ABSTRACT

Construction and Collaboration have become synonymous terms for any value added activity within the construction industry. Most of the key players in the Architecture-Engineering-Construction community are quick in adapting to this wave of technological advancement. As these changes occur, the demand for advanced skill levels from new construction graduates is also increasing. While it has been established through past research that BIM in construction education is a necessary component, it is also important to encourage the practice of collaboration.

This paper summarizes the research, design, construction and execution of a virtual construction lab titled DECIMAL or Design Engineer Construct Integrated Management Lab at the Del E. Webb School of Construction (DEWSC), Arizona State University. Modeled on a modern construction trailer, it is equipped with sophisticated computing facilities and movable furniture. By using Virtual Design and Construction (VDC) technology as a collaboration tool in a pod-based collaborative space, participation and discussion is promoted. Construction situations are simulated through project based scenarios such as bid preparation, site logistics planning, coordination meetings, project schedule development. The problems are explored using Building Information Modeling (BIM) functionalities like parametric modeling, quantity take off and estimating. Industry instructors are a major element for the successful execution. The goal is to encourage collaboration and interdisciplinary participation and leverage the seamless integration of VDC and BIM throughout the construction management curriculum, with the lab providing the environment for such activities to occur.

Keywords – BIM Education, VDC, Collaboration, Construction Management, Undergraduate courses

1. INTRODUCTION

The digital representation of design and construction data in the form of information rich geometric models constitutes the skeleton of Virtual Design and Construction. Using the embedded intelligence for simulating the process of building from design to construction and operations, while significantly improving the efficiency and productivity, is the essence of Building Information Modeling or BIM. Research indicates that amongst stakeholders, contractors see the highest Return on Investment in BIM. To further their profitability they see the value in investing in software, training and developing collaborative BIM procedures within their organizations (McGraw Hill 2009). The industry has realized the value in BIM and championed its use for technological, organizational and philosophical advancements. However, academia has found it difficult to move as rapidly, perhaps due to the conflicting ideologies of teaching BIM as a single application versus teaching the core concepts behind it. (Ibrahim 2007) Survey reports indicate that there is a need for trained and qualified personnel...
in BIM (Pavelko 2010). Currently the construction industry hires architects, engineers and construction professionals with prior experience in BIM, making the hiring process very competitive (Hardin 2009). New graduating professionals are expected to bridge this gap. While it is important that academia teaches its students the current practices in the industry, it is also responsible for mentoring leaders of tomorrow who can improve the existing processes with new ideas. However knowing BIM as a software application is not enough for graduates to contribute in the industry if they are not aware of the accompanying processes, concepts and environments.

The concepts of BIM in architecture, engineering and construction can be viewed as different aspects of the same cube. The basic tools are mostly similar but their usage depends on the practices of the particular discipline. Three common ideologies of incorporating BIM in academia are popular – 1) offer BIM as an elective or a workshop, 2) make it an advanced degree program and 3) restructure the existing curriculum (Deamer 2011). All three cases have their challenges mostly because BIM is a fairly new idea and requires the knowledge of a variety of different programs and processes. This paper will address the development of an integrative curriculum incorporating BIM in the undergraduate Construction Management program at the Del E. Webb School of Construction (DEWSC) Arizona State University (ASU).

DEWSC has explored the concept of collaboration in the BIM environment through an immersive collaboration environment called the Design Engineer Construct Integrated Management Lab or DECIMaL developed in January 2012. Improved standards in the Architecture Engineering Construction (AEC) realm and new alternative delivery methods contractually and philosophically require collaboration amongst the key players (Ghosh 2012). The existing infrastructure of academic institutions does not always provide a ‘room’ for collaboration. This paper also discusses the space design of DECIMaL and the advantages of such an environment in promoting collaboration amongst students.

