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IMPLEMENTATION OF THE BIM BODY OF KNOWLEDGE (BOK) FRAMEWORK FOR PROGRAM PLANNING IN ACADEMIA

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ABSTRACT

Academia has utilized various Body of Knowledge (BOK) publications to benchmark and explore required content for curriculum development. Departments have developed specific programmatic plans using a discipline specific BOK to ensure that students are graduating with the skills and knowledge required to meet the needs of the workforce. The Academic Interoperability Coalition (AiC) recently developed a holistic and dynamic framework to explore the BOK of building information modeling (BIM). To date, the BIM BOK is a framework for competency requirements at the entry, middle and expert levels of BIM use. Since BIM is becoming a standard practice in the global architecture, engineering, construction, owner and operator (AECOO) industry, programs are now moving past introductory courses in modeling and focusing on assessing their curricula based on a more long-term perspective regarding meeting industry needs. In the initial steps of working to implement the AiC BOK framework, researchers completed a mapping procedure using similar methods to those found in literature. The mapping procedure linked the BIM BOK items with academic student learning outcomes with inputs from industry advisory boards (IABs), which reflected regional priorities of career-specific BIM competency expected from college graduates. The mapping exemplified possible implementation of the AiC BIM BOK in college BIM curriculum integration, and may offer assistance to peer educators for developing implementation models to review learning outcomes as compared to industry needs.

Keywords: Building information modeling, body of knowledge, competency, workforce, student learning outcomes

1. INTRODUCTION

The development of the Building Information Modeling Body of Knowledge (BOK) framework was the initial work toward assisting industry with several contributions, one of which was to provide educators and corporate trainers with a roadmap and common curriculum to bridge the current gap between academic learning outcomes and workplace performance requirements via BIM education and professional training. The efforts of the development of the BOK framework

are summarized in an overview and then then further explained in terms of how this research may contribute with both academic student learning outcomes and industry training recommendations.

2. SUMMARY OF BOK FRAMEWORK

2.1 The AiC's BOK Development

In an effort that began in 2015, the Academic Interoperability Coalition (AiC) developed a framework to explore the BIM BOK. The BIM BOK is defined as systematically curated concepts and nomenclature, knowledge, best practices, standards and outcomes pertaining to BIM and its implementation. The list of items developed as part of the BOK framework addresses BIM use cases from 4 different considerations:

- Levels of Implementation (Plan it, Coordinate it, Manage it, and Do it)
- Role of User (Designer, Contractor, FM/Operations, Consultant/Generalist)
- Both Organizational and Project considerations
- Levels of Performance (Entry, Mid, and Full Performance)

There was a total of sixty-seven (67) preliminary BIM BOK line items. These BIM BOK contents, or line items, were subject to analysis by a Delphi panel of BIM experts from the AECOO industry. The panel's review provided a ranking of important items as well as an indication of the levels of consensus among the Delphi panel members to not only ensure a complete list but to also ensure that the panelists were in agreement on the list. The results of the analysis also provided a clear indication that the industry agrees where along a continuum the "expert" user should be in terms of what they know, but for the entry and mid-levels users, it was evident that there is no clear understanding of the required knowledge needed. Each of the line items were ranked on a Likert scale by the panelists with regards to importance, and of the items initially identified in the BOK, Figure 1 shows the totals rankings. There are a total of 1,608 item rankings and 84% of those possibilities were between important and very important.
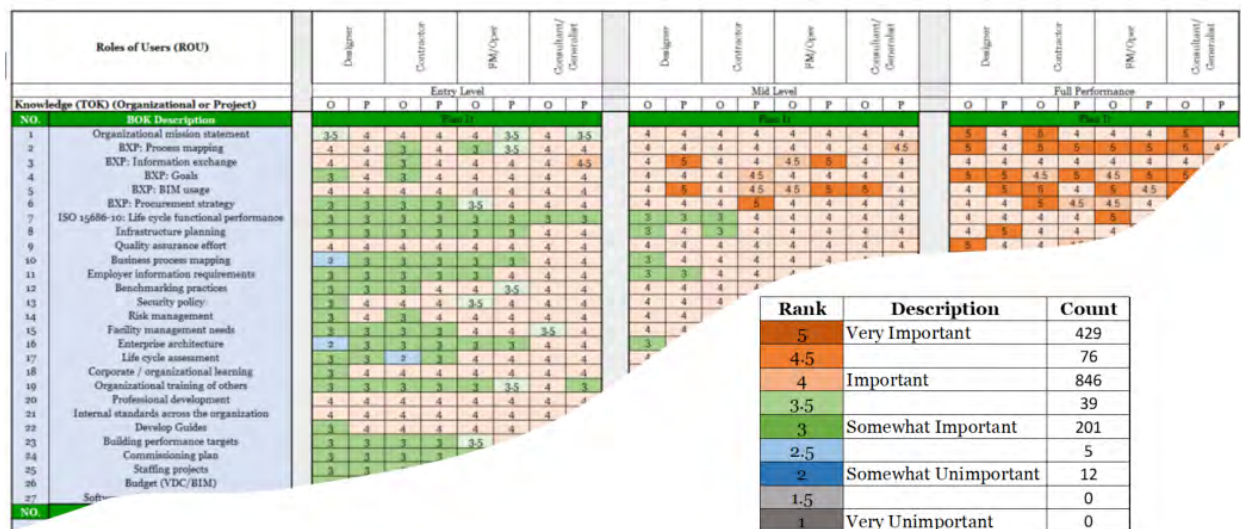

