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## **Construction Software Technology Education at California Polytechnic State University – San Luis Obispo**

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### **ABSTRACT**

This paper discusses the challenges, accomplishments and overall process of teaching Building Information Modeling (BIM) at a major university. The focus of the California Polytechnic State University – San Luis Obispo (Cal Poly-SLO) Construction Management Department's Technology class was to introduce and utilize relevant technologies currently deployed within the Architecture, Engineering and Construction (AEC) industry. Industry partners from the Cal Poly-SLO Construction Management Advisory Council (CMAC) participated in a survey and/or an interview to understand industry expectations in regards to technology readiness from a future graduate. Based on these results and the support of the departments Technology Advisory Committee (CTAC), the course implemented ten of the top software platforms into the class. Following each quarter course session, students participate in a survey regarding their understanding of the software tools and whether they feel confident deploying those tools in their professional careers. This paper introduces the software platforms introduced in the course, the lab-based exercises the students complete in order to prepare graduates to be successful entering the workforce and the results of the industry and student surveys/interviews. Further survey/interview data will be collected to determine if the construction technology skill-set development fulfills the dual goals of preparing students as well as graduating 1<sup>st</sup>-year AEC professionals capable of utilizing these software platforms effectively and efficiently. UPDATE: Due to the reviewers comments upon abstract acceptance, the paper was expanded to include a comparison of BIM curriculum deployment at a similar institution.

### **1. INTRODUCTION**

As industry continues to embrace the use of technology and Building Information Modeling (BIM) workflows, institutes of higher education around the country are attempting to respond to the trend and prepare their graduates for this modern workplace (Wu, 2014). The institutes of focus for this paper are California Polytechnic State University, San Luis Obispo, located in San Luis Obispo, California (Cal Poly – SLO) and Wentworth Institute of Technology, located in Boston, Massachusetts (WIT). Each university's intent with their respective construction management departments is to provide an education that meets and exceeds the requirements for accreditation through the American Council for Construction Education (ACCE), wherein a basis for curriculum is stated as follows:



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“The purpose of curriculum... is to prepare graduates who can provide leadership roles in construction... The curriculum should be responsive to social, economic, and technical developments and should reflect the application of evolving knowledge in construction...”

The ACCE encourages accredited programs to regularly evaluate current curricula and develop new curricula that reflect changing construction technologies and management trends” (ACCE, 2018).”

An additional requirement for ACCE Accreditation is for the school to engage with industry regularly through the development of a panel of professionals that help provide insight into the current status of industry and to advise the program in ways to consistently produce graduates who can provide immediate value to the industry. This panel is known as an Industry Advisory Board (IAB). As an outcome of regular meetings and strong relationships with their respective IAB’s, both Cal Poly - SLO and Wentworth Institute of Technology have identified (through both formal and informal discussions and surveys) that current industry professionals who are able to hire graduates, are looking for students with direct knowledge of BIM software. This finding was the impetus for reflecting on the current status of courses at each institute. As an outcome of this reflection and revision process, both schools have created ways to introduce students to BIM software through an introductory course but in very different ways. The purpose of the following discussion is to compare/contrast the approach of each course and provide a baseline for further development of a standardized, BIM-integrated curriculum.

### 1.1 Institutional Synergy

During the course of this study, it became clear that both construction management programs at Cal Poly – SLO and WIT share similar ideologies. While the approach to satisfy those ideologies may be different at each institution, one of the fundamental pedagogical concepts deployed by both is that of experiential learning. Per Kolb (1984), “Knowledge is derived from and tested out in the experiences of the learner”. In addition, both CM programs are located within similar colleges – WIT in the College of Architecture, Design and Construction Management and Cal Poly – SLO in the College of Architecture and Environmental Design. The collaborative nature of each of these colleges that house the CM programs promotes the experiential learning concepts with studio/lab courses that provide the students with the ability to apply theory to practice. Wentworth promotes the Creative Problem Solving/Spirit of Innovation ethos and Cal Poly’s Learn-by-Doing philosophy has been the foundation of the institution since its inception. Both approaches attempt to accomplish the same goal, producing men and women that have the technical skills to be successful upon entry into industry.

