Curriculum Development for Building Information Modeling

Heather Ciszczon
Arizona State University
Tempe, AZ 85281
heather@asu.edu

Allan D Chasey
Arizona State University
Tempe, AZ 85281
achasey@asu.edu

Abstract

Employers in the Architect Engineer Construction (AEC) industry have the expectation that construction school graduates will have a working knowledge of Building Information Modeling (BIM). Arizona State University's Del E. Webb School of Construction has been addressing that expectation by providing a senior level Project Management (CON 453) "BIM" course. Since implementation, the content and structure of the course has evolved and strengthened, due primarily to industry involvement.

BIM implementation at ASU focuses on a hands-on learning approach utilizing a combination lecture and lab. The practical realities of BIM are developed and reinforced during the weekly class supported by a variety of guest lecturers including architects, construction managers, subcontractors, engineers and suppliers. The lectures provide examples of how BIM has been put into practice across the project lifecycle, including topics in modeling, preconstruction, coordination, fabrication, and commissioning.

During the lab period, students use structured tutorials, supplemented with videos, to implement BIM skills, often utilizing real building information models. The customized tutorials provide a step-by-step guide to the software, allowing for self-paced learning, as well as easy future reference. Industry BIM professionals deliver the material, advising on best practices, challenges they face, and the importance of a skill within their day-to-day practice.

This paper will present sample tutorials of the curriculum. It will also describe how the content was developed, and how industry input was vital to that development. A framework for designing BIM coursework to meet evolving industry needs will be discussed.

Keywords: *Building Information Modeling (BIM), Curriculum Development, BIM Education*

1. INTRODUCTION

The Del E. Webb School of Construction (DEWSC) at Arizona State University is highly focused on preparing students for immediate entry into the construction industry workforce. The school has an extraordinary record of job placement, even in down economies. For instance, the Spring 2011 graduating class of nearly 80 students seeking employment all received job offers. The high placement rate has been attributed to the school's excellent relationship with the industry, and its responsiveness to industry needs and expectations.

One of those expectations has been that construction school graduates have a working knowledge of building information modeling (BIM) software and workflow. In one form or another, BIM has rapidly become the industry standard for commercial projects. Construction

companies in the southwest market tend to rely on new hires to acquire appropriate talent rather than re-training in-house personnel. There is a lack of trained and qualified graduates to meet demand (Pavelko & Chasey, 2010). Recognizing this need, the DEWSC has incorporated BIM coursework into the construction management program for undergraduate students.

2. BIM COURSE DESIGN

Several factors shaped how BIM was incorporated into the undergraduate construction management curriculum at ASU. First, it had to be added to an already full program as a standalone BIM/Project Management course, and accordingly had to be accomplished in one semester. This was due to a variety of reasons including meeting accreditation criteria, adding additional courses in an already full curriculum, and the incorporation of ever-changing software and workflow for a new course.

Given the standalone course decision and the need to have a broad knowledge of construction means and methods, estimating, scheduling, and team management as necessary prerequisites for BIM training (the classic chicken vs. egg scenario), this dictated the need to deliver the BIM course in a student's senior year. It was also recognized that BIM for construction students is not the same as BIM for architectural and/or engineering students. The construction industry uses BIM tools in a different way and for different reasons than designers. Accordingly, the course design had to be created with construction in mind, which meant it had to be developed from the ground up and not borrowed from another discipline.

DEWSC has offered the senior level course in BIM for construction since 2008 and has continuously updated and improved the course based on industry response, software developments, and lessons learned from each course. The current course design is based on an integrated lecture/lab approach, both equally critical to the student's success in acquiring a working knowledge of BIM.

3. LECTURE DESIGN

The lecture portion of the course meets twice a week and is important because it places BIM in the context of the AEC industry as a whole. This is accomplished through guest lectures from industry professionals representing the various stakeholders in a typical project. This component gives students a real-time and real-world sense of BIM's role in the construction of commercial projects. Industry professionals from contractors, architects, subcontractors, suppliers and vendors provide an industry wide view of the implementation of BIM tools in the industry today. The project life-cycle is thoroughly discussed as well as understanding the development of a BIM execution plan.