Figure 1. Example of Line Item Results and the BOK Total Rankings

2.2 BOK for Academic Use – Literature Review

To begin the implementation process for the BOK, a review of the applications of BOK items to various curricula were explored. The applications of a BOK for a particular industry or discipline have been used in practices similar to the AiC goals and to ensure competencies for individuals within those industries. In most cases, academia has used the BOK as a way to benchmark student outcomes to what is being taught to meet the needs of an industry. Academia must also rely on a BOK in many cases to ensure that students are graduating with the skills and knowledge required to meet the needs of the workforce. Wadzuk et al. (2009) recognized the need to meet a changing engineering industry and developed an internal BOK for engineering mechanics courses. The study utilized a methodology consisting of six steps to develop a BOK for any curriculum and its associated learning outcomes. The research divided the engineering industry's BOK into capabilities and additionally into basic/foundational, technical and professional practices. The authors provided a case application and example of the methodology and described some unexpected benefits such as the capability to examine the BOK to introduce creativity to teaching plans (for example combining topics not traditionally explored in the same course). The methodology provided a systematic way to "break the BOK down into small movable pieces" to allow for restructure of the curriculum. The primary difference in the 6-step approach in the Wadzuk et al. (2009) BOK was its application across an entire curriculum, as opposed to the need to develop BIM topics and coverage for what is typically one or two courses for most programs.

A similar application of an industry BOK was used by DeMers (2009) whereby he stated that the BOK is a "reflection of the task force's underlying objectives to define the current state of the body of knowledge, reduce the recognized shortage of well-educated personnel, and correct the observed mismatch between the educational process and industry needs" which are identical to the AiC Committee objectives. DeMers' (2009) purpose was to explore the ability to translate the BOK for University Consortium for Geographic Information Science (UCGIS) to the classroom by dividing the BOK into knowledge areas and linking them to learning objectives. Additionally, Blooms Taxonomy was utilized to determine the appropriate levels of learning for each of the learning objectives. The results identified the connection in the BOK and Bloom's Taxonomy and indicated that in most cases, the UCGIS-BOK was defined mainly at the comprehensive levels (Boom's Levels 2 or 3). DeMers' used a hierarchy of knowledge areas, which was subdivided into explicit units, and then the units were decomposed into specific topics. The primary concern in the approach was to initially ensure that the foundational knowledge was addressed.

A more recent example, and also one that utilized a different methodology, Balreira et al. (2017) reviewed a course at the introductory level for the computer graphics industry. Like the BIM-BOK, the example was for a specific course and is also a BOK for a rapidly changing technology. Balreira et al. (2017) noted that the computer graphics industry has experienced rapid change, and that the BOK they referenced had increased from 14 areas to 18 areas in its most recent update in 2013. The authors in this case reviewed the number of research publications from the top 6 journals of the computer graphics field and compared to the BOK and course topics. They also explored the textbooks utilized in various programs to assess content areas taught at comparable institutions. Although the study was a review of course content, the authors stated that more than half of the courses were taught with the faculty member's own notes and therefore, with regards to textbooks, they stated that "considering the relatively young age of Computer Science when compared with other fields such as Physics and Mathematics, maybe the community does not have yet a consensual view of what an introductory course should offer, and this impacts the use of textbooks" (Balreira et al., 2017, pg.6). This observation is relevant to the

BIM-BOK as similar hurdles experienced when BIM courses were established without the aid of a textbook; but, as the construction industry has matured, so has the academic coursework. Table 1 outlines the AiC process, currently at Step 4) compared to processes by Wadzuk (2009) and DeMers (2009).

Table 1. BOK Curriculum Development Process (Adapted from Wadzuk et al. 2009)

AiC		Wadzuk et al. (2009)	DeMers (2009)
First meeting 2015	Step 1	Create all-inclusive topic list containing topics traditionally taught	Identify learning objectives
Committee Process	Step 2	Development of a mechanism for all stakeholders to provide input	
Delphi Process	Step 3	Synthesis and evaluation of the data collected	Applied Bloom's Taxonomy to determine levels of learning
Delphi Process and Industry Review	Step 4	Creation of the prioritized topic list to be included in the curriculum	
ongoing	Step 5	Parsing of the BOK into logistical modules	Divide the BOK into knowledge areas
ongoing	Step 6	Development of course format, sequence, and content to best fit the BOK	Link the learning objectives with the BOK knowledge areas

2.3 BIM Maturity and the BOK

Since BIM use in the construction industry has grown exponentially (and subsequently the academic coursework has changed) it is necessary to include how maturity is assessed and its potential role in the AiC-BOK efforts. According to Succar (2010) the following definitions provide guidance as to the various terms used. The use of previous literature (Succar, 2010) and the development of the BIM-BOK is to state that capabilities refer to teams while competencies will be used to describe individual levels of performance.

