary attempt of teaching MOOC of BIM. In Proceedings of the International Conference on Education Reform and Modern Management, Hong Kong, 19–20 April 2015; Volume 15, pp. 93–95, ISBN 978-94-62520-66-0.
3. Abbas, A.; Din, A.U.; Farooqui, R. Integration of BIM in construction management education: An overview of Pakistani Engineering universities. *Procedia Eng.* **2016**, *145*, 151–157. [[CrossRef](#)]
4. Macdonald, J.A. A framework for collaborative BIM education across the AEC disciplines. In Proceedings of the 37th Annual Conference of Australasian University Building Educators Association (AUBEA), Sydney, Australia, 4–6 July 2012.
5. Huang, Y. A review of approaches and challenges of BIM education in construction management. *J. Civ. Eng. Archit.* **2018**, *12*, 401–407. [[CrossRef](#)]
6. Huang, Y.L. Developing a modular advanced BIM course in construction management. *J. Build. Constr. Plan. Res.* **2018**, *6*, 198–214. [[CrossRef](#)]
7. López-Zaldívar, O.; Verdú-Vázquez, A.; Gil-López, T.; Lozano-Diez, R.V. The implementation of building information modeling technology in university teaching: The case of the Polytechnic University of Madrid. *Int. J. Eng. Educ.* **2017**, *33*, 712–722.
8. Ahn, Y.; Cho, C.; Lee, N. Building information modeling: Systematic course development for undergraduate construction students. *J. Prof. Issues Eng. Educ. Pract.* **2013**, *139*, 290–300. [[CrossRef](#)]
9. Pikas, E.; Sacks, R.; Hazzan, O. Building information modeling education for construction engineering and management. II: Procedures and implementation case study. *J. Constr. Eng. Manag.* **2013**, *139*, 05013002. [[CrossRef](#)]
10. Tsai, M.H. A peer review system for BIM learning. *Sustainability* **2019**, *11*, 5747.
11. Clevenger, C.; Glick, S.; del Puerto, C.L. Interoperable learning leveraging building information modeling (BIM) in construction education. *Int. J. Constr. Educ. Res.* **2012**, *28*, 101–118. [[CrossRef](#)]
12. Forsythe, P.; Jupp, J.; Sawhney, A. Building information modelling in tertiary construction project management education: A programme-wide implementation strategy. *J. Educ. Built Environ.* **2013**, *8*, 16–34. [[CrossRef](#)]
13. Suwal, S.; Järväjä, P.; Rahman, A.; Gonzalez, V. Exploring BIM-based education perspectives. In Proceedings of the 38th Australasian Universities Building Education Association Conference, Auckland, New Zealand, 20–22 November 2013.
14. Šadauskienė, J.; Pupeikis, D. Review of BIM implementation in higher education. *J. Sustain. Archit. Civ. Eng.* **2018**, *1*, 99–109. [[CrossRef](#)]
15. Lewis, A.; Valdes-Vasquez, R.; Clevenger, C.; Shealy, T. BIM energy modeling: Case study of a teaching module for sustainable design and construction courses. *J. Prof. Issues Eng. Educ. Pract.* **2015**, *141*, C5014005. [[CrossRef](#)]
16. Giannakos, M.N. Exploring the video-based learning research: A review of the literature. *Br. J. Educ. Technol.* **2013**, *44*, 191–195. [[CrossRef](#)]
17. Choi, H.; Johnson, S.D. The effect of context-based video instruction on learning and motivation in online courses. *Am. J. Distance Educ.* **2005**, *19*, 215–227. [[CrossRef](#)]
18. Yousef, A.M.F.; Chatti, M.A.; Schroeder, U. Video-based learning: A critical analysis of the research published in 2003–2013 and future visions. In Proceedings of the eLmL 2014: The Sixth International Conference on Mobile, Hybrid, and On-line Learning, Barcelona, Spain, 23–27 March 2014; pp. 112–119.
19. Volery, T.; Lord, D. Critical success factors in online education. *Int. J. Educ. Manag.* **2000**, *14*, 216–223. [[CrossRef](#)]

20. Johnson, S.D.; Aragon, S.R. An instructional strategy framework for online learning environments. In *Facilitating Learning in Online Environments*; John Wiley & Sons: San Francisco, CA, USA, 2003; pp. 31–43.
21. Brecht, H.D. Learning from online video lectures. *J. Inf. Technol. Educ.* **2012**, *11*, 227–250.
22. He, Y.; Swenson, S.; Lents, N. Online video tutorials increase learning of difficult concepts in an undergraduate analytical chemistry course. *J. Chem. Educ.* **2012**, *89*, 1128–1132. [[CrossRef](#)]
23. Wong, J.K.; Oladinrin, O.T.; Ho, C.M.; Guilbert, E.; Kam, R. Assessment of video-based e-learning in a construction measurement course. *Int. J. Constr. Manag.* **2018**. [[CrossRef](#)]
24. Guo, P.J.; Kim, J.; Rubin, R. How video production affects student engagement: An empirical study of MOOC videos. In Proceedings of the First ACM Conference on Learning@ Scale Conference, Atlanta, GA, USA, 4–5 March 2014; pp. 41–50.
25. Udomdech, P.; Papadonikolaki, E.; Davies, A. An alternative project-based learning model for building information modelling-using teams. In Proceedings of the 34th Annual ARCOM Conference, Belfast, UK, 3–5 September 2018; pp. 57–66.
26. Rahman, R.A.; Ayer, S.K.; London, J.S. Applying problem-based learning in a building information modeling course. *Int. J. Eng. Educ.* **2019**, *35*, 956–967.
27. Wu, W.; Luo, Y. Project-based learning for enhanced BIM implementation in the sustainability domain. In Proceedings of the 9th BIM Academic Symposium and Job Task Analysis Review, Washington, DC, USA, 7–8 April 2015; pp. 2–9.
28. Wu, W.; Hyatt, B. Experiential and project-based learning in BIM for sustainable living with tiny solar houses. *Procedia Eng.* **2016**, *145*, 579–586. [[CrossRef](#)]
29. Luo, Y.; Wu, W. Sustainable design with BIM facilitation in project-based learning. *Procedia Eng.* **2015**, *118*, 819–826. [[CrossRef](#)]
30. Zhang, J.; Xie, H.; Li, H. Project based learning with implementation planning for student engagement in BIM classes. *Int. J. Eng. Educ.* **2018**, *35*, 310–322.
31. Leite, F. Project-based learning in a building information modeling for construction management course. *J. Inf. Technol. Constr.* **2016**, *21*, 164–176.
32. Kang, S.C. 3D CAD Application. Available online: <https://www.coursera.org/learn/3d-cad-application> (accessed on 29 September 2019).
33. Barison, M.B.; Santos, E.T. Review and analysis of current strategies for planning a BIM curriculum. In Proceedings of the 27th Conference of International Council for Building W78, Cairo, Egypt, 16–18 November 2010.



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