4. LAB DESIGN

The labs meet once per week and are designed provide a higher teacher/student ratio. Industry professionals assist with the class to provide the students with the clear message that BIM is highly integrated into the construction process. Also, the content of the lectures and labs are designed to be closely aligned to ensure that the theory and application processes are understood in addition to just software training.

The DEWSC experience has demonstrated that teaching BIM software modules in the lab setting is best accomplished by using self-paced tutorials aimed at specific tasks incrementally building upon another. This is primarily because students come to the lab with varying levels of

computer proficiency, experience with CAD-type software packages, the ability to visualize in three dimensions, and learning processes. The self-paced tutorials enable students to deal directly with the material and avoid the challenges of pacing a lab for the both the quick and slow students. The tutorials also make it possible for students to work outside the lab setting if they require more time to accomplish any given module or want to study particular material further. Another advantage is to serve as a reference, not only for the final project, but post-school in potential jobs, given that very little construction-oriented BIM reference material is currently available.

The progression of exercises given in the labs roughly parallels the workflow of a typical commercial project as it moves from concept through construction documents to the construction process. The tutorials were developed to promote a continuous experience of building a single project, the College of Nursing facility at ASU's downtown campus. Students were provided part of the architectural model, as well as subcontractor fabrication models, to complete the tutorials. This emphasizes the lifecycle of the project in a BIM setting, as well as the real-world challenges of file size, maintenance, and clashing issues. The software packages used represent the range of tools commonly used including Google SketchUp, Autodesk Revit Architecture, and Autodesk Navisworks Manage. A list of tutorials for the semester is given in Appendix A.

5. TUTROIALS

The individual tutorials for the school year were developed by the lab teaching assistance in the Del E Webb School of Construction using previous semester's material as a foundation. Tutorial modules are custom-designed or adapted from software vendor examples or construction company in-house training materials. While the tutorials are specifically task/skill-based, with step-by-step instructions, each lab began with a big picture discussion of the skill set being developed. Industry professionals from Phoenix-based commercial general contractors deliver the material at each of the labs. This reinforces the applicability of the skill sets, as well as gave students the ability to question processes and workflows. The industry experts advise on best practices, the importance of particular skills to their specific company, and the challenges they face, providing students with concrete examples of how BIM is practiced in reality, outside of the given material in the tutorials.

Each tutorial is discussed and demonstrated by an industry professional and/or teaching assistant at the beginning of the lab. Students can work along with the instructor during the demonstration or they can observe, take notes, and attempt the module after the demonstration. Each lab is two hours long and the initial discussion typically lasts under 30 minutes. This allows plenty of time for one-on-one questions during the lab. Sufficient teaching assistants and lab instructors are available to ensure students do not have to wait long to obtain assistance. Students are also encouraged to use their peers as an additional resource. To receive credit for each assignment, students are required to electronically submit a deliverable in a specified format.