Specifically, regarding the BIM education deployment at each institution, it should also be noted that both Cal Poly – SLO and WIT partner with some of the major AEC software providers commonly utilized in industry today. The collaborative relationships both institutions have with the following entities, among many, are critical to the success of our students: Autodesk; Bluebeam®; Trimble; Procore®, etc. Without this software industry support, our students would not have the ability to experience current industry practices.

### 1.2 Background

To preface, both authors of this paper have a prior history of collaboration through their respective graduate work at Arizona State University’s Del E. Webb School of Construction (ASU DEWSC). While researching and teaching at ASU as part of their Ph.D. program, they were integral in the development of an interdisciplinary, BIM-based course called CON 575 – Information Technology in Construction. This course was a collaboration between graduate students in the Construction Management Master’s Degree program



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and the Master of Architecture Degree program within the Herberger Institute for Design and the Arts. The impetus for the development of this course stemmed from research undertaken by the authors while at ASU indicating a growing interest among students in learning about BIM workflows for career preparation. At the time of the initial course offering for CON 575, it was the author's belief that "an enhanced collaboration environment utilizing a cross-disciplinary pedagogical model will enhance student learning and provide greater value to BIM education as a whole" (Cribbs et al., 2015). This is still the ideal outcome, but the approach has been simplified.

### **1.3 Discussion**

Borrowing from the experience at Arizona State University discussed above, each author assisted their current respective institute in revising an introductory level course offering to engage more of the required BIM aspects identified by their Industry Advisory Boards. Wherein the CON 575 course discussed above was a trial in modifying a course based on identified trends in student learning while simultaneously responding to "the changing requirements of the National Architectural Accrediting Board (NAAB) and the American Council for Construction Education (ACCE) (Cribbs 2015)," each of the courses recently developed at Cal Poly SLO and WIT are meant to be a continued response to IAB requests, as well as the newly updated requirements of the ACCE accreditation process, at the undergraduate level. These courses are solely focused on the Construction Management curriculum and currently omit the requirements of NAAB.

## **2.0 WENTWORTH INSTITUTE OF TECHNOLOGY – CONM 1500: CONSTRUCTION GRAPHICS**

At Wentworth Institute of Technology, CONM 1500: Construction Graphics is a course offered to freshman during their spring semester. This course is the students first formal exposure to construction documents (drawings and specifications), as well as Building Information Modeling (both software solutions and workflows). This course sets the groundwork for the following ACCE student Learning Outcomes (SLO's):

- SLO 7 - Analyze construction documents for planning and management of construction processes;
- SLO 10 - Apply electronic-based technology to manage the construction process.

In order to meet these requirements, the course is broken into two lab components: Plan Reading & Revit. "The course introduces the fundamentals of various drawing techniques that are used in the creation of a set of construction plans and teaches students how to read and interpret information on civil, architectural, and structural prints. It also introduces a computer-aided drafting software such as Revit" (CONM 1500 Syllabus, WIT). Per the course syllabus, students should be able to do the following upon completion of the course:

### **2.1 Analyze construction documents for planning and management of construction processes**

- Sketch simple objects using pictorial drawing methods
- Draw orthographic views of an object
- Identify different kinds of drawings that form a set of construction drawings and how they are organized
- Recognize symbols that represent various items and products such as building materials and fixtures
- Interpret and use specific information from drawings
- Use architectural/engineering scales to measure scaled dimensions
- Apply mathematical operations using architectural dimensions

### **2.2 Apply electronic-based technology to manage the construction process**

- Use Revit to open, manage, and modify previously developed 3D model files
- Describe the basic drawing and editing tools in Revit
- Develop basic 3D building models with components such as walls, windows, doors, floors, and roofs
- Create different views and sections in a Revit model
- Set up sheets for plotting with text, dimensions, details, tags, and schedules

Week#	Revit Lab Topic	Plan Reading Lab Topic
1	-Introduction -Starting an Architectural Project	-Introduction -Construction Drawing Organization -Construction Math and Application
2	-Creating Walls -Using Basic Building Components-I	-Lines and Symbols -Fundamental Drawing Practices (Pictorial) -Fundamental Drawing Practices (Multiview)
3	<i>No Monday (01/21/2019) Class: MLK Holiday</i>  -Using the Editing Tools	<i>No Monday (01/21/2019) Class: MLK Holiday</i>  -Reading Measuring Tools and Using Scales  -Site Plans
4	-Working with Datum Plane and Creating Standard Views	-Architectural Drawings (Floor Plans and Schedules)
5	-Using Basic Building Components-II	<i>Exam 1</i>
6	-Using Basic Building Components-III	-Architectural Drawings (Elevations and Sections)
7	<i>No Monday (02/18/2019) Class: Presidents Day Holiday</i>  -Adding Site Features -Using Massing Tools	<i>No Monday (02/18/2019) Class: Presidents Day Holiday</i>  -Foundation Prints 1
8	-Adding Annotations and Dimensions	-Foundation Prints 2

