Journal of Civil Engineering and Architecture 14 (2020) 100-108
doi: 10.17265/1934-7359/2020.02.006

Introducing BIM to Construction Management Students: A Case Study of Using Lego Blocks as Instructional Tool

Yilei Huang

Department of Construction & Operations Management, South Dakota State University, Brookings, SD 57007, USA

Abstract: As the construction industry is transitioning into the building information modeling (BIM) era, many construction management (CM) programs are actively integrating BIM into their curriculum. For new CM students who are unfamiliar with the BIM concept, a connection is desired to link 2D drawings with 3D models. This paper presents a case study that uses Lego blocks as an innovative instructional tool to introduce BIM to new CM students. The approach employs a physical Lego model house as the connection between the 2D and 3D worlds in an introductory BIM course and aims to demonstrate the benefits of BIM over 2D CAD through a hands-on session. CM students are instructed to build a Lego house first with a set of typical 2D construction drawings, including plan, elevation, and section sheets, and then with a 3D model in a BIM program. Students are guided to navigate the model and then use it as a 3D reference to complete the Lego house. Through the hands-on session, students will naturally establish the connection between 2D drawings and 3D models. In addition, by comparing the efforts needed to complete the Lego house with both methods, students can easily recognize the benefits of using BIM in CM. This case study demonstrates the procedures of using Lego blocks as an instructional tool in a hands-on session of an introductory BIM course.

Key words: BIM, construction management, Lego blocks, instructional tool, hands-on.

1. Introduction

While the construction industry has been transitioning from a 2D world with CAD drawings to a 3D world with building information modeling (BIM), many construction management (CM) programs in the U.S. are actively adopting a variety of methods to integrate BIM contents in their curriculum. The different approaches include adding standalone BIM courses, utilizing existing BIM courses from cross-disciplinary programs, incorporating BIM within the CM capstone/project course, and integrating BIM into existing CM courses [1]. Despite the various approaches, for new CM students who have not been exposed to 3D building models, a connection is desired to link the 2D and 3D worlds and introduce the concept of BIM in CM. Once the connection is established and new CM students become more familiar with the navigation of 3D models, they will be able to gain confidence in using BIM for various CM tasks.

To establish this connection between 2D drawings with 3D models, this paper presents a case study of an innovative approach that introduces BIM to new CM students through a single hands-on session. The hands-on session actively engages new CM students in exploring BIM by requiring them to build a model house with Lego blocks using a BIM model as construction documents. When students complete the Lego house with the help of BIM, they will naturally develop the connection between 2D CAD drawings and 3D BIM models and recognize the benefits of using BIM in CM. In addition, literature has shown that a hands-on session will better prepare new CM students for subsequent coursework and promote team building skills in a teamwork environment [2]. The case study presented in this paper demonstrates the procedures of using Lego blocks as an instructional tool in a hands-on session of an introductory BIM course.

Corresponding author: Yilei Huang, Ph.D., CM-BIM, Assistant Professor, research fields: building information modeling, virtual reality and mixed reality in construction management.

2. Literature Review

Due to decade uses of paper plans in the construction industry, 2D drawings have always been adopted in construction management education as a pedagogical tool [3]. While being widely used, it often requires some degree of students' prior experience to interpret 2D drawings since students must perceptually visualize the components of a structure from lines and symbols in a drawing set and mentally combine them into a virtual structure. Students with little or no previous experience often face challenges and must spend more time interpreting 2D drawings [4]. Using BIM as a pedagogical tool in construction management education can assist students in understanding the complexity of construction projects in both the process and product [5, 6]. In addition, many students are aware of BIM as the emerging technology used in the industry and have the expectations of learning the latest and most essential paradigm in a construction management program [7].

A construction kit offers innovative ways to provide students with hands-on sessions that simulate the actual construction management experience. McIntyre used the Tektōn Hotel Plaza Set, a girder and panel building kit, in a first-year introductory construction management course to mimic an array of construction management functions and responsibilities that are required for a typical construction project [2]. Other hands-on sessions in construction management courses primarily focused on senior capstone design projects [8, 9]. These hands-on sessions with construction kits have proven to be able to prepare students for subsequent coursework and promote team building skills in a teamwork environment [2].