- BIM Maturity refers to "the quality, repeatability and degrees of excellence within BIM capability."
    - Various models exist to gauge maturity
    - Identifies levels of competency.
- BIM Capability denotes the minimum ability to perform a task or deliver a BIM service/product.
- BIM Competencies. At the individual level, Succar (2010) delineates competencies by technology, process and policy areas.
    - The *individual competency index (ICI)* uses five levels (0-4) where Level 1 (basic), Level 2 (intermediate), Level 3 (advanced) and Level 4 (expert) denotes extensive knowledge, refined skill and prolonged experience in performing a defined competency

at the highest standard. The index also identifies two competency divides: the learning divide separating level 0 from level 1, and the time/repetition divide separating level 3 from level 4 (Succar et al., 2013).

o The AiC Committee uses three Levels of Performance (LOP): LOP indicate the stratification of performance depending on educational background and professional experience, and suggest the progression of performance from Entry, Middle to Full based on both education and training.

The BIM BOK provides a comprehensive framework based on many of the historical efforts to date in BIM research which addressed how to assess maturity levels. BIM Maturity not only provides the industry a method to assess their performance levels, but it can also be used as a benchmark for academic student learning outcomes. The BIM BOK did not negate the industry benchmarking aspect since these maturity models were referenced in the development of the BOK. Research has provided multiple (9 maturity models) which Wu et al. (2017) evaluated. One of the key findings indicated that each had specific strengths and weaknesses and there was no singular optimum solution, primarily because it was difficult to assess a broad number of metrics while also keeping the model simple and easy to use. (The metrics and assessments used in the 9 models ranged from 96 questions to less than 20 questions.) However, there are only a few cases (Pikas et al. 2013; Succar and Sher 2014) that introduced the conceptual workflow to identify, classify, and aggregate BIM competency items that need to be taught at educational institutions or trained in the workplace to equip current and future industry professionals. BIM maturity has become a way to recognize the changing industry and a method to benchmark with industry.

The next steps (Steps 5 and 6 in Table 1) is to discern from the BOK items, a mapping to the BOK items and identify competencies for an introductory BIM course vs. what should be taught in more advanced courses. Academia may then define competencies and define levels of learning to meet those competencies. Academic programs are establishing exactly what is taught and how it is taught (guest speakers, theoretical, modeling assignments and exercises) and additionally, with consideration to integrate BIM throughout the curriculum in courses such as estimating and scheduling and finally, in Capstone courses. Conversely, content areas from other courses are incorporated into BIM courses. McCuen and Coetzee (2016) required students to incorporate project management knowledge before modeling by creating a model development plan and a model management plan based on contract language and a 2D set of project drawings. These examples of cross-integrated learning showcases the higher levels of Bloom's Taxonomy.

3. CASE EXAMPLES FOR BIM BOK & CURRICULUM MAPPING

The mapping process used by three programs provide possible uses of the BIM-BOK as a guide for course content planning. By using the BIM BOK Curriculum Integration Description, course planning becomes a more standardized process whereby improvements through benchmarking and adding to either the integration descriptions or to the line item list will provide a means for course improvements. Three BIM courses were used to map a similar process with the BIM-BOK. Table 2 provides an example of all three courses. Case examples 1 and 2 are from course content areas that are both at the Coordinate It Level of Implementation but have two very different teaching examples for the same Student Learning Outcome. Case three was from a course that has implemented content at an integrated level and used the ABET Student Learning Outcome.

The examples provided below are in a format that may be used by any faculty member to create a similar mapping process. Cases 1 and 2 (respectively) are provided below:

Case Example 1
BIM BOK Curriculum Integration Description
- ROU: Contractor
- LOI: Plan It & Coordinate It
- TOK: Project
- LOP: Entry & Middle Level

BOK Line Item:
- BXP: Goals
- BXP: BIM Usage
- Model coordination
- Pre-construction issue resolution
- Model validation
- Project Controls – Budgeting/cost
- Project Controls – Scheduling/time

SLOs & measurable performance
- BXP: Goals – At the end of the learning module, students should be able to:
  - Explain the relevance of BIM Goals to the project BIM team
  - Explain the relationship between project BIM Goals and LOD
- BXP: BIM Usage – At the end of the learning module, students should be able to:
  - Identify BIM Uses in multiple phases of a facility's lifecycle
  - Explain the type of graphical and information content needed to meet a specified BIM Use
- Pre-construction Issue Resolution – At the end of the learning module, students should be able to:
  - Explain the use of BIM to resolve pre-construction issues
  - Apply pre-construction knowledge to analyze a design model
  - Apply BIM technology to resolve constructability issues during pre-construction
- Model Validation - At the end of the learning module, students should be able to:
  - Analyze the design model to validate its accuracy in comparison to the construction documents
  - Perform model preparation to meet the prescribed BIM Use
- Model Coordination - At the end of the learning module, students should be able to:
  - Explain the concept of project spatial coordination and its purpose
  - Explain the general work flow and identify key parties and their roles & responsibilities involved in this process
  - Perform model preparation, model data management and other critical spatial coordination tasks with appropriate technology
- Project Controls – Budgeting/Cost - At the end of the learning module, students should be able to:
  - Explain the concept of 5D BIM and its potential value
  - Explain required quantity and cost information
  - Identify quantities for the appropriate estimating level (e.g. CY, SF, etc.) upfront
  - Validate and prepare design model for QTO
  - Manipulate models with appropriate applications/functions to acquire quantities usable for estimation
- Project Controls – Scheduling/Time (4D Simulation) - At the end of the learning module, students should be able to:
  - Explain the concept of project spatial coordination and its purpose
  - Identify work sequence, time durations, and resources for construction process
  - Perform model preparation, model data management and other critical spatial coordination tasks with appropriate technology