6. TUTORIAL CASE STUDY

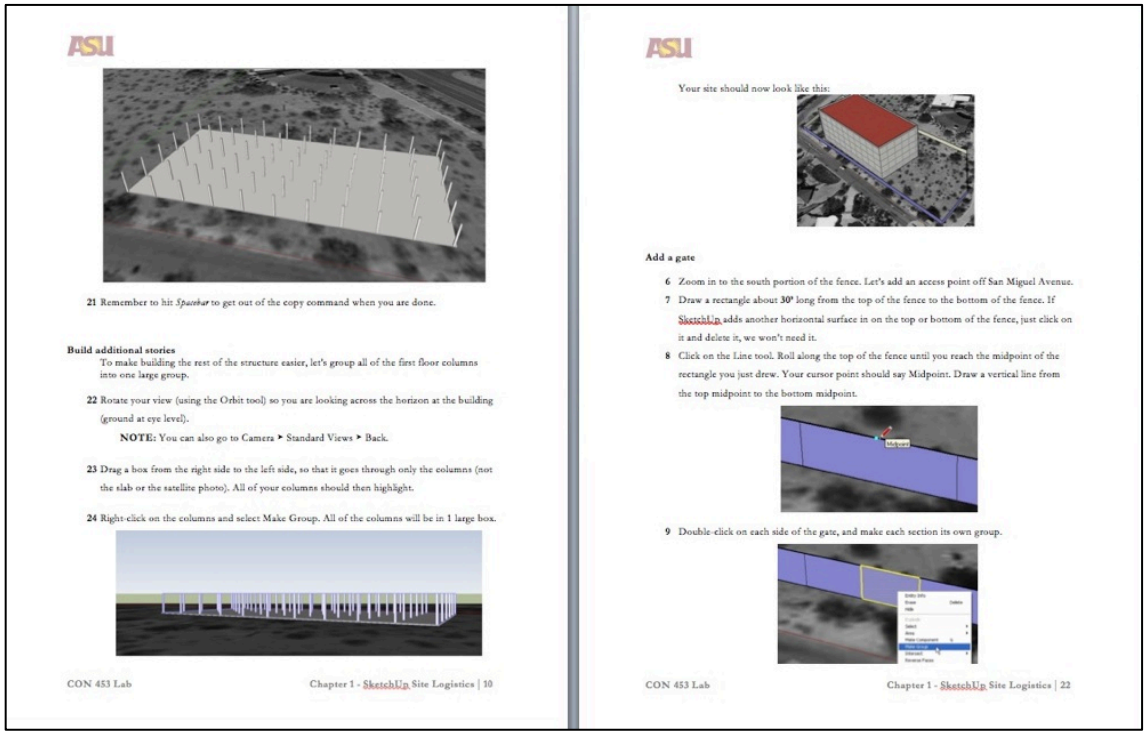
ASU's College of Nursing and Health Innovation building provides a home to one of the largest nursing programs in the U.S. and serves as the downtown campus gateway. A fast-track, design-build project costing $27million, the 84,000 square-foot, 5-story building houses classrooms, labs, faculty offices, a conference space with a 200-seat auditorium, and student facilities in an

urban greenfield setting. The building, which is located at Third and Fillmore streets in the heart of downtown Phoenix, was completed in July 2009 and is LEED Gold certified (Figure 1).

Figure 1. Case study used in tutorials – the ASU College of Nursing Building, Phoenix, Arizona

7. BIM TUTORIALS

Google SketchUp is the first software package the students encounter due to its simple interface, ease of use, and immediate visualization capabilities, which parallel architectural workflows. In working through the SketchUp tutorial modules (Figure 2) over the course of two weeks the students are introduced to 3D modeling concepts and skills, with emphasis placed on skills used in the construction setting, rather than in design. Students learn modeling skills that relate directly to project startup logistics discussed in the lecture portion of the class, including creating a 3D placeholder building on a site, layout of the construction yard and fencing, and placing equipment, to allow for review by the construction team.



ASU

21 Remember to hit *Spacebar* to get out of the copy command when you are done.

Build additional stories

To make building the rest of the structure easier, let's group all of the first floor columns into one large group.

22 Rotate your view (using the Orbit tool) so you are looking across the horizon at the building (ground at eye level).

NOTE: You can also go to Camera ▸ Standard Views ▸ Back.

23 Drag a box from the right side to the left side, so that it goes through only the columns (not the slab or the satellite photo). All of your columns should then highlight.

24 Right-click on the columns and select Make Group. All of the columns will be in 1 large box.

CON 453 Lab Chapter 1 - SketchUp Site Logistics | 10

ASU

Your site should now look like this:

Add a gate

6 Zoom in to the south portion of the fence. Let's add an access point off San Miguel Avenue.

7 Draw a rectangle about 30' long from the top of the fence to the bottom of the fence. If SketchUp adds another horizontal surface in on the top or bottom of the fence, just click on it and delete it, we won't need it.