3. Background

3.1 Inspiration

The approach of building a model house with Lego blocks using a BIM model as construction documents in a hands-on session was inspired by the BIM Education Program of the Associated General Contractors (AGC). The program is designed to prepare construction professionals at all experience levels to successfully implement BIM on a construction project [10]. The completion of the program, which contains four one-day courses, makes the participant eligible to take an exam and obtain the AGC Certificate of Management-Building Information Modeling (CM-BIM).

The hands-on session occurred during day four of the program where Lego blocks from a model house (model number: 40154, 174 pieces) were provided. Participants were assigned different roles, including a mason, a carpenter, a door and window installer, a roofer, a landscaper, etc., with exclusive access to a single block type with a specific color. A project manager was also appointed for overall supervision. A set of 2D CAD drawings similarly to construction documents were provided and a 3D BIM model was available upon request. The crew must work within their assigned discipline, meet milestones of several building components, adhere to specified safety regulations, and eventually complete the Lego house within the allocated time. This hands-on session was highly engaging and cooperative and was much enjoyed by all participants. The author had since believed that a similar session could be developed as a hands-on activity to introduce BIM to new CM students and had managed to locate another Lego model house with existing digital model. The case study presented in this paper utilized the new and more complicated Lego model house but simplified the requirements from the AGC's session, such as crew discipline, milestones, and safety regulations.

3.2 Learning Objectives

Three learning objectives of the hands-on session were identified to align with the cognitive learning process in Bloom's Taxonomy. The original taxonomy was later revised and defined with six levels as "remember, understand, apply, analyze,

evaluate, and create" from lower- to higher-order thinking skills, as illustrated in Fig. 1 [11].

The three learning objectives are that upon completion of the session, students will be able to: 1) understand the connection between 2D drawings and 3D models; 2) apply navigation tools to locate information needed; and 3) analyze the benefits of using BIM in CM. The three learning objectives align with the lower to middle levels "understand, apply, analyze" process and match the workflow of the hands-on session where students would first identify the relationship between 2D drawings and 3D models, then learn to use a BIM program to look for the required information, and finally recognize the benefits of using a BIM model in this process once the model house is completed.

4. Development of Instructional Tools

4.1 Selecting a Lego Model House

When searching for a Lego model set as an instructional tool for the hands-on session, three conditions were taken into consideration: 1) the Lego set is a model house representing modern building construction; 2) the Lego set is commercially available so that the hands-on session can be disseminated and repeated; 3) a digital format of the Lego set is accessible and can be converted into a BIM format.

Lego provided its own designer tool, the Lego Digital Designer (LDD), and hosted an LDD Gallery with free access to the digital format lxf file of a variety of commercial and custom-built Lego sets. Through a complete search within the LDD Gallery, the Lakeside Lodge (model number: 31048, 368 pieces) was considered the optimal set under the above conditions and selected for the hands-on session. The selected set contains three different model houses and the main model was selected due to its representation of a typical house construction, as demonstrated in Fig. 2. Unfortunately, the LDD Gallery has ceased operation since early 2018, but the selected Lego set can still be found at third-party sites, such as Eurobricks (https://www.eurobricks.com/forum/index.php?showtopic=41226&view=findpost&p=2432275) and Brickshelf (http://www.brickshelf.com/gallery/Gnac/Creator/_31048a.lxf).

4.2 Converting into A BIM Model

The digital format of Lego sets is downloaded as lxf files, which cannot be read directly by any BIM programs. In order to use a digital Lego set in the hands-on session with BIM, a series of steps has been identified to convert an lxf file to a commonly used BIM format, Autodesk Navisworks nwd file:

