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## **AC 2012-5422: VIRTUAL CONSTRUCTION + COLLABORATION LAB: SETTING A NEW PARADIGM FOR BIM EDUCATION**

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## **Virtual Construction + Collaboration Lab: Setting a new paradigm for BIM education**

### Abstract

Building Information Modeling has been embraced and determined to be a core component of the undergraduate construction management program at several major universities across the United States. Currently, in some programs, Building Information Modeling (BIM) is being taught in a lecture - lab setting in Project Management courses. Industry involvement has continued to improve the course offering by including relevant areas of information and skills needed to enter the workforce. However, it is critical to capitalize on both the intra and interdisciplinary collaborative aspect of BIM to set higher standards for research and development, education and practice. It is essential to grow and build upon these aspects to remain current with the changing trends in the Architecture Engineering and Construction (AEC) industry. This paper summarizes the research to develop a curriculum progression involving the use of BIM tools at every relevant stage of a student's academic career, culminating in a capstone project as a Virtual Construction and Collaboration Lab.

The Virtual Construction and Collaboration Lab (VC<sup>2</sup>L) is a pod based collaborative learning environment at the Del Webb School of Construction (DEWSC), Arizona State University, wherein interdisciplinary groups of students can investigate real-world projects from the viewpoint of industry representatives in their own particular field of study. Collaboration is a team assignment, modeling the project life cycle, concentrating on the pre-construction phases as this is when major decisions regarding contract schedule and cost are confirmed. At this stage, students are engaged in not just learning the tools that constitute BIM, but in applying these tools to add and extract information to better aid the construction process. Lab time is preceded and supported by a Project Management lecture; then VC<sup>2</sup>L provides the environment to test and execute BIM on real life projects.

In order to provide this level of expertise in students as they progress through the undergraduate level, it is essential they are well versed with the software applications ahead in their academic coursework. As a result, students are introduced to digital modeling through Autodesk® Revit®, at the 200 (sophomore) level, along with reading blueprints through a Construction Working Drawing Analysis course. To further increase the knowledge for future applications, at the 300 (junior) level a class is offered in a variety of software applications such as Autodesk® Revit®, Navisworks®, and SketchUp. This class provides the basic application of these tools in a construction setting. A capstone elective course will provide students with an extensive BIM experience for those wanting to be immersed in construction applications beyond the basic quantity take-off, scheduling, and site layout.

As the industry grows and adapts to the latest trends, it is essential that students follow suit and go one step further. Academia must mirror the permeability of BIM in all the levels of courses offered in a Construction Management program.

## Introduction

Collaboration in all aspects of design, engineering, construction and management is critical for defining better standards of building. The current trends in alternative project delivery contractually require an increased level of collaboration throughout the life-cycle of a project.<sup>2</sup> It is essential for reducing design and coordination errors, cost effective and expedited delivery, and for increasing the overall value of architecture and construction. Understanding and implementing this concept of collaboration requires a cultural change in already established mindsets and workflows. Building Information Modeling (BIM) is the process which aids this cultural change.

Past reports and surveys indicate that there is a lack of trained and qualified construction personnel. Increasing the construction skill level can be overcome by introducing standalone BIM courses throughout the Construction education program and by establishing industry partnerships<sup>1</sup>. Several institutions now have courses teaching BIM software in the architecture, construction engineering and construction management departments. In many cases the focus is on learning the software applications which are a part of the BIM package<sup>1</sup>. The students graduating from such courses are not experts but do get a taste of BIM and what to expect when they enter the industry. To further integrate the changing patterns of industry growth, the curriculum must now focus on the aspect of collaboration as kindled by BIM. To mirror this paradigm, a Virtual Construction + Collaboration Lab (VC<sup>2</sup>L) becomes the environment where students apply their education and skills to solve real world problems. It also becomes the platform for experimentation and research that can ultimately be brought to the industry.

## Background

Past research and surveys, exploring the needs of the industry related to the desired skills of new hires, have indicated the growing demand for BIM<sup>1</sup>. To fulfill this need, two approaches have been taken for the curriculum - integrating BIM in one or two courses in a Construction Management curriculum or implementing BIM through several courses, such as in a 5 year Architectural Engineering curriculum. The latter does not offer traditional Construction Management classes such as estimating, scheduling and project management as stand-alone classes<sup>1</sup>. In the effort of integrating BIM while meeting the challenges of accreditation, existing workload and the ever-changing software, the Construction Management undergraduate program at the DEWSC, Arizona State University started offering a senior level BIM lab in conjunction with a Project Management lecture. This integrated lab-lecture has been offered since 2008<sup>9</sup>. The lecture meeting twice a week “provides an industry wide view of the implementation of BIM tools in the industry today, discussing project life-cycle and the development of a BIM execution plan.”<sup>9</sup> The lab meeting once a week offers “software tutorials that emphasize the lifecycle of the project in a BIM setting and the real-world challenges of file size, maintenance, and clashing issues.”<sup>9</sup> These efforts of bringing BIM into an academic curriculum is supported by industry professionals who dedicate their time and share data or sample projects for training purposes.