8 Click on the Line tool. Roll along the top of the fence until you reach the midpoint of the rectangle you just drew. Your cursor point should say Midpoint. Draw a vertical line from the top midpoint to the bottom midpoint.

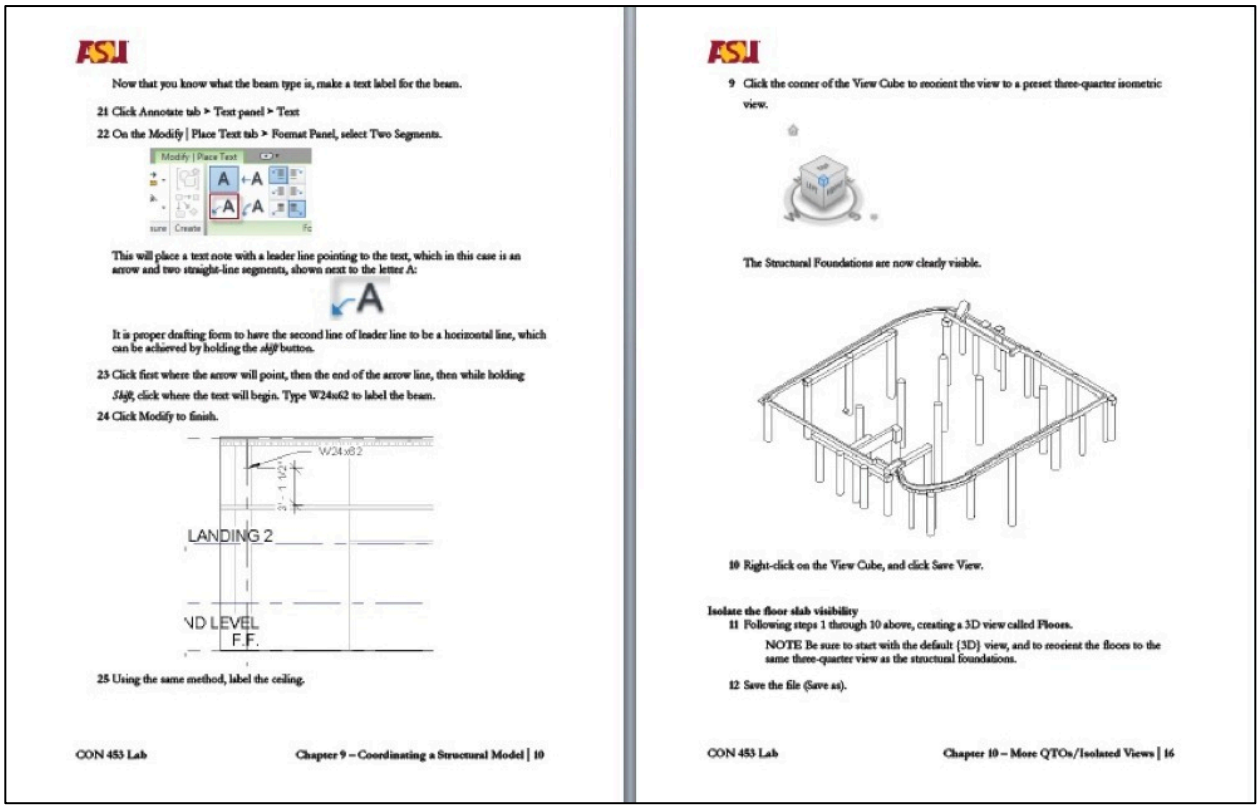
9 Double-click on each side of the gate, and make each section its own group.

CON 453 Lab Chapter 1 - SketchUp Site Logistics | 22

Figure 2. SketchUp tutorials. Left: modeling the building on the site. Right: adding a site fence gate.