Week#	Revit Lab Topic	Plan Reading Lab Topic
	<i>&amp; <u>Start Working on the Project</u></i>	
	<b>Spring Break: 03/02/2019 thru 03/08/2019</b>	
9	-Creating Project Details and Schedules <i>&amp; <u>Working on the Project</u></i>	-Structural Prints -Welding Prints
10	-Creating Drawing Sheets and Plotting <i>&amp; <u>Working on the Project</u></i>	<i>Exam 2</i>
11	- Creating 3D Views <i>&amp; <u>Working on the Project</u></i>	-Residential Framing Prints
12	- Rendering Views and Creating Walkthrough - Using Advanced Features <b>Revit Lab Exam for W, Th &amp; F sections</b>	-Specifications and Building Codes -Construction Materials - Types and Uses
13	<b>Revit Lab Exam for M sections</b> <b><i>Final Projects Due in Lab</i></b>	-Estimating Construction Costs
14	<i>No Monday (04/15/2019) Class: Patriot's Day Holiday</i> <i>Classes end on Tuesday 04/16/2019</i>	<i>No Monday (04/15/2019) Class: Patriot's Day Holiday</i> <i>Classes end on Tuesday 04/16/2019</i>
15	<b>Final Exam Period: 04/18/2019 thru 04/23/2019</b>	<b>Final Exam Period: 04/18/2019 thru 04/23/2019</b>

During the spring semester of the 2019 academic year, the course spanned seven (7) sections of approximately 15-20 students each. The lead instructor coordinated across 6 faculty members, three of which were full-time professors and 3 which were dedicated adjuncts from industry. The class period itself was a dedicated lab session that was scheduled for 2 hours and 50 minutes twice per week and totals three (3) credit hours at the Institute level. There are no prerequisites required to enroll in this course. The makeup

of this course is interesting to note, as the students engaged will simultaneously be learning how to read construction plans, elevations, sections, schedules, etc. while concurrently modeling buildings in Revit, with an end goal of creating a basic set of construction drawings from the model. This approach may seem counter-intuitive, as modeling a building requires a student to know how to read drawings and this course is most likely their first formal exposure to plans and specifications (except those with prior industry experience). To assist with this potential information disconnect, the course is structured to present the fundamentals of drafting views during the first two weeks of the plan reading portion of the lab while an overview of BIM and the Autodesk user interface is introduced in the Revit lab portion. This frontloads the basics of each portion of the class and allows the students to begin understanding how to think in 3d by lifting two-dimensional drawings (multi-view pictorials) into axonometric and perspective views in the Plan Reading Lab prior to modeling in the Revit portion of the course.

The main classroom in which the Revit portion of CONM 1500 is taught, is modeled to be a collaborative work environment. The space is reconfigurable so that student workstations can be grouped together in clusters of four (4) or aligned in rows for more of a lecture style learning environment. This type of reconfigurable lab space has been proven as an effective learning environment via previous research undertaken by Chasey et al. (2012), in which they developed the “Virtual Construction and Collaboration Lab (VC<sup>2</sup>L) (figure 2)” to foster continuous and spontaneous interaction among student peers and instructors (Figure 3 through 6).



**FIGURE 1: PROPOSED VC<sup>2</sup>L LAYOUT (CHASEY ET AL. 2012) - USED W/ PERMISSION FROM AUTHOR(S)**



**FIGURE 3: CLUSTER LAYOUT OF BOND VIRTUAL DESIGN & CONSTRUCTION LAB AT WIT (IMAGE TAKEN DURING FINAL PHASE OF FIT-OUT)**





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The lab also contains state of the art computing technology. The front of the classroom contains three large monitors that are controlled via the instructor's workstation, which subsequently has three computer monitors connected to the server tower. These visual controls also connect to a smart projector on the sidewall of the room so students near the back of the classroom can have greater visual access to live demonstrations which are being presented via any of the computer monitors at the instructor's table. This smart projector also allows the instructors to capture redlines and snapshots of model demonstrations so they can be uploaded to a Learning Management System (LMS) for all students to review following the lab session. Every student has their own laptop and engages their own hardware and software in each of the labs. This setup allows students a lot of freedom to collaborate and learn in both a formal classroom setting and individual setting with the similarity of the same computer.