## Theory

Collaborative Learning is a pedagogical concept in which students work in groups and benefit from peer learning while achieving a common academic goal. It fosters critical thinking and problem solving skills by promoting discussion, clarification and evaluation of ideas of team members<sup>4</sup>. It finds its roots in the ‘dialectical method’ of reasoning as abstracted by Hegel and Kant, which is the three fold model of thesis-antithesis-synthesis. More recently the works of Russian psychologist Lev Vygotsky (1896-1934) which were translated and published in 1962, detailed the idea of ‘Social Development Theory’<sup>5</sup> which forms the foundation of constructivism. It states that while social interaction plays a fundamental role in the process of cognitive development, most of the learning occurs in the Zone of Proximal Development (ZPD), which is the distance between the students’ ability to perform a task with collaboration and independently<sup>5</sup>. This collaborative or constructivist form of learning is a theory that replaces the passive instructional approach and concentrates on active learning through dialogue, constructing, inventing and creating. The learners are no more just passive recipients of information that they are expected to memorize, rather they actively demonstrate their learning and understanding by summarizing their ideas and developing critical questions<sup>3</sup>.

## VC<sup>2</sup>L Lab Design

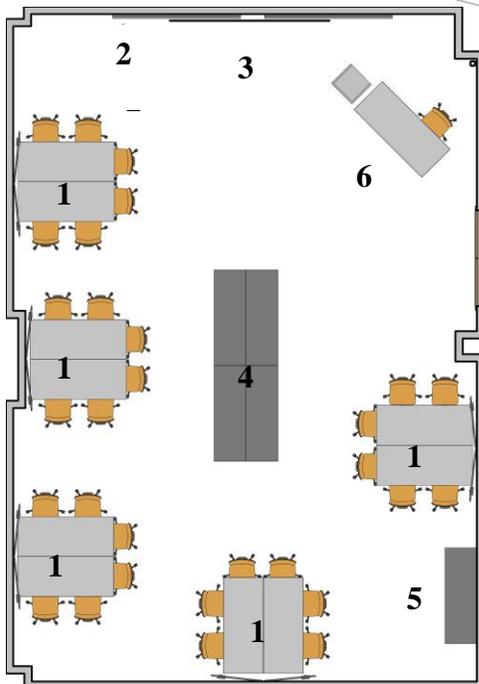
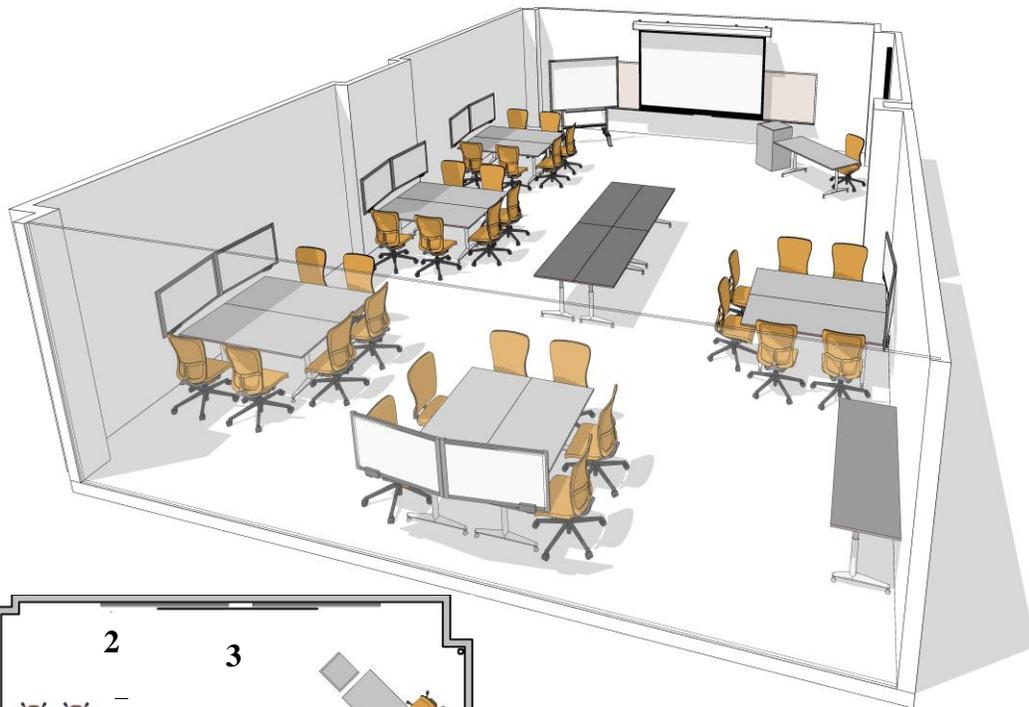
To facilitate effective collaboration, the interior space has to be designed to stimulate group work and conversations with supporting tools and technology. Several studies have been done by space planners, furniture companies and computer scientists focusing on behavioral patterns, knowledge sharing and practice methods. The specific features of the space depend on the task structure, cognitive complexity of the group task and on-going communication needs<sup>6</sup>. A report by the furniture company Herman Miller states that co-location, proximity and visual access are the prime design considerations for making a room for collaboration<sup>7</sup>.