Case Example 2
BIM BOK Curriculum Integration Description
- ROU: Contractor
- LOI: Coordinate It

- TOK: Project
- LOP: Entry & Middle Level

BOK Line Item:

- Model Coordination
- Pre-construction Issue Resolution

Interpreted BIM SLOs & measurable performance

- <u>BIM-based Spatial Coordination</u>. At the end of the learning module, students should be able to:
    o Explain the concept of project spatial coordination and its purpose
    o Explain the general work flow and identify key parties and their roles & responsibilities involved in this process
    o Identify the project life cycle phases and importance of model development LOD to spatial coordination
    o Perform model preparation, aggregation, clash detection, model data management and other critical spatial coordination tasks with appropriate technology
    o Generate and maintain spatial coordination report, and analyze pre-construction and construction issues related to spatial coordination in a team environment
- <u>4D Simulation</u>. At the end of the learning module, students should be able to:
    o Explain the concept of project spatial coordination and its purpose
    o Explain the general work flow and identify key parties and their roles & responsibilities involved in this process
    o Identify the project life cycle phases and importance of model development LOD to spatial coordination
    o Perform model preparation, aggregation, clash detection, model data management and other critical spatial coordination tasks with appropriate technology
    o Generate and maintain spatial coordination report, and analyze pre-construction and construction issues related to spatial coordination in a team environment
- <u>Model-based QTO & Cost Estimating.</u> At the end of the module, students should be able to:
    o Explain the concept of 5D BIM and its potential value
    o Explain required quantity and cost information at different project phases
    o Identify quantities for the appropriate estimating level (e.g. CY, SF, etc.) upfront
    o Validate and prepare design model for QTO
    o Manipulate models with appropriate applications/functions to acquire quantities usable for estimation

Table 2 provides another format showing a linear flow of cases 1 and 2, which may also be used for the mapping process.

Table 2. Alignment of the BOK to the LOPs and Bloom's Taxonomy of Learning.

Case Example 1

BOK Levels of Implementation	BOK Knowledge	Bloom's Taxonomy	Accreditation - Student Learning Outcomes	Student Competency (Course Learning Outcomes)	BOK Level of Performance	Industry Performance Expectation / BIM Maturity
Plan It		Remembering			Entry Level	Bachelor's degree or equivalent technical education
Coordinate It	BIM Processes and Tools for Constr. (BIM360, Assemble, and Estim. & Sched.)	Understanding			Middle Level	*Entry Level* qualifications plus 3-5 years of experience in BIM practices
Manage It		Applying	SLO #10: Apply electronic-based technology to manage the construction process.	Students begin to put the information they are learning into context. They are able to integrate ideas across multiply situations, or utilize the content in a new way.	Full Performance	*Middle Level* qualifications plus 5 or greater years of experience in BIM pract.
Do It		Analyzing Evaluating Creating				

Case Example 2

BOK Levels of Implementation	BOK Knowledge	Bloom's Taxonomy	Student Learning Outcomes	Student Competency	BOK Level of Performance	Industry Performance Expectation / BIM Maturity
Plan It		Remembering			Entry Level	Bachelor's degree or equivalent technical education
Coordinate It	Model Coordination & Pre-Construction Issue Resolution	Understanding			Middle Level	*Entry Level* qualifications plus 3-5 years of experience in BIM practices
Manage It		Applying	SLO #10: Apply electronic-based technology to manage the construction process.	Apply BIM in an integrated project delivery process via project-based learning experience.	Full Performance	*Middle Level* qualifications plus 5 or greater years of experience in BIM pract.
Do It		Analyzing Evaluating Creating				

Case Example 3

BOK Levels of Implementation	BOK Knowledge	Bloom's Taxonomy	Student Learning Outcomes	Student Competency	BOK Level of Performance	Industry Performance Expectation / BIM Maturity
Plan It	Understands just your own model	Remembering	SLO #6: Solve problems & design components, systems or processes appropriate to the discipline.	CLO #1: Develop a building information model and assess the technical impacts.	Entry Level	Bachelor's degree or equivalent technical education
Coordinate It		Understanding			Middle Level	*Entry Level* qualifications plus 3-5 years of experience in BIM practices
Manage It		Applying			Full Performance	*Middle Level* qualifications plus 5 or greater years of experience in BIM pract.
Do It		Analyzing Evaluating Creating				

4. DISCUSSION & FUTURE RESEARCH

This research primarily explored the next steps (Steps 5 and 6 in Table 1) in implementing the BIM BOK starting with a mapping process to identify target BIM competency in alignment with program priorities and institutional contexts, with active involvement of local industry. The academic uses of the BIM BOK can promote consistency between career-specific competency requirements and academic student learning outcomes, and help delineate proficiencies which may then be used to create course objectives and later, to create better job descriptions and recruiting methods. Future research will investigate the specific pedagogical models that best fit into BIM competency development among college students, and the factors that might influence the student learning outcomes.