The Autodesk product Revit Architecture is the second software package encountered by the students (Figure 3). This represents a significant step up in difficulty because of the complexity of the program and the different layout of the program's interface, as well as the parametric "smart" 3D modeling capabilities. All the tutorials are conducted in Revit Architecture though the computers in the lab are also loaded with Revit Structure and Revit MEP.

The Revit portion of the course is broken into 10 tutorial "chapters" which are investigated over a period of 5 weeks. In working through the second group of tutorials, the students develop elementary modeling skills, which provide them the ability to perform site modeling, as well as understand the design workflow within the software structure. Once basic modeling principals are understood, including datums/grids, element properties, and sheet set up, students are then asked to investigate complex models from a construction perspective. To engage students in model analysis and extraction skills, the tutorials task them to perform quantity takeoffs and execute model element and family changes, as well as create sections and isolated views for visualizing constructability.



Now that you know what the beam type is, make a text label for the beam.

21 Click Annotate tab > Text panel > Text

22 On the Modify | Place Text tab > Format Panel, select Two Segments.

This will place a text note with a leader line pointing to the text, which in this case is an arrow and two straight-line segments, shown next to the letter A:

It is proper drafting form to have the second line of leader line to be a horizontal line, which can be achieved by holding the *shift* button.

23 Click first where the arrow will point, then the end of the arrow line, then while holding *Shift*, click where the text will begin. Type W24x62 to label the beam.

24 Click Modify to finish.

25 Using the same method, label the ceiling.

CON 453 Lab Chapter 9 – Coordinating a Structural Model | 10

9 Click the corner of the View Cube to reorient the view to a preset three-quarter isometric view.

The Structural Foundations are now clearly visible.

10 Right-click on the View Cube, and click Save View.

Isolate the floor slab visibility

11 Following steps 1 through 10 above, creating a 3D view called Floors.

NOTE Be sure to start with the default {3D} view, and to reorient the floors to the same three-quarter view as the structural foundations.

12 Save the file (Save as).

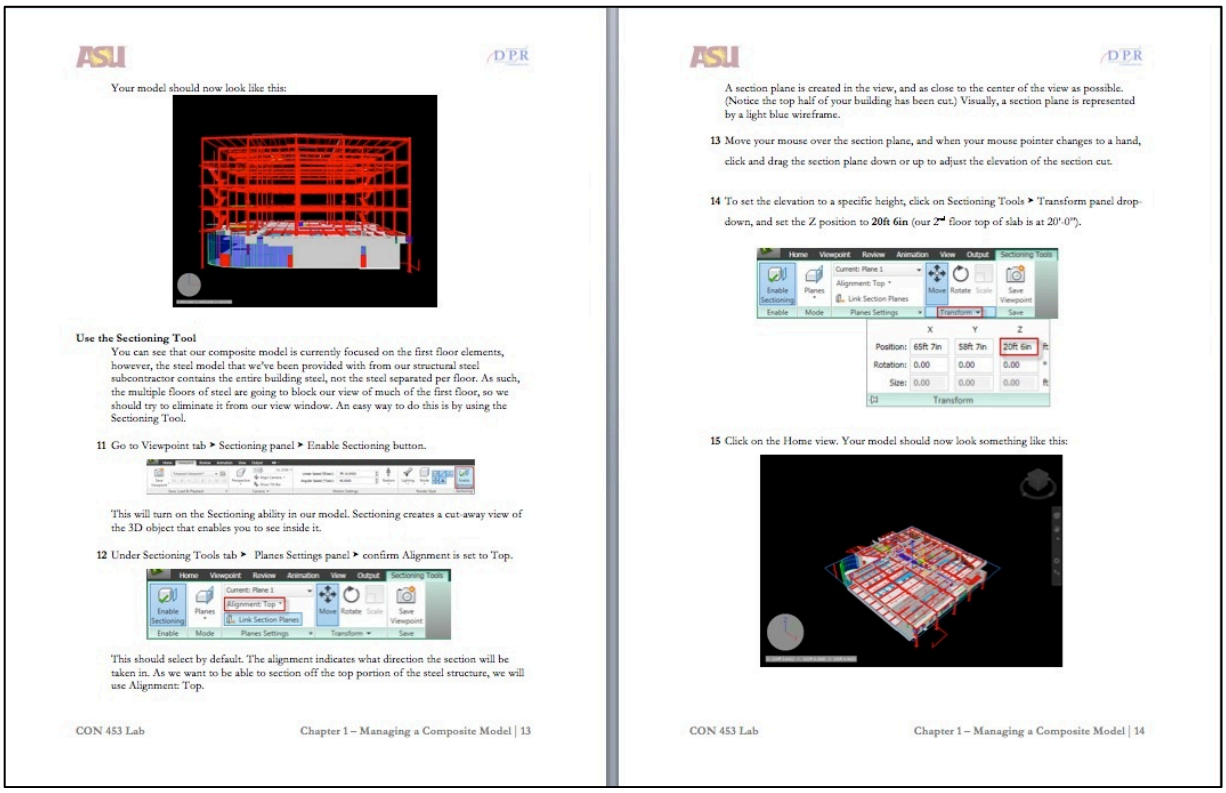
CON 453 Lab Chapter 10 – More QTOs/Isolated Views | 16