With these concepts in mind, the design and layout for the VC<sup>2</sup>L went through several iterations to recreate an atmosphere of collaboration, imitating the interior of a construction site office. The idea was to exploit the full potential of the experimental space by providing flexibility between ‘pod-based’, lecture hall and conference room settings. The maximum capacity of the available space was set at 30 considering the intake of the course. Studies indicate that smaller group sizes (less than 4) lack the diversity and varied expertise for collective decision making and larger groups (more than 6) do not ensure participation of all group members<sup>4</sup>. Considering this, it was decided to limit the number of members to a maximum of 6 in each pod. The lab is equipped with sophisticated computing systems to handle modeling and simulation exercises, LCD screens, white boards and projectors with the capability of transforming any flat surface to an interactive work surface. The main controls are handled by an instructor station which functions as the centralized server, creating a local network for the lab. Sophisticated switching devices allow the function of replicating the screen content of any of the five pods onto the front projecting screen or any combination of screens.

## Plan1.0 - Pod

A ‘pod’ based configuration is defined as ‘group of four to six workstations surrounded by high

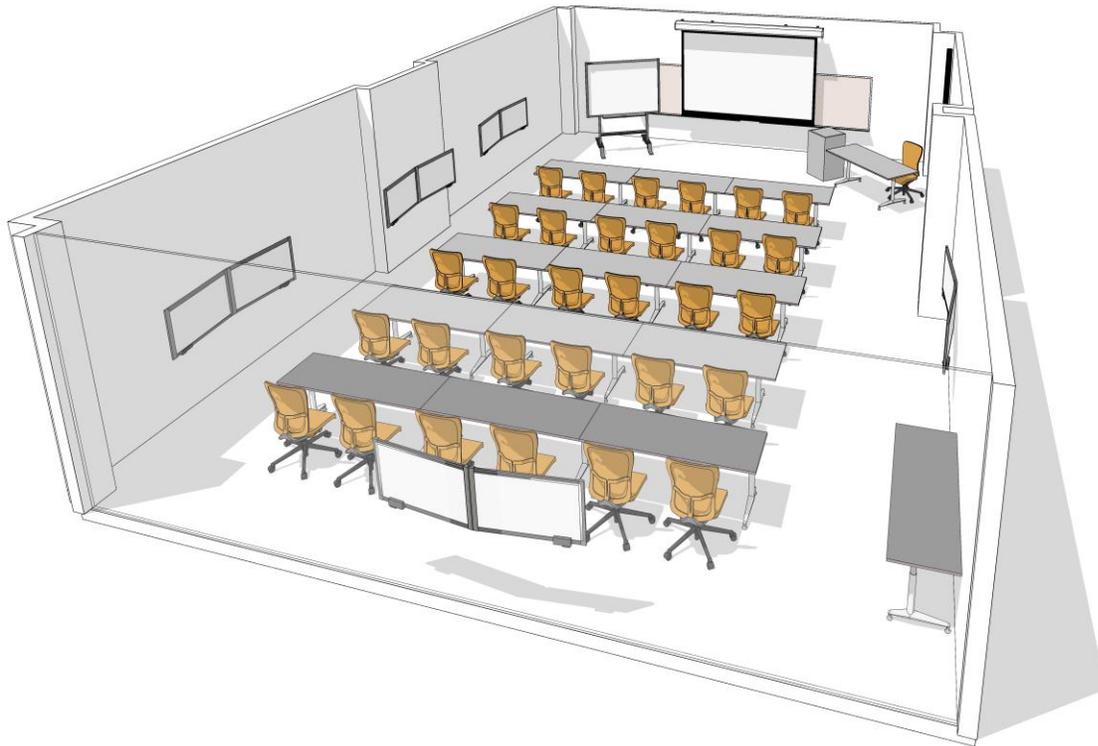
panels around the perimeter of the group'.<sup>6</sup> The key feature is to provide 'high visual and aural access to group members'.<sup>6</sup> There are 5 pods with 6 group members each. Each pod has two adjoining 30"x72" tables which make up the work surface. Two rollable chairs are placed on each three sides. The fourth side, butts against the wall or the perimeter vertical surface on which LCD monitors are mounted. Each pod has a resident computer, with the CPU and other peripherals located under the work surface. The pod is also equipped with a power strip and switcher for connecting laptops and displaying content on the screens. The instructor station has the controls to switch the display on the front projection screen to display the content of any of the individual pods. This gives the instructor the ability to focus the attention of the class when and where required. Extra tables (24" x 60") are joined together to form a long blue print table on which paper drawings can be rolled out. The students can gather around the table for discussions pertaining to construction drawings. These tables can also be used for expanding the size of the workstation to accommodate larger groups.