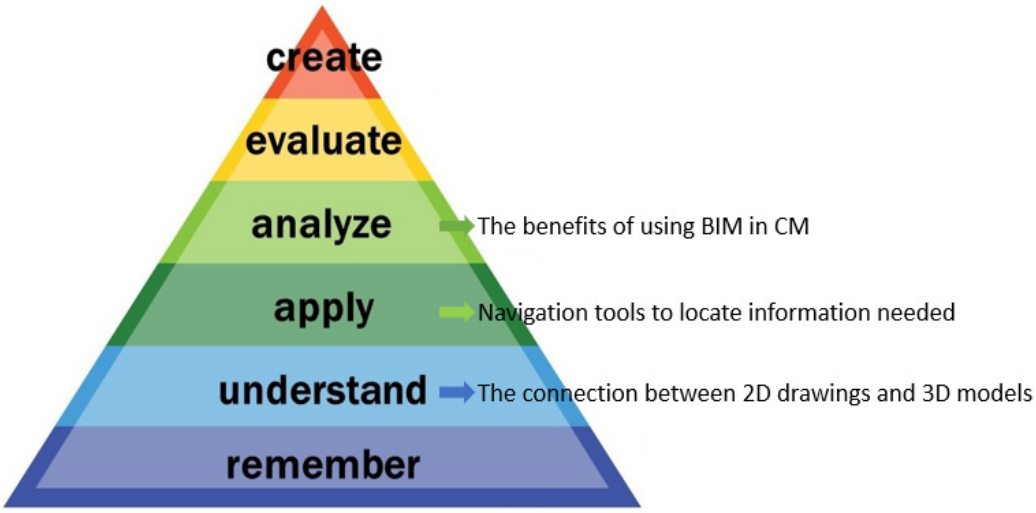

Fig. 1 Three learning objectives aligning with the cognitive learning process of Bloom's Taxonomy.

Fig. 2 Selected Lego set for the hands-on session (adapted from Lego.com).

Fig. 3 Selected Lego set in LeoCAD before adjustment.

(1) Open the downloaded lxf file with LDD and simply export it to ldr format;

(2) Open the ldr file with LeoCAD, an open-source Lego designer tool, and export it to 3ds format. Before exporting, it is necessary to examine the model in LeoCAD to ensure all blocks remain their correct position. In the case of the selected Lego set, several blocks needed relocation and reorientation adjustments, including the two horn decoration blocks mounted to the exterior wall, as illustrated in Fig. 3;

(3) Open the 3ds file with Autodesk 3ds Max and export it to fbx format. 3ds Max is a professional program for 3D modeling, animation, and rendering. In the case of the selected Lego set, 3ds Max was also used to remove unneeded objects from the model house, including the person, the moose, and other landscaping objects;

(4) Open the fbx file with Autodesk Navisworks and save it as nwd format. Navisworks is the most commonly used BIM program in CM for design review, project coordination, and model-based estimating and scheduling. The digital format of the selected Lego set has now been adjusted and converted into a BIM model, as shown in Fig. 4;

(5) Create individual sets within the nwd file to group blocks of the same building component. A typical BIM model created from a native BIM modeling program would already place objects of the same type in the same group, separated by each level, so creating sets for an entire BIM model only takes minutes. The same task for a Lego set is, however, very time-consuming since all blocks are unorganized as separate pieces, and as a result, each block needs to be sorted out manually to match their respective building component. Despite all the efforts, for the selected Lego set, thirteen sets were created for different building components, including appliance, beams, ceiling, chimney, doors and windows, floor, foundation, furniture, ground, roof, walkway, walls, as well as other accessories. Figs. 5 to 8 demonstrates four examples of the building component sets which are foundation, walls, doors and windows, and roof.

4.3 Generating CAD Drawings

In order for students to establish the connection between the traditional 2D CAD drawings and the

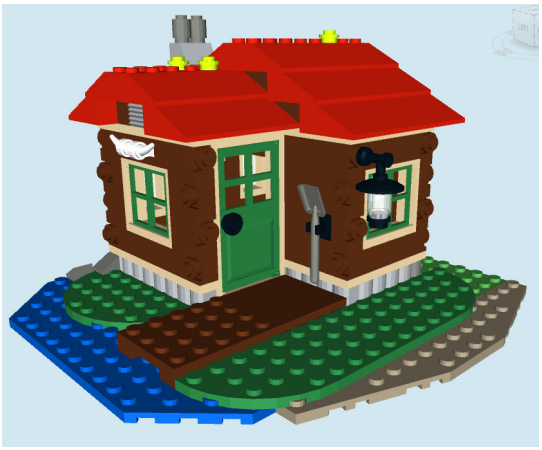

Fig. 4 Selected Lego set in Navisworks after editing with 3ds Max.