Figure 3. Revit tutorials. Left: Identify and annotate a beam. Right: Isolating the foundation view.

Autodesk's Navisworks Manage is the third and final package studied by the students (Figure 4). This software is usually easier for the students to learn because it maintains a similar interface as Revit. However, the practicalities of understanding file types, and maintaining an organizational system for model updating can offset the familiarity with interface.

During the 4-week, 4 chapter Navisworks portion of the class, students are given actual construction models of the College of Nursing building, including architectural, structural,

ductwork, and fire protection. Before students can perform clash detection analysis and create sequencing 4D animations, they learn to navigate a model and manipulate elements and views, critical skills for entry BIM engineers. Given real-world models to clash, students often lack the experience to distinguish trade components, and understand priority relationships. For example, students identify a fire sprinkler branch line conflict with a main line duct as a "pipe" clash with duct, and will relocate the duct instead of the branch line. Regardless, the process of clash detection, and the value of a federated model that can easily be navigated are well understood by students at the end of the module.



Your model should now look like this:

Use the Sectioning Tool

You can see that our composite model is currently focused on the first floor elements, however, the steel model that we've been provided with from our structural steel subcontractor contains the entire building steel, not the steel separated per floor. As such, the multiple floors of steel are going to block our view of much of the first floor, so we should try to eliminate it from our view window. An easy way to do this is by using the Sectioning Tool.

11 Go to Viewpoint tab ➤ Sectioning panel ➤ Enable Sectioning button.

This will turn on the Sectioning ability in our model. Sectioning creates a cut-away view of the 3D object that enables you to see inside it.

12 Under Sectioning Tools tab ➤ Planes Settings panel ➤ confirm Alignment is set to Top.

This should select by default. The alignment indicates what direction the section will be taken in. As we want to be able to section off the top portion of the steel structure, we will use Alignment: Top.

CON 453 Lab Chapter 1 – Managing a Composite Model | 13

A section plane is created in the view, and as close to the center of the view as possible. (Notice the top half of your building has been cut.) Visually, a section plane is represented by a light blue wireframe.

13 Move your mouse over the section plane, and when your mouse pointer changes to a hand, click and drag the section plane down or up to adjust the elevation of the section cut.

14 To set the elevation to a specific height, click on Sectioning Tools ➤ Transform panel drop-down, and set the Z position to **20ft 6in** (our 2nd floor top of slab is at 20'-0").

15 Click on the Home view. Your model should now look something like this:

CON 453 Lab Chapter 1 – Managing a Composite Model | 14

Figure 4. Navisworks Manage tutorial. Left: section through a composite model. Right: Horizontal sections.