1. 'Pod' equipped with dual monitors, a resident computer and switcher for plugging in laptops
2. Interactive wall surfaces
3. Projection Screen
4. Table for layout drawings
5. Space for printer and storage for drawings
6. Instructor Station

## Plan 2.0 - Lecture Hall

To maintain maximum flexibility of the program of the space, the furniture can be moved around to configure a lecture hall setting for seminars.



## Curriculum Progression

The aim of the undergraduate Construction Management program is to integrate BIM throughout the four year course so that on graduating, students have a clear understanding of the means and methods of the industry. Students in this program do not handle software applications in the same way as architecture students where they use standalone programs for studio projects. Consequently the integration of BIM in the program has been methodical and not just borrowed from an existing tutorial or discipline. The instructors follow a Socratic method of teaching, while the assignments are designed to encourage the students to work collaboratively in teams.

## CON 244: Working Drawings Analysis

The minimum requirement to be a part of the field of construction is knowing how to read working drawings and being able to translate the information into tangible results. This course covers reading and understanding architectural drawings for residential and commercial buildings. 3D models are introduced that helps develop an understanding of how to read and visualize information.

This sophomore level class meets twice a week for a 1 hour 30 minute lecture and 1 hour 30 minute lab period. The lecture covers a basic overview of construction drawings and how they are organized; recognizing the various building components, the different construction methods and the various components of major systems as represented on working drawings. The lab period is reserved for group assignments where students work with paper drawings and are also shown the translation of the same intent in Revit Architecture, Structure and Mechanical.

Table 1.0 - CON244 Syllabus

Lecture/Lab Topic	
1	Materials and Specifications
2	Site Work and Civil Works
3	Foundations and Concrete
4	Steel Structures and Welding
5	Wood Structures
6	HVAC Mechanical Systems
7	Plumbing (Water and Waste Systems)
8	Electrical Systems
9	Architectural
10	Advanced Print Reading
11	Building Information Modeling

Working Drawing Analysis is currently offered as a required course at the Del Webb School of Construction in the Fall and Spring semesters. In most cases, the students do their first internship the following summer, where they are able to apply the knowledge gained.

CON 394: Introduction to BIM

A survey undertaken by Colorado State University shows that a majority of the undergraduate Construction Management students prefer if the existing CAD courses in the lower level classes are replaced by a standalone BIM course which teaches the use of the software at a simple level<sup>8</sup>. The CON394 course is offered as a required course at the junior level to focus on learning the modeling tools. This is an additional skill, which will be an advantage for students who take the senior level Project Management and BIM class. The tutorial modules are adapted from software vendor tutorials and construction company in-house training materials. The experience in the program has demonstrated that students are most comfortable with self-paced tutorials that incrementally build upon each another. It roughly “parallels the workflow of a typical commercial project as it moves from concept through construction documents to the construction process.”<sup>9</sup> The software packages used specifically for this course are - Google SketchUp, Revit Architecture and Navisworks Manage.

Table 2.0 - CON394 Syllabus

	Software	Lab Topic
1	SketchUp	Introduction to SketchUp
2	SketchUp	Creating a Site Logistics Plan and Adding Elements

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

### CON 453: BIM and Project Management (capstone course)

A senior level capstone course in a lecture-lab format introduced BIM in the curriculum four (4) years ago. As the industry has progressed and software workflows have changed, the course has undergone several changes to keep the course updated. The objectives of the course are -

- Develop an understanding of the project management process, including defining, planning, executing, controlling and closing and the use of BIM technology to support the construction process.
- Gain a general knowledge how BIM and LEED integrate with project delivery strategies.
- Learn to use the techniques and methodologies of BIM to assist with today's construction process.