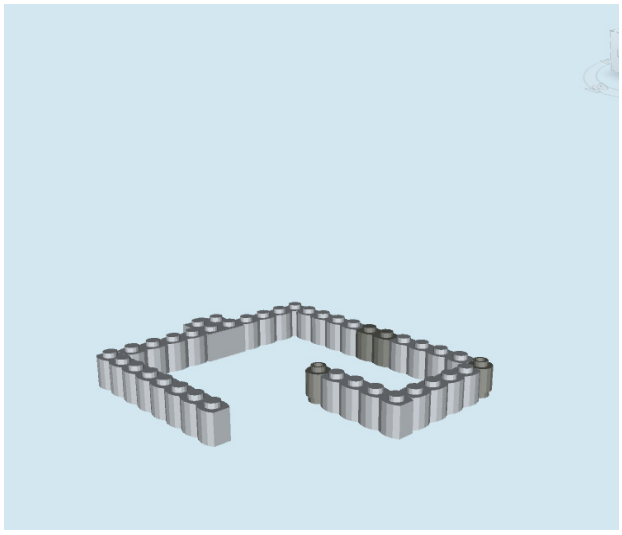

Fig. 5 Foundation set of the Lego BIM model in Navisworks.

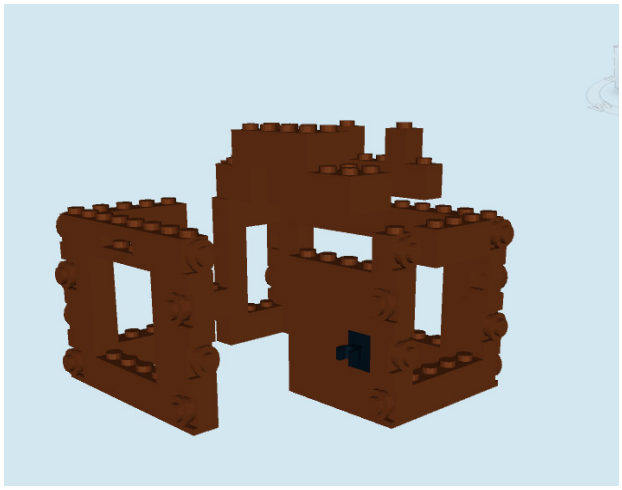

Fig. 6 Walls set of the Lego BIM model in Navisworks.

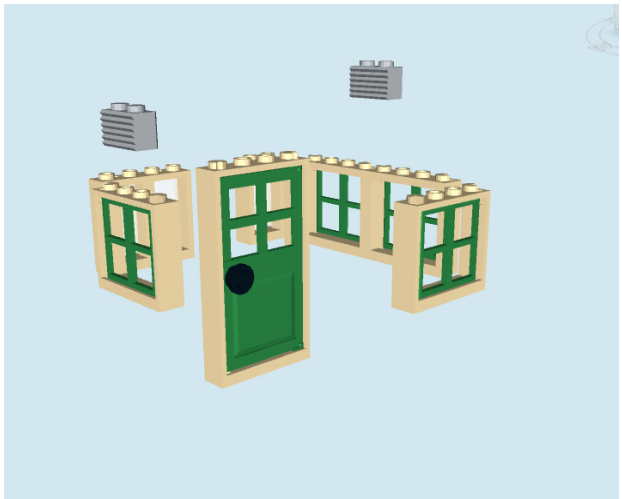

Fig. 7 Doors and windows set of the Lego BIM model in Navisworks.