2. VDC/BIM IN EDUCATION

2.1 Collaboration in the Classroom

BIM is the digital language for communicating information in the lifecycle of a building. It is a database of information that improves the collective decision making process by simulating situations, conditions and results. If deployed correctly with accurate information, it is efficient and less time consuming than traditional methods of information sharing. BIM enables discussions, clarification and evaluation of ideas, and fosters problem solving skills – which are also the essentials of collaborative learning (Gokhale 1995). Collaborative exercises have always been promoted in the classroom. Group projects are assigned, teams are expected to meet outside the class times, and students are encouraged to participate, question and develop ideas through reasoning – stemming from the concepts of Socratic Method of teaching. In such environments students learn from active participation rather than being passive recipients of information (Ghosh 2012). Students are able to create mini-environments of collaboration by temporarily re-arranging the furniture and sitting around desks as a group to have deeper discussions. Latest developments in furniture design and IT provide sophisticated solutions for the same basic concept. These include movable collaboration workspaces with wireless digital technology, audio and video technology to record group activities that can be replayed to analyze team behaviors, image capturing digital screens replacing the traditional whiteboard, and Cloud Computing that can give students access to files and documents from virtually anywhere. Social networking platforms and web based video calling help a team to work virtually, removing the notions of a necessary physical space.

Advancement in web based information and communication technology has definitely improved the sharing of information and ease of interaction. However, it is impossible to separate interpersonal and inter group communication from the construction process (Dainty 2006). The most critical asset in the construction industry is people therefore, human interactions and tangibility of the environment are as important as the virtual presence of
information. A construction manager spends more than half of his/her time interacting with people – including engaging in conversations, networking, listening to colleagues, collecting and transferring information and directing subordinates (Dainty 2006) To be future leaders, the tech savvy generation of Construction Management students have to be adept at learning people skills as well as technical skills. Fundamentally, if construction is considered a social activity, then collaboration is its critical characteristic and VDC and BIM are its drivers.

2.2 Environment Design

Most computer based learning is traditionally done in a Computer Lab which is characterized by rows of computers usually facing an instructor station. In some cases the single monitor is substituted with two, making it easier to see and do. The learner may have an instructional video or a written tutorial on one screen and the software program running on the other monitor. Individual stations like these are beneficial for focused learning of software programs. Also popular are immersive environments using Second Life® created by Linden Lab where construction activities can be simulated on a life size scale. Such scenarios are useful for safety training, understanding construction sequencing, crew co-ordination and interface management by being able to virtually locating yourself on a job site. (Ku 2009)

While these solutions are ideal for individual learning, they do not always promote discussions amongst peers for collective decision making. To motivate group work, the space has to be designed per collaborative features such as co-location, proximity, visual and aural access and supported by tools and technology that can stimulate collaboration (Ghosh 2012, Herman Miller 2012). The design for DECIMaL was based on the precedent of a job site trailer – ‘the communication hub of a project’ (Hardin 2009). A construction professional, when assigned on a project will spend most of his/her time either inside a trailer or outside on the site. The interior of a trailer usually has individual stations or desks for the officers and a conference room for weekly meetings and co-ordination sessions. Depending on the size and duration of the project and the capacity of the company, the trailer is upgraded with features like LCD screens, SMARTBoards™ and servers linked with wireless networks, making it BIM ready (Hardin 2009). DECIMaL was designed for maximum flexibility within the existing resources. The parameter was to accommodate 30 students in an existing room of size 29'x42'. Primary configuration of 'pods' of six was adopted, each with a resident computer and two LCD screens. A brief description of the lab follows:

“This experimental space has the flexibility of transforming between ‘pod-based’, lecture hall and conference room settings by simple re-arrangement of furniture. The primary layout for collaboration is the ‘pod’ - which is a workstation seating six with a single computer, two LCD monitors and power outlets for connecting personal laptops. The lab is equipped with sophisticated computing systems to handle modeling and simulation exercises, LCD screens, whiteboards 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 pods onto the front projection screen or any combination of screens. This gives the instructor the ability to focus the attention of the class when and where required.”