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ACKNOWLEDGMENTS

AN APPLICATION OF BIM-BASED VIRTUAL PUNCH LISTING IN CONSTRUCTION EDUCATION

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1. ABSTRACT

Virtual reality (VR), as a modern, effective, and popular type of information and communication technology (ICT), allows students to interact with the 3D model of the building before even it is constructed. Users enter into a virtual environment with high levels of interactivity and visualization, and perform actions in real-time that affect the virtual world. It is no doubt that the VR technology will change the way of learning with its active participation and interaction. The virtual environment is created based on building information, where Building Information Modeling (BIM) plays an important role in providing the dynamically changing data and a 3D building representation. With the help of BIM, VR environment can be explored by designers and contractors to resolve potential issues at the design stage, and even afterwards, when punch lists are created. Punch listing is crucial in completing and closing out a construction project on time. However, virtual punch lists are yet to be produced to check the 3D model beforehand and resolve potential issues related to the design and use of the building at the early stages of the project.

Future construction graduates need to be equipped with the VR technology and the virtual punch listing knowledge to keep up with the emerging technologies and the needs of the industry. This study uses VR and BIM as tools to explore their combined use and benefit for construction management (CM) students. The objectives of this paper are to discuss: (1) how VR technology can be implemented in construction education, (2) how virtual punch listing can be used effectively to improve the understanding for CM students. This study gives an overall guideline to help educators in implementing VR in CM courses.

Keywords: BIM, Virtual Reality (VR), CM Education, Virtual Punch Listing

2. INTRODUCTION

The learning era of CM has been enriched with the introduction of smart learning environments. As one of the smart learning environments, VR has been widely used in the industry and has become a valuable asset for CM education. Some pioneer industries using VR are medicine (Riener & Harders 2012) and aerospace (Stone et al. 2011). Regarding education, VR has been used in civil engineering (Sampaio 2010) and construction (Messner et al. 2003). VR's usefulness in education and its benefits in increasing students' understanding have been emphasized in the previous studies, as students could visualize complex systems better in the virtual environment.

With its dedication to collaboration, BIM feeds real-time information to the VR system and promotes integration between the design and the sensory model in the 3D virtual environment. As it is possible to perform virtual walkthroughs in a building before a single nail is placed at the site, VR offers potential design issues to be realized and corrected before the actual construction. By this way, VR technology has potential to save time and money for the sake of design and non-design parties. As an additional benefit BIM-VR combination offers a better understanding of the project by revealing any design mistakes that can be overlooked in 2D drawings.

Despite the benefits of VR improvements, it still has its own challenges such as the need for VR educated users. In order to keep up with the emerging VR technologies and the needs of the industry in this sense, future construction graduates need to be equipped with the VR technology. Additionally, the virtual punch listing knowledge will help students to resolve potential issues related to the design and use of the building at the early stages of the project. Modern CM education should embrace these terms, however the best practices of VR integrated CM education is not set yet. This paper explores how VR technology can be implemented in construction education, specifically by using virtual punch listing effectively to improve the understanding of CM students. Virtual punch listing is defined in this study as the virtual checking of punch list elements at the design stage to ensure the completeness of the project requirements. The results of the study will reveal best practices and challenges in teaching with VR.

3. VR BACKGROUND

VR has its roots back to 1960s, when helmet mounted display (HMD) devices were first introduced to fighter pilots (Furness 1989). This technology was believed to improve education due to its benefits of simulation of complex systems, visualization, fast and slow time simulation, high levels of interactivity, and inherent flexibility/adaptability (Kalawsky 1996).

The use of VR in design and construction applications requires a 3D model that can be imported to the VR system. With VR, design and non-design users have the potential to virtually walk through in the 3D model of a building yet to be built. Therefore, users get the chance to interact with the 3D model and collaborate with one another base on the representation provided by the virtual environment. Considering its benefits for the construction industry, VR has been used for visualization of construction plans and schedules (Haymaker and Fischer 2001), communicating and training the project team (Haymaker and Fischer 2001), as well as construction scheduling and interactive site experiences (Messner et al. 2003).