Industry professionals including contractors, architects, engineers, sub-contractors, consultants, BIM and Visual Design and Construction engineers are invited to lecture and assist with the labs. Students are exposed to the industry and vice versa, which in turn ensures better learning, exposure to the current trends and job opportunities. The one hour lecture, meeting twice a week highlights the industry wide application of BIM in project management, project life cycle and the development of a BIM Execution plan. The lecture is followed by a two (2) hour lab. The lab schedule is divided into individual and group projects, wherein the students get a learning tutorial outlining the core concepts of the software which they further use for their immersive

group assignments. They do not just learn the software but use the concepts to solve a management issue. The projects require them to use a combination of software's, highlighting the importance of interoperability in BIM. The VC<sup>2</sup>L is an ideal setting for this class to conduct collaborative group projects using project management and BIM skills. Industry professionals bring in real world problems that are converted into assignments.

Table 3.0 - CON453 Syllabus

	Lab Topic	Individual/Group	Software
1	SketchUp Overview	Individual	SketchUp
2	Revit Architecture Overview	Individual	Revit Architecture
3	Creating a Site Logistics plan and sequencing for material/equipment	Group	SketchUp and Synchro
4	Central file and Worksharing, working on a network. Extracting usable information from the model.	Individual	Revit Architecture
5	Creating a schedule and material quantity take off for developing an estimate on a complete project. (Each group role-plays the part of a subcontractor bidding for a job)	Group	Revit Architecture RSMMeans D-Profiler (Overview)
6	Animation, navigation and clash detection in Navisworks	Individual	Navisworks
7	Mock Clash Detection meeting - 1st Round Updates. (Each group conducts a co-ordination meeting, finding, analyzing and reporting clashes for a different section of a building.)	Group	Navisworks

	Lab Topic	Individual/Group	Software
8	Mock Clash Detection meeting - 2nd Round Updates.	Group	Navisworks
9	4D Scheduling	Individual	Navisworks / Synchro
10	4D Scheduling	Group	Navisworks / Primavera

This course is meeting for the first time in VC<sup>2</sup>L for the Spring 2012 session. Intuitively the students are more active and dynamic when participating in the lab work, rather than sitting back and just being passive recipients of instructions. Since they are given the schedule up front, they are more diligent in learning so that as a group they can perform better. They are asking more questions, searching for solutions and thinking through the processes.

Survey data indicates a slight increase (4%) in the number of students having previous knowledge or experience in BIM. More students are accepting the fact that BIM is an integral part of the construction industry and are likely to use it in their first jobs. By raising the level of education, we are seeing a drop of 13% in the students who feel the pace for instruction is suited to them. 32% of the current students feel the pace is too fast for them, which further reinforces the need to include an intermediary BIM course (CON394). While a consistent majority of 60% of the students prefers individual instruction, the rest feel they understand the application better in a collaborative environment which is the VC<sup>2</sup>L.

## Conclusion

Building Information Modeling is a process which aids the integration, collaboration and project management for the Architecture, Engineering and Construction industries. Its benefit is being seen in the construction industry and increasingly companies are adapting it. As the demand increases, it is becoming even more important for a construction curriculum to allow the traditional methods of education to incorporate technology and skills for future growth. To allow for the existing heavy workload of the undergraduate program of Construction Management (CM) to absorb BIM, it is important to integrate it throughout the curriculum. As this methodical change happens, the existing skill level of the students who are not habitual users of the computer programs will have to be addressed. At the same time, to keep up with the changing delivery methods and workflows of the industry, a culture of collaboration with other fields - architecture, engineering and management has to be promoted. The Virtual Construction + Collaboration Lab provides the most suitable environment for training and group work.

However, since software technologies are ever changing, the CM curriculum needs to be continuously updated to keep up with those changes. Industry involvement is of prime importance and professionals play a big role in training, research and development. Industry grants have been a major contributing factor for developing the VC<sup>2</sup>L at the Del Webb School of Construction at ASU. However, the big idea is not the development of a single lab, but the concept of promoting collaboration through a ‘pod’ based spatial organization, recreating realistic situations. While industry provides the technical know-how, academia provides the environment for research - developing a skilled workforce.

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Appendix A: Photographs of a lab in session at VC<sup>2</sup>L, DEWSC, ASU