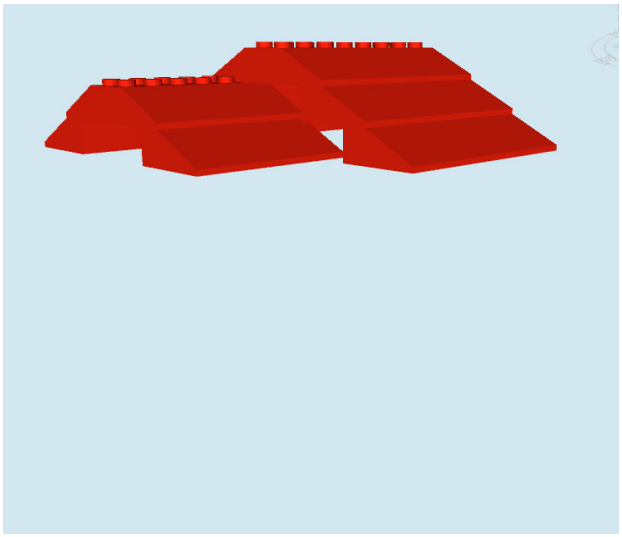

Fig. 8 Roof set of the Lego BIM model in Navisworks.

new 3D BIM models during the hands-on session, a set of CAD drawings similar to typical construction plans needs to be generated, too. The Lego BIM model itself does not contain any native CAD drawings and Navisworks, mostly as a design review tool, does not have the capability of generating CAD drawings from BIM models. As a result, 3ds Max is required again following a series of steps below:

(1) Open the 3ds file with 3ds Max previously edited and saved and export it to dwg format which contains 3D CAD information;

(2) Start Autodesk Revit, the most commonly used BIM modeling program, with an architectural template and import the dwg file in black and white;

(3) Set the visual style to hidden line so that only the outline of each block shows up. By orienting to the four side views and the top view, the four exterior elevation plans and the roof plan can be easily generated, as demonstrated in Fig. 9;

(4) Other CAD drawings can be generated using the same method, but extra prior editing in 3ds Max is required. This is because Revit does not support section or elevation cuts through 3D CAD models (dwg files). A workaround is identified within 3ds Max to generate the various plan sheets and section sheets. Generally speaking, all the blocks that would appear in front of the desired plan view or section

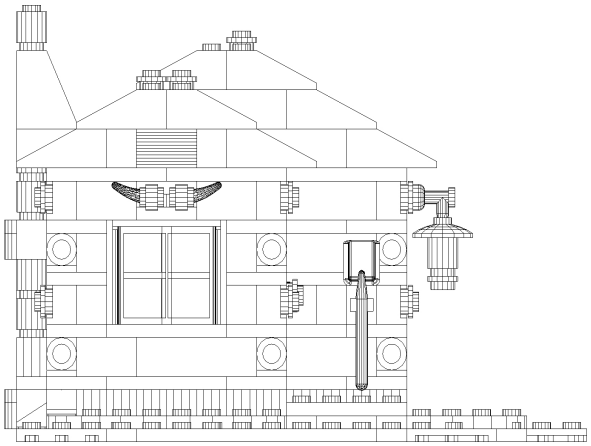

Fig. 9 Left elevation plan of the Lego BIM model.

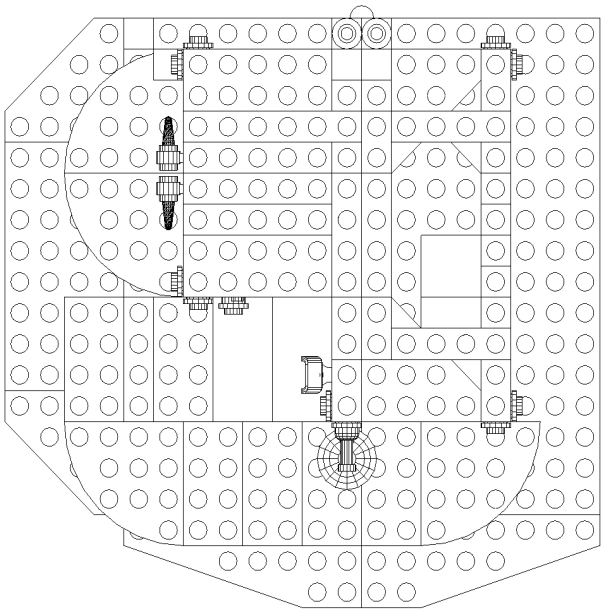

Fig. 10 Roof framing plan of the Lego BIM model.