Construction education in classroom has benefited from VR and its combinations with 2D, 3D, or 4D models, the most recent studies including 4D integration. Immerging Computer-aided Design (CAD) or BIM) into VR simulations were experimented by many researchers, and was reported to improve students' understanding of construction projects and plans (Messner et al. 2003). BIM was integrated with 2D images on job site to understand the most efficient training styles for safety with the help of hazard training modules (Chen et al. 2013). A combination of 4D CAD modeling and a full-scale VR environment was used to create an interactive learning experience focused on construction sequences. Students were asked to experiment with different construction sequences, temporary facility locations, trade coordination, safety issue identification, and design improvements for constructability, and the results showed that the VR technology brought invaluable opportunities to construction education by providing a detailed understanding of planning issues through virtual and interactive site visits (Messner et al. 2003). The role of open source collaborative design in architecture and construction are discussed through three 'Wikitecture' experiments by using the virtual world Second Life, and the process was found be effective in terms of creativity, motivation, and flexibility (Chase et al. 2008). BIM was integrated with VR role-playing scenarios to enhance architecture, engineering, and construction (AEC) student learning. A virtual BIM environment was used for collaboration as well as creating a 'green' training environment for virtual on-site visiting to actual HVAC systems. The experimented virtual environment showed potential in improving large-scale green building training, while reducing data interoperability issues (Shen et al. 2012).

4. VR IMPLEMENTATION AT JEFFERSON

1.1 VR Equipment and Setup

Architecture and construction companies have been using VR to visualize, communicate, and evaluate the design of buildings and urban environments (Bertol 1997). As VR applications have become more accessible and available to the industry, the need for VR educated graduates has increased. There were still

concerns about teaching VR, such as the need for experienced lecturers, dedicated laboratories, and supporting textbooks and lectures for VR courses (Burdea 2004).

The needs depend on the type of VR implementation. There are two broad types of VR utilization depending on the technology used. Non-immersive or desktop VR uses keyboard and mouse as control tools to navigate in a virtual environment. Immersive VR uses special displays like HMDs and hand-hold controllers to connect user to the 3D model. The system used in this study will be called immersive as goggles and controllers were used to explore the virtual environment. HTC Vive VR System (**Error! Reference source not found.**) was used with a compatible laptop and a TV as a stereo projector on a screen. The software (SteamVR 2017) allows for a room-scale or standstill virtual exploration. In order to give students mobility, a room-scale set up was performed. Room-setup included defining the VR boundaries by the help of two base stations (**Error! Reference source not found.**). Users had to stay in the boundary of the room-scale for the VR equipment to work properly. The setup can be performed with a dedicated area, or for mobile VR settings, it can be performed in any area that is at least 2m by 2m (6.56' by 6.56'). There is an additional software requirement for 3D models to be transferred to the VR software (IrisVR 2017).
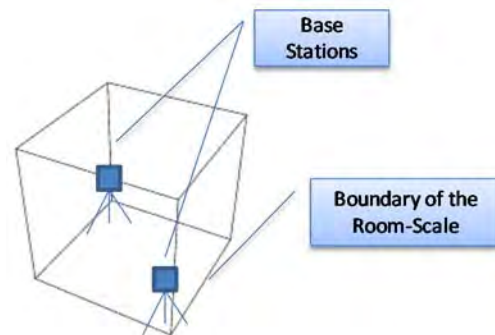

Figure 1. VR Equipment

Figure 2. VR Room Setup

1.2 VR Integration into the Curriculum

After presenting the basics of the VR technology and background setup is achieved, the pedagogy of VR implementation in CM education can be discussed. The pedagogical implementation requires students to have room in their curriculum to expand the uses of VR. Several institutions have started to integrate VR in construction research and education. Penn State Architectural Engineering has developed ongoing research programs in VR and has used VR in an advanced project management class for 4D CAD modeling (Messner et al. 2003). Washington State University Construction Management is developing a BIM Lab that uses VR for student training in visualization and navigation (WSU 2017). Eastern Illinois University is offering Global Study Options with projects embracing VR methods (EIU 2017). In addition to these institutions, Autodesk University offered a variety of VR based courses in AU Las Vegas 2017 (AU 2017).

At Jefferson, VR is integrated into undergraduate and graduate curricula vertically through selected courses (Figure 3). *CMGT 450 Construction Management Seminar* introduces students with the knowledge of BIM and VR as emerging construction trends, and uses VR for demonstration purposes. *CMGT 499 Construction Capstone Project* utilizes VR to improve students' understanding on a real construction project that they bid at the end of the class, while improving their peer-to-peer learning skills. At the graduate level, the BIM class *MCM 602 Construction Information Modeling* particularly integrates VR to Revit models to highlight potential design mistakes and apply the concept of virtual punch listing. The intersection group is composed of students that are taking both courses in the same semester.
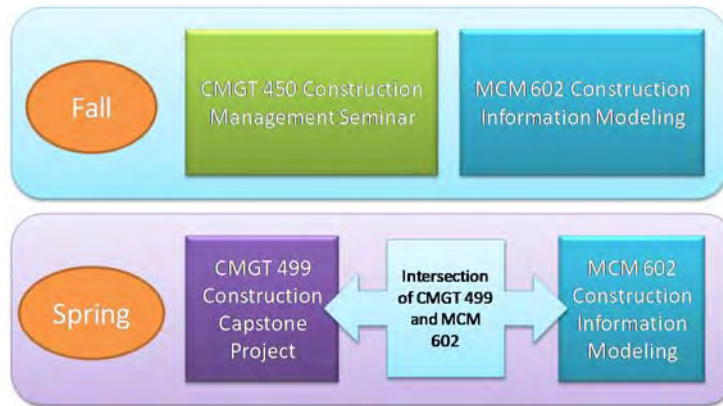
Figure 3. VR Integration at Different Levels of the Curriculum