A final project using real-world Target store models incorporates a comprehensive assessment of the semester. Students start back with SketchUp to build a site logistics plan for the building; create quantity takeoffs and sectional constructability details in Revit; and perform clash detection and sequencing animations in Navisworks.

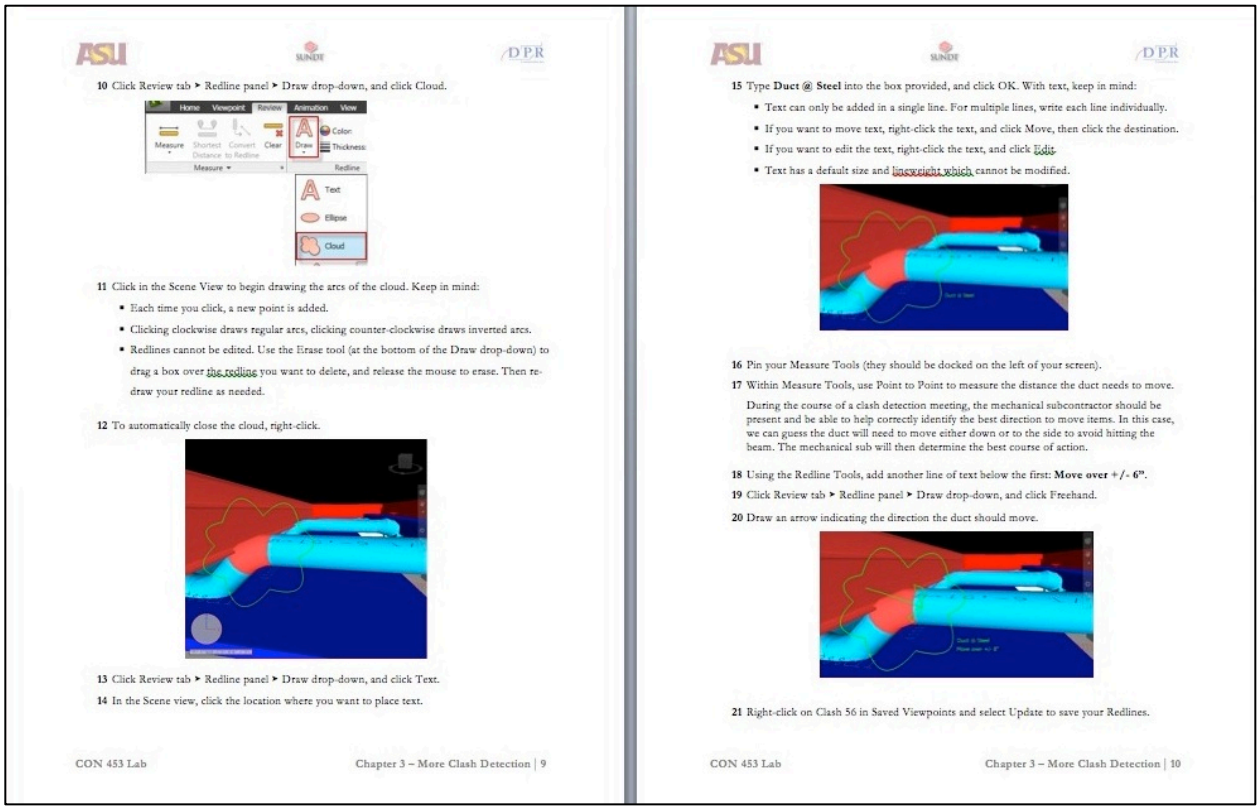
8. CONCLUSION

The experience of the DEWSC's most recent graduating class demonstrated convincingly that BIM training in the context of a well-rounded curriculum greatly enhances the employability of construction students. Moreover, it has been confirmed over the three years of implementing the DEWSC BIM program that lectures or labs alone are not enough – students require both learning methods in order to develop the intellectual and practical skill necessary to function in BIM project environments.