view need to be removed in 3ds Max prior to exporting to a dwg file. The specific steps are:

i. Copy the 3ds file as a new file and open it with 3ds Max. Remove all block objects above the roof framing level and export as a dwg file. Import it to Revit as indicated above, orient to the top view, and generate the roof framing plan sheet, as shown in Fig. 10;

ii. Back to 3ds Max, remove all blocks above the ceiling level and export as a dwg file. Import it to Revit, orient to the top view, and generate the ceiling plan sheet;

iii. Back to 3ds Max, continue removing all blocks above the floor level and export as a dwg file. Import it to Revit, orient to the top view, and generate the floor plan sheet, as shown in Fig. 11;

iv. Back to 3ds Max again, keep removing all blocks above the foundation level and export as a dwg file. Import it to Revit, orient to the top view, and generate the foundation plan sheet, as shown in Fig. 12;

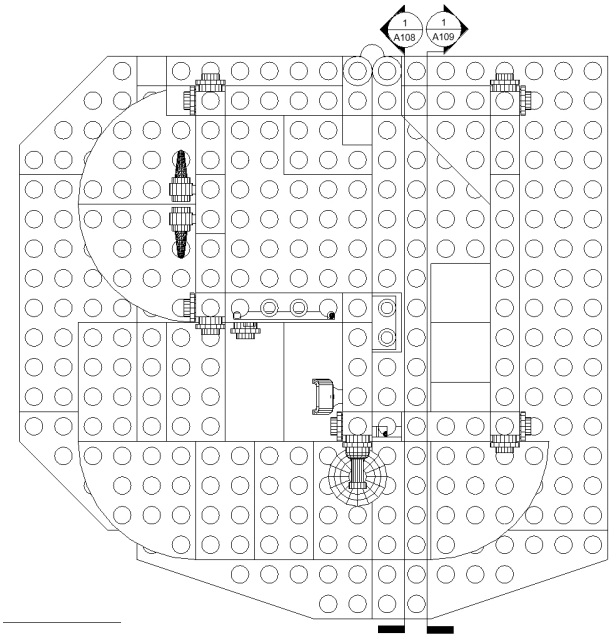

Fig. 11 Floor plan of the Lego BIM model.

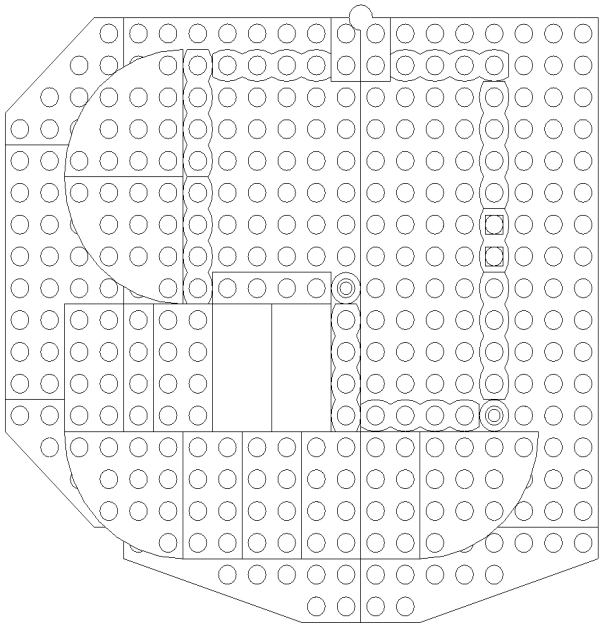

Fig. 12 Foundation plan of the Lego BIM model.

v. Back to 3ds Max, finally remove all blocks above the site level and export as a dwg file. Import it to Revit, orient to the top view, and generate the site plan sheet;

vi. The left section and right section plans can be generated with a similar approach;

(5) Finally, create a cover sheet with Revit that includes a 3D rendering image of the Lego set, as demonstrated in Fig. 4, and an index of the twelve generated sheets including:

- C101 - Site Plan
- A101 - Floor Plan
- A102 - Front Elevation
- A103 - Rear Elevation
- A104 - Left Elevation
- A105 - Right Elevation
- A106 - Ceiling Plan
- A107 - Roof Plan
- A108 - Left Section
- A109 - Right Section
- S101 - Foundation Plan
- S102 - Framing Plan