### **3.0 Cal Poly – SLO – CM 280: Building Information Modeling**

Similar to CONM 1500, the CM 280 course at Cal Poly – SLO offers students their first immersion into the technology world of the architecture, engineering and construction (AEC) environments. The course description per the Cal Poly – SLO catalog is as follows:

“Use of building information modeling software to emphasize residential, commercial, and heavy civil assembly methods and techniques. BIM drafting applications integrated with construction materials, details, and assemblies supporting the understanding of the construction building process.”

Per the Winter Quarter 2019 syllabus, the specific Course Goals and Course Learning Outcomes (CLO's) are:

- **Course Goals:**
  - To demonstrate an ability to use a number VDC/BIM programs and the variety of the tools each program has to offer, demonstrated through the mastery of CLO's;
  - To demonstrate an ability to create models, schedules, and estimates with an emphasis on 3D models, demonstrated through the mastery of CLO's;
  - To demonstrate an ability to extract construction information using current industry BIM/VDC practices, demonstrated through the mastery of CLO's.
- **Course Learning Outcomes (CLO's):**
  - Understand why BIM is an important part of the Construction Industry, and how it is utilized by companies in the industry;
  - Grasp the concepts of 3D (information model), 4D (construction sequencing), and 5D (Cost);
  - Learn about various VDC/BIM programs – their strengths and weaknesses;

- Obtain basic knowledge in each program to create models, schedules, and estimates with an emphasis on 3D models and how to extract information;
- Be able to read, generate, and transfer CAD drawings to accurately depict the model.

In addition, the course also supports several ACCE SLO's as noted below.

- SLO 1: Create written communications appropriate to the construction discipline;
- SLO 4: Create construction project cost estimates;
- SLO 5: Create construction project schedules;
- SLO 10: Apply electronic-based technology to manage the construction process (embedded assessment instrument);
- SLO 15: Understand construction quality assurance and control.

The Cal Poly – SLO curriculum committee has synergized the goals, CLO's and ACCE SLO's into this mandatory course for all CM majors. The structure of the course is unique in the fact that while it was instructor designed, it is primarily peer-to-peer content delivery. Utilizing Instructional Student Assistants (ISA's), the interaction between peers and cohorts results in a richer student experience collaborative environment. Plus, due to the amount of material and software covered during a quarter session, it is beneficial to have students who have been through the course to assist in leading the students through the course deliverables as well as becoming champions of the content through innovation and refinement of weekly deliverables. As is noted in the course schedule below, the CM 280 class covers a multitude of software platforms as well as the interoperability between the software.

Choose Unit Type	Topical Outline	CLOs	PLOs	Instructional Activities	** Method of Assessment
<b>Module I</b>	<b>BIM Intro / Bluebeam</b> Assignment 1: BIM Intro Assignment 2: Bluebeam	1 – 5	10 1, 10	Lecture and Program Walk-Through	2, 3 1 1
<b>Module II</b>	<b>Revit</b> Assignment 3a: Revit Floorplans Assignment 3b: Revit Renderings	1 – 5	10 10	Lecture and Program Walk-Through	2,3 1 1
<b>Module III</b>	<b>Assemble</b> Assignment 4: Assemble Takeoff	1 – 5	4, 10	Lecture and Program Walk-Through	2,3 1
<b>Module IV</b>	<b>ArchiCAD</b> Assignment 5a: ArchiCad Floorplans Assignment 5b: ArchiCad Renderings	1 – 5	10 10	Lecture and Program Walk-Through	2,3 1 1
<b>Module V</b>	<b>Tekla</b> Assignment 6a: Tekla Model Assignment 6b: Tekla Takeoff	1 – 5	4, 10 10	Lecture and Program Walk-Through	2,3 1 1
<b>Module VI</b>	<b>Microsoft Excel</b> Assignment 7: Excel Project	1 – 5	4, 15	Lecture and Program Walk-Through	2,3 1
<b>Module VII</b>	<b>Navis Works/BIM 360 Glue</b> Assignment 8: Clash Report & RFI	1 – 5	1,10	Lecture and Program Walk-Through	2,3 1
<b>Module VIII</b>	<b>Sketchup</b>	1 – 5		Lecture and Program	2,3