Figure 1 – DECIMaL layout
3.0 DISCUSSION

BIM was first introduced at DEWSC, as a lab component to a senior level Project Management course in Fall 2008 (Pavelko 2010). Since it was the first introductory class, the course focused more on learning the software applications such as SketchUp, Revit Architecture and Navisworks. The same structure is now being offered as a standalone 1 credit computer application course at the Sophomore and Junior levels as 'Introduction to BIM' (CON394). The goal is to teach BIM processes as an overall concept and concentrate on learning how to use the software applications that comprise the BIM toolbox. Since it requires individual learning, the class is conducted in a traditional computer lab. Students are expected to learn basic 3D modeling, navigation and methods of extracting data from existing Information models. The previous year at the Freshman-Sophomore level, they are required to enroll in 'Working Drawings Analysis' (CON244) which is a lecture that 'covers an 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' (Ghosh 2012). The DECIMA L space is an ideal environment for the students to spread out paper drawings on large tables and work through the assignments of reading and deciphering the working drawings together. They are also introduced to the changing standards of drawing brought about by BIM.

At DEWSC, BIM is introduced as a concept in the relevant Construction Management subjects (Table 1), taught as software applications in a standalone course (CON394) and utilized for a culminating experience of using BIM for Project Management in a capstone course (CON453). It is important to note that in order to be familiar with visualization and digital technology or use BIM for future purposes, it is important to have a strong foundation of basics. Table 1 is just a sample of the classes offered by DEWSC that incorporate some part of BIM education and also leverage collaboration among students.
<table>
<thead>
<tr>
<th>Course Name</th>
<th>Concepts covered</th>
<th>Future application of these concepts in understanding the VDC/BIM process or for strengthening collaboration</th>
<th>Collab on VDC or BIM tools/ processes</th>
<th>Time spent on VDC or BIM tools/proceses</th>
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| Year I Working Drawings Analysis                | - Learning how to read and understand construction drawings, symbols, specifications and terminologies  
- Introduction to 3D modeling and visualizing information                          | Visualization of digital 3-dimensional information and Industry standards                                         | Yes                                   | 10 hours (present)                      |
| Year II Microcomputer Applications for Construction | - Geometric modeling to represent operation of construction equipments (such as a crane)  
- Developing a cost database in CSI Master Format using Microsoft Access             | Spatial requirements for productivity and safety                                                                    | No                                    | 3 hours (future)                       |
| Year II Building Construction Methods, Material & Equipments | - Tangibility of materials, visual understanding of equipments, developing a sense of how a building comes together  
- Identifying roles in the process of construction                                       | Vertical integration of courses to foster sense of progression (future)                                              | Yes                                   | N/A                                     |
| Year III Introduction to BIM                    | - Software applications taught at present: Revit Architecture, SketchUp, Navisworks  
- Future: Bentley Systems                                                              | Learning BIM as a tool for future use                                                                               | No                                    | All Semester                           |
| Year III Planning & Scheduling                  | - Project Scheduling methods such as Bar Charts, CPM and PERT, AOA, AON and VPM techniques; resource allocation and time/cost analysis  
- Software used: Primavera P6, MSProjects                                               | Creating schedules, and simulating activities                                                                     | No                                    | All Semester                           |
| Year IV Advanced Estimating                    | - Concepts of pricing and markup, development of historic costs, life cycle costing, change order and conceptual estimating  
- Groups work with Construction companies on real life projects                          | Costing and Estimating                                                                                            | Yes                                   | N/A                                     |
| Year IV Heavy Construction Estimating           | - Methods analysis and cost estimation for construction of highways, bridges, tunnels, dams, and other engineering works.  
- Software: HCSS Estimating program                                                      | Collaboration and interaction with groups of people                                                                | Yes                                   | N/A                                     |
| Year IV Project Management I                   | - Using case based scenarios for simulating common Project Management issues faced during pre-construction and construction | Collaboration, interaction and preparing for common real life challenges faced in the industry                  | Yes                                   | All Semester                           |