5. Workflow of the Hands-On Session

After all the instructional tools had been developed, the hands-on session was ready to begin. The session was given in an introductory BIM course to new CM students who had little exposure to 3D or BIM models. The session aimed to help new CM students transition from 2D CAD drawings to 3D BIM models and establish a connection between the two by using the physical Lego model house. The session also helped to promote the benefits of using BIM in CM through the comparison between using CAD drawings and BIM models to complete the Lego model house. In addition, the hands-on session served as a bridge for new CM students to learn various BIM tools in a computer program.

5.1 Building with 2D CAD Drawings

The hands-on session started with the traditional 2D CAD drawing approach. Students were divided into groups of three to four, and each group was given the generated CAD drawing set as the standard construction documents instead of Lego instruction and the Lego blocks as construction materials. Students were then instructed to work together to build the Lego model house based on the drawings, starting from the site plan and foundation plan with references to other sheets. Since the drawings were generated in black and white, students could refer to the rendering image on the cover sheet to determine the color of individual blocks.

Students were first allocated fifteen minutes to work with the CAD drawings. During this time, all groups were able to complete the site and foundation based on the drawings, although with possible mistakes. Once the students began to build the walls and chimney, all groups started to struggle with the information available from the drawings since it required frequent alternation between the different elevation sheets and section sheets. Students were then allowed to submit requests for information (RFIs) and started to talk about the difficulties with the CAD drawings. In response to the RFIs, they were instructed to locate the BIM model nwd file on the course page in the online learning system.

5.2 Introducing BIM and Navigation Tools

Once students had downloaded and opened the BIM model in Autodesk Navisworks, they were instructed to suspend construction of the Lego model house and focus on learning the basic features of Navisworks. All students showed great interest in learning the BIM model and believe it to be a better reference to build the rest of the model house. Students were then instructed to learn the navigation tools of pan, rotate, and zoom and practice the selection and view tools including select, select multiple, hide, and hide unselected (isolate). Finally, the thirteen created sets were introduced, and students were instructed to apply the navigation, selection, and view tools to browse

through each set. Once students become familiar with the BIM model, they were instructed to resume the Lego model house.

5.3 Building with 3D BIM Model

With the BIM model now available, students were able to identify individual blocks considerably easier by hiding other blocks or isolating the desired blocks. The BIM model also helped significantly in understanding the connection between different blocks by observing them from different views. While continuing with the walls, several groups quickly identified errors in their site installation due to overlapping blocks shown in the CAD drawings and had to rework on the site. Most groups had soon recognized the importance of the BIM model and assigned a dedicated member as the BIM person while other members focused on construction. This assignment of roles happened naturally and was a perfect resemblance of real-world projects where a dedicated BIM coordinator manages the BIM process. With the help of the BIM model, all groups successfully completed the Lego model house within the regular class period of one hour fifteen minutes.

6. Student Feedback

Although formal written feedback was not collected from students for this single hands-on session of the course, students were asked about their opinions about learning BIM with a Lego model house as an instructional tool. Students highly recognized the help of BIM in putting the physical model house together and strongly valued this hands-on session in the course. Students were able to easily identify the benefits of using BIM in CM through the hands-on session of building the Lego model house, which include:

(1) A BIM model can reveal a great number of details of a project that are simply hidden in a CAD drawing set due to the view limitations within the plan, elevation, and section sheets. These details often require references to various detail sheets in a drawing set if properly identified, otherwise they can be easily overlooked. With the BIM tools, these details can be located and understood easier;

(2) Objects in a BIM model can be either hidden or isolated so that the desired building components can be inspected without the obstruction of other objects in front of them. These features are particularly beneficial to students who are used to CAD drawings since they have now seen a new way to examine the relative position of building components. With the ability to isolate objects, referring to multiple CAD sheets in a drawing set to identify spatial location is no longer needed;

(3) A BIM model helps to reduce the number of errors tremendously in construction projects and as a result, less amount of rework is needed. In this hands-on session, clash detection was not introduced, and the amount of rework could be reduced simply by better understanding the project design;

(4) Because of the above advantages of 3D BIM models over 2D CAD drawings, it consequently reduces the time needed to complete the project. In real-world construction projects, shorter project duration translates to less project overhead cost, which benefits both the owner and the contractor.