The users in this study are divided into two groups. The first group is composed of students, who do not have Revit or other 3D modeling knowledge (e.g. CMGT 450 and CMGT 499 students). The students are exposed to BIM knowledge and the VR technology in order, where BIM knowledge is very basic and does not include any software applications. The second group has taken a BIM class, where they learn the extents of Revit Architecture, Structure, Mechanical, Electrical, and Plumbing (MEP), as well as estimating and clash detection (e.g. MCM 602 students). This group has BIM-based capabilities including 3D visualization. Some students have had CAD knowledge as well.

VR implementation requires a 3D model, which is generated from BIM (Revit in this case) and user input. The suggested input-output network for VR education is given in Figure 4. The equipment mentioned above and Revit 3D models can be used in the virtual environment for visualization and analysis of design, training of CM students, and collaboration with other disciplines. The main focus of this study is on the visualization and analysis of design through virtual punch listing.
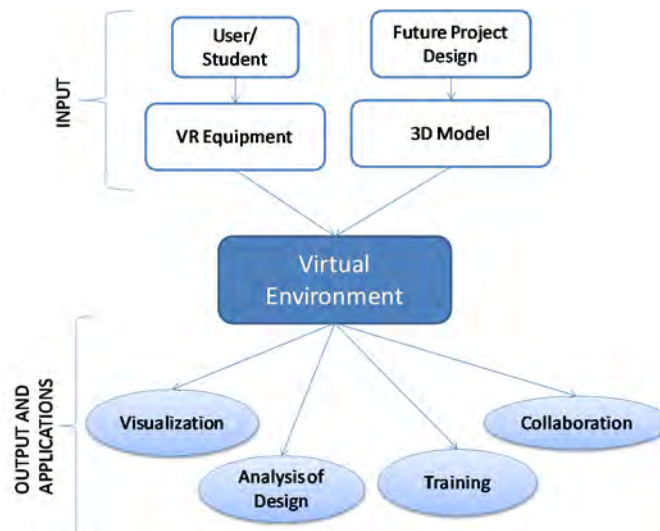

Figure 4. VR Implementation

1.2.1 Virtual Punch Listing and Its Application in CM Education

Punch lists are documents created toward the end of the construction to make sure all work is installed as planned. Punch listing is crucial in completing and closing out a construction project on time. Virtual punch lists are yet to be produced to resolve potential issues related to the design and use of the building. Students

in undergraduate (senior) and graduate (masters) level courses have been introduced to the concept of VR and virtual punch listing in different manners with selected case studies. In order to introduce VR to students, suggested steps from previous studies (Ausburn and Ausburn 2004) were modified as below:

- Discuss benefits, strengths, and limitations of VR in construction
- Provide an overview of the types of VR systems
- Explain how VR systems used in the construction industry
- Discuss how they might apply VR in the future
- Include how VR can be placed in their curriculum
- Encourage them to explore VR technologies and companies using VR
- Assist them in hands-on developments

For CMGT 450, students were asked to discuss BIM and VR in two separate discussion assignments before using the VR tools. The benefits, strengths, uses, and types of BIM and VR applications were discussed in class before the virtual walk-through. Then, students were given a short (5 minute) VR training with SteamVR Tutorial to get comfortable with the spatial space and VR controllers. TV projection allowed all students to be a part of the training process. After the tutorial, students were given the task to perform the virtual punch listing and compare PDF plans to the Revit models.

For CMGT 499, VR was used to introduce students to the virtual punch listing, as well as to the real project that they will be hypothetically bidding in this course. Students, who have Revit knowledge due to their involvement in MCM 602, shared their insight with their group members.

The most extensive use of VR has been performed in MCM 602 class, where students learn to develop and edit Revit models. The same tutorial steps were followed for these students, however there was no need to mention the BIM knowledge. On top of their current BIM and Revit knowledge, BIM-VR relationship was emphasized.

Four case studies were used for VR punch listing (Table 1). The Revit model of a campus building at Jefferson-East Falls was used for the first virtual punch listing. The reason for starting with this building was to give students the opportunity to compare a Revit model with an as-built model. They have compared PDF drawings with Revit model, and both with the actual building. In Case Studies 2 and 3, buildings in other locations were used, so students did not have a chance to see the actual building. They based their comments on PDF drawings and the Revit models. Case Study 4 was selected from a textbook, with the reason that it has all interiors exteriors, structural elements, and most MEP systems completed. As the completeness of the 3D model affects students understanding, this model was used to give students an opportunity to see a building that is ready for occupancy.