Nonetheless, the curriculum for students in construction management must evolve. First, it must continue to parallel and mimic how BIM is implemented by the industry. Second, it must

continually be updated as the software evolves. Third, it must continually be refined to accommodate and enhance student abilities and learning styles.

Finally, the notion of BIM training for construction students as a standalone course may fall by the wayside. A better pedagogy may be to review every course and find ways to include appropriate BIM material within each and every one.



10 Click Review tab ➤ Redline panel ➤ Draw drop-down, and click Cloud.

11 Click in the Scene View to begin drawing the arcs of the cloud. Keep in mind:

- Each time you click, a new point is added.
- Clicking clockwise draws regular arcs, clicking counter-clockwise draws inverted arcs.
- Redlines cannot be edited. Use the Erase tool (at the bottom of the Draw drop-down) to drag a box over the redline you want to delete, and release the mouse to erase. Then re-draw your redline as needed.

12 To automatically close the cloud, right-click.

13 Click Review tab ➤ Redline panel ➤ Draw drop-down, and click Text.

14 In the Scene view, click the location where you want to place text.

CON 453 Lab Chapter 3 – More Clash Detection | 9

15 Type **Duct @ Steel** into the box provided, and click OK. With text, keep in mind:

- Text can only be added in a single line. For multiple lines, write each line individually.
- If you want to move text, right-click the text, and click Move, then click the destination.
- If you want to edit the text, right-click the text, and click Edit.
- Text has a default size and lineweight which cannot be modified.

16 Pin your Measure Tools (they should be docked on the left of your screen).

17 Within Measure Tools, use Point to Point to measure the distance the duct needs to move.

During the course of a clash detection meeting, the mechanical subcontractor should be present and be able to help correctly identify the best direction to move items. In this case, we can guess the duct will need to move either down or to the side to avoid hitting the beam. The mechanical sub will then determine the best course of action.

18 Using the Redline Tools, add another line of text below the first: **Move over +/- 6"**.

19 Click Review tab ➤ Redline panel ➤ Draw drop-down, and click Freehand.

20 Draw an arrow indicating the direction the duct should move.

21 Right-click on Clash 56 in Saved Viewpoints and select Update to save your Redlines.

CON 453 Lab Chapter 3 – More Clash Detection | 10

Figure 5. Navisworks Manage tutorial. Left and Right: Clash detection isolated on structural steel vs. ductwork.

9. ACKNOWLEDGEMENT

Genuine appreciation to the dedicated industry professionals at DPR Construction, Gilbane Building Company, and Sundt Construction who provided materials, support, and served as instructors for the BIM lab.

10. REFERENCES

Pavelko, C., and Chasey, A., "Building Information Modeling in Today's University Undergraduate Curriculum", Digital Proceedings, BIM-Related Academic Workshop, Session 100, EcoBuild America, Washington, D.C., 7-9 Dec, 2010.

Appendix A

The tutorial modules used over the course of a one semester lab on BIM for Construction:

Unit	Software	Subject
1	SketchUp	Intro to SketchUp
2	SketchUp	Creating a Site Logistics Plan and Adding Elements
3	Revit	Intro to Revit. Creating a Site and Adding Elements
4	Revit	Datums and Grids
5	Revit	Working with Basic Elements: Slabs, Columns, and Walls
6	Revit	Changing the Properties of Elements: Roof, Doors, and Windows
7	Revit	Tracing from 2D Drawings
8	Revit	Quantity Take Offs – Exporting to MS Excel
9	Revit	Working with Sheets for Plotting
10	Revit	Linking to a Structural Model and Notating Sections
11	Revit	Quantity Take Offs with Isolated Views
12	Navisworks	Intro to Navisworks. Interface, File Types, Navigating
13	Navisworks	Clash Detection Basics: Batches, Results, Measuring, Views
14	Navisworks	More Clash Detection: Updating Files, Redline Tools
15	Navisworks	4D Timeliner: Import Schedules, Create Tasks, Search Sets, Export