Overall, students highly valued this hands-on session of using Lego blocks as an instructional tool to introduce BIM. Students believed it was a class session with lots of fun and at the same time they really learned and remembered the knowledge through the hands-on experience. Students appreciated the instructor's efforts in making the activity happen and wished to be able to do it again and in other CM courses, too.

7. Conclusions

Many CM programs in the U.S. have employed different strategies to integrate BIM contents in their curriculum as the construction industry is transitioning into the new BIM era. This paper presents a case study

that uses Lego blocks as an innovative instructional tool to introduce BIM to new CM students. The approach employs a physical Lego model house as the connection between the 2D and 3D worlds in an introductory BIM course and aims to demonstrate the benefits of BIM over 2D CAD through a hands-on session. The hands-on session has proven to prepare students for subsequent coursework and promote team building skills in a teamwork environment. This hands-on session was highly valued by students and helped them recognize the benefits of using BIM in CM. The case study presented in this paper demonstrates the procedures of using Lego blocks as an instructional tool in a hands-on session of an introductory BIM course.

References

[1] Huang, Y. 2018. "A Review of Approaches and Challenges of BIM Education in Construction Management." *Journal of Civil Engineering and Architecture* 12 (6): 401-7.

[2] McIntyre, C. 2013. "Development and Delivery of a First-Year 'Construction Management Experience' Course." *Proceedings of the 2013 ASEE North Midwest Section Conference*, Fargo, ND, October 17-18, 2013.

[3] Zolfagharian, S., Gheisari, M., Irizarry, J., and Meadati, P. 2013. "Exploring the Impact of Various Interactive Displays on Student Learning in Construction Courses." *Proceedings of the 120th ASEE Annual Conference and Exposition*, Atlanta, GA, June 23-26, 2013.

[4] Irizarry, J., Meadati, P., Barham, W.S., and Akhnoukh, A. 2012. "Exploring Applications of Building Information Modeling for Enhancing Visualization and Information Access in Engineering and Construction Education Environments." *International Journal of Construction Education and Research* 8 (2): 119-45.

[5] Boon, J. and Prigg, C. 2011. "Releasing the Potential of BIM in Construction Education." *Proceedings of the Management and Innovation for Sustainable Build Environment*, Amsterdam, Netherlands, June 20-23, 2011.

[6] Pikas, E., Sacks, R., and Hazzan, O. 2013. "Building Information Modeling Education for Construction Engineering and Management. II: Procedures and Implementation Case Study." *Journal of Construction Engineering and Management* 139 (11): 05013002.

[7] Nawari, N., Chichugova, T., Mansoor, S., and Delfin, L. 2014. "BIM in Structural Design Education." *Proceedings of the 2014 International Conference on Computing in Civil and Building Engineering*, Orlando, FL, June 23-25, 2014, 2143-2150.

[8] Scalza, A. 2007. "Organizational Behavior in the Classroom: Project Based and Experiential Learning in the Construction Management Curriculum." *Proceedings of the 2007 ASEE Middle Atlantic Section Fall Conference*, November 2007.

[9] Lee, N., Ponton, R., Jeffreys, A.W., and Cohn, R. 2011. "Analysis of Industry Trends for Improving Undergraduate Curriculum in Construction Management Education." *Proceedings of the 47th ASC Annual International Conference*, Omaha, NE, April 6-9, 2011.

[10] Associated General Contractors of America (AGC). *Building Information Modeling Education Program*. Accessed December 13, 2019. URL: https://www.agc.org/learn/education-training/building-information-modeling-education-program.

[11] Anderson, L. W., Krathwohl, D. R., Airasian, P. W., Cruikshank, K. A., Mayer, R. E., Pintrich, P. R., Raths, J. and Wittrock, M. C. 2001. *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives, Complete Edition*. Pearson, New York City.