Table 1 - Sample of courses offered

The senior level capstone course, Project Management I and BIM (CON453), is offered as a 3 credit course in a lecture-lab format – 2 hours of lecture and 2 hours of lab per week. Student groups are engaged in case based
project management scenarios which have to be solved using BIM tools and processes. One example is the 'Site Logistics Lab':

Objective: The objective of this assignment is to create a successful site logistics plan for the University of XYZ Stadium Project.

Assignment: This assignment will be a team project. Each team will create a 3D site logistics plan. From the base plan provide the team will model the elements needed for construction operations. Each team will present their plan. The assignment will be graded on the following: Organization of the site logistics plan, Using all the assigned elements and constraints, Ability to communicate your plan in the model and team presentations

Project Background: The University of XYZ football stadium currently has bleacher seating in the north end zone. The bleachers will be demolished and stadium seating with offices, concessions, and suites will be added. The north end zone stadium will tie into the existing stadium. The University has allowed the soccer field to be used for construction operations, staging, and laydown to take place.

Challenges: As with every project there are certain challenges and constraints. The constraints that exist on this project are: 1) Construction on and around the field need to be completed for the start of the 20xx season, 2) The new facility needs to tie into existing utilities, 3) The soccer field is the only area for construction staging and laydown for materials

Each person in the group of 5 donned the hat of a stakeholder – Owner, University Representative, Construction Project Manager, Project Engineer and Architect. They were provided a conceptual 3D model of the site in SketchUp. They had to work through the options and present the optimum logistics solution. Some of the teams started by sketching on printed copies, other groups broke up into discussions, and others evaluated their options by establishing constraint based on codes. Each team had a different approach, but had to present their option as a 3D model using SketchUp by the end of 2 hours. A few groups went a step further and developed a sequencing plan using Synchro and Navisworks. Using the switching capability, the screen could be shared between pods without anyone having to leave their stations.

4.0 CONCLUSIONS AND FUTURE WORK

The application of BIM in construction has numerous advantages. As academia absorbs its value in the classroom, it opens up more avenues for research and growth. At DEWSC the collaborative nature of the construction industry is emulated in the classroom by providing the atmosphere for it to happen. In the first year of DECIMaL, several challenges which were faced have propelled the evaluation and transformation of the curriculum even further.

Challenge #1: Late adopters of technology
Construction education attracts students from various backgrounds; students’ fresh out of high school and professionals with years of experience take the same courses. The exposure to digital tools often varies in this mix creating different levels of understanding of processes and technology. It is important to have a broad understanding of interfaces that can be helpful in learning other programs.

Challenge #2: Students with varying interests.
The use of BIM in building design is widespread, giving access to numerous case studies and models for classroom use. However the use of BIM for infrastructure and heavy civil projects is only recently gaining traction. At DEWSC, we are already incorporating the use of specialized software tools in our courses. Research
is required to develop a course focusing on the use of BIM and GIS technology in the classroom to cater to a variety of interests.

Challenge #3: From BIM to Collaboration
Collaboration is a cultural challenge and BIM is a cultural and technological challenge. To raise the level of education in Construction Management, academia and industry can provide the space and knowledge. However, considerable effort from the students is required to truly reap benefits.

At present, the undergraduate Construction Management programs in academia are responding to the industry demands of BIM. Academics must re-instate its position as the leader of the industry and pave the way for future leaders. Educators must acknowledge the experience and technological adeptness of the younger generation as an advantage and use that skill to leverage more advanced research. Students must be challenged to take the risks of the marketplace. (Deamer 2011) In order to be ready for the uncertainties of the economy they must possess multiple skills to be marketable. Educators, students and industry need to work together to establish a culture of collaboration through technology.

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REFERENCES
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