	Assignment 9: Site Logistics		10	Walk-Through	1
<b>Module IX</b>	<b>Synchro</b> Assignment 10: Synchro Project	1 – 5	5,10	Lecture and Program Walk-Through	2,3 1
<b>Module X</b>	<b>Course Wrap Up / Final(s)</b> Take-Home Final Exam	1 – 5	1,4,5, 10,15		3
<p><b>** A Method of Assessment</b> gauges student achievement of each CLO. The Methods of Assessment for this course are:</p> <ol style="list-style-type: none"> <li>1. Individual Assignments;</li> <li>2. Individual In-Class Quizzes;</li> <li>3. In-Class Exam and take-home Exam, made up of: multiple choice and work problems utilizing the softwares learned throughout the quarter.</li> </ol>					

While introducing these systems over the quarter session is a lot of information to digest, the interoperability, interdisciplinary and collaborative focus of this course allows the students to experience different platforms and engage with the instructor, ISA peers and respective classmates. As noted by Phillips, et al. this generation of students benefit greatly from peer-to-peer interaction as well as experiential learning (2014). In addition, due to the fact that the current traditional undergraduate student has been exposed to the digital environment since birth, research suggests that these students are able to grasp technological content and application thereof in a relatively short span (Phillips, et al. 2014). Utilizing this hypothesis, the Cal Poly – SLO CM Department have been able to garner results that are satisfactory to our industry partners for graduating CM seniors.

In order to measure the Cal Poly – SLO CM Department students' performance upon graduation, the department conducts regularly scheduled meetings with the IAB, formally called the Construction Management Advisory Council (CMAC). One of the offshoots of these conversations has been the development of a sub-committee with CMAC. Initiated in 2017, the Construction Technology Advisory Council (CTAC), created by a Cal Poly – CM alum, continues to probe the technology currently deployed by industry with an eye for emerging technological trends and advises faculty on how to continue to refine CM 280 and BIM education deployment throughout the curriculum.

#### 4. 0 INSTITUTIONAL COMPARATIVE ANALYSIS

Given the similarities between the institutional and CM program goals at both WIT and Cal Poly – SLO, the deployment of BIM education at the undergraduate level is consistent with ACCE requirements and subsequently, each program's IAB. However, several distinct differences are noted. First, the laboratory space at WIT is a dedicated space for BIM education, while the computer lab at Cal Poly – SLO is open to all CM majors while still serving as the host of CM 280. Secondly, the peer-to-peer interface at Cal Poly – SLO is a different approach to content delivery, with the ISA's assisting both the instructor and the students on how to approach and ultimately execute each assignment. Lastly, the distinction of the timing of the offering should be addressed. At WIT, the course is offered in the Freshman year of the student's spring semester while at Cal Poly – SLO the suggested 4-year academic flowchart has the CM 280 course being taken in the student's 1<sup>st</sup> quarter of their 2<sup>nd</sup>-year. This is a unique distinction in the fact that the Cal Poly – SLO students may have had more exposure to the BIM environment through other courses in the curricula and/or industry internships.

#### 5.0 CONCLUSIONS AND FUTURE RESEARCH



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Each of the CM programs at Cal Poly – SLO and WIT are primarily following the same recommendations of their respective IAB, the ACCE requirements and the internal goals of BIM education via faculty. The approach to CONM 1500 at WIT and CM 280 at Cal Poly – SLO are structured differently yet still accomplish the overall goal of providing current undergraduate CM students with a firm foundation in which to develop their own personal technology education goals and outcomes.

Due to the differences in CM student industry experience and the academic level of each course being offered, future research should focus on gathering data from each student population. Specifically, concerning the level of satisfaction in which the courses prepared the student to enter industry with confidence to perform BIM-related tasks and/or to be able to communicate with owners, designers, subcontractors, etc. in the prevalent terminology being utilized in the AEC industry today. The data collected could then be an additional tool for the departments and faculty to continually refine course material as well as make recommendations regarding the technology needs – hardware, software, facility space considerations – to continue to have a positive impact on student experience.

## 6.0 REFERENCES

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