Table 1. Case Studies Used for VR Punch Listing

Case Studies	Description	Size of Project	Revit Model Completeness

Case Study 1	Campus building at Jefferson-East Falls	14,500 SF	Architectural Elements:
			    Exterior and interior walls, doors, windows, curtain walls, stairs, floors (finishes up to a certain point), ceiling systems, bathroom fixtures
			Structural Elements:
			    None
			MEP Elements:
			    Electrical fixtures, air diffusers

Case Study 2	Fraternity building at	20,400 SF	Architectural Elements: Exterior and interior walls, doors, windows, curtain walls, stairs, floors (finishes up to a certain point), ceiling

	another campus		systems, bathroom fixtures, kitchen countertop and some cabinets
			Structural Elements:
			    Basement/Foundation walls and footings
			MEP Elements:
			    Electrical fixtures

Case Study 3	Church building	12,000 SF	Architectural Elements:
			    Exterior and interior walls, doors, windows, curtain walls, stairs, floors (finishes up to a certain point), ceiling systems, bathroom fixtures, kitchen countertop and some cabinets
			Structural Elements:
			    None
			MEP Elements:
			    Electrical fixtures

Case Study 4	Textbook example/office building	11,600 SF	Architectural Elements:
			    Exterior and interior walls, doors, windows, curtain walls, stairs, floors (finishes completed), ceiling systems, bathroom fixtures, kitchen countertop and some cabinets, interior elements such as furniture
			Structural Elements:
			    Foundation walls and footings, columns, beams, and joists
			MEP Elements:
			    Electrical fixtures, air diffusers, VAV boxes, AHU, and complete duct system

1.2.2   Virtual Punch Listing Results and Analysis

By performing virtual walkthroughs in the four case studies mentioned before, students prepared a list of discrepancies and issues in the design as given below:

- Case Study 1: Campus Building
    - Finishes in the Revit model was different that the finishes in the actual building. Some examples were color of toilet partitions, color and pattern of carpet, and missing carpets in certain areas.
    - Some door and window types seemed different from the actual, possible due to Revit's lack of proper family files.
    - Lack of interior furniture was reported to decrease the quality of VR experience.
    - Some part of floor was missing below the stairs.
    - There was floor above the stair opening.
    - Elevator was missing.
    - Some incorrect dimensions were figured out by comparing the appearance of the user in the real and virtual space.
- Case Study 2: Fraternity Building
    - Walking in a building that the users did not know create issues in other areas, which will be discussed in the next section.
    - Some window sill heights were incorrect due to the virtual height of the user

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- o Floor finishes were incorrect or incomplete
- o Some walls seemed to be joined in 2D, but in the virtual model, they were not actually joined.
- o Types of some bathroom fixtures were incorrect.
- o Stairs around the concrete patio on the south side did not match with the floor.
- o Bulkheads at the basement were made of concrete instead of interior partitions.
- o There was an elevation difference in landing and stairs, which resulted in a gap in between landing and stairs.
- o There was a ceiling system above the stair opening.
- o Some doors should be flipped to have the same inside-outside view
- Case Study 3: Church Building
  - o Ceiling bulkhead material was incorrect.
  - o Tiles and ceiling finishes are missing
  - o Frames of doors were not at the same height with one another
  - o Some doorframes stick outside the wall/door.
  - o Double doors are missing at the Sanctuary
  - o Some bathroom fixtures are incorrect
  - o Widths of the bathroom stalls look small
  - o Wall connection issues existed at some of the corners
  - o Ceiling grids were incorrect in some locations
  - o Gym floor boundary was not correct
- Case Study 4: Office Building
  - o Clashes were visible between electrical fixtures and air diffusers at certain locations.
  - o Duct connections did not seem connected in some places because of either the flex duct installation or graphics.
  - o Around the north stairs, there was a gap between walls.
  - o In some locations, there was disconnections between exterior and interior walls

When the results are evaluated, it was apparent that the VR walkthroughs have improved students understanding of the projects, as well as improved their critical thinking skills to observe and analyze mistakes in a Revit model. Although the case studies were seemed appropriate in 2D versions and in Revit's 3D model in most cases, there were still many issues when a virtual punch listing was performed. Common issues were incorrect item types, lack of finishes, and floor-stair connections. Especially stair-floor connections have been an issue with MCM 602 students when they start to create floors and ceiling systems in Revit. Students tend to place floors away from stairs, which hinders building users to use the stairs and step onto the second floor. Another common mistake is to place ceilings or floors on top of stair openings. With VR walkthrough, students were able understand the importance of correcting their mistake and how their mistakes end up in the final version of the building. All students reported an increase in their understanding of 3D construction models with VR technology, which has showed an improvement to traditional construction education as supported by previous studies (Ku and Mahabaleshwarkar 2011). Additionally, they observed how VR punch listing could supplement Revit models and the construction process, when used appropriately.

5. CONCLUSIONS AND FUTURE WORK

The VR lab at Jefferson allowed CM students to walk in Revit 3D models to assess the educational value of VR. Two experiments were conducted to see:
1) How VR technology can be implemented in construction education?

2) How virtual punch listing can be used effectively to improve the understanding of students?

This paper addresses VR implementation through setup guidelines and best practices on vertical integration into undergraduate and graduate CM curriculum. A variety of case studies was used to perform VR walkthroughs with CM students to explore the combined benefit of BIM and VR technologies. The results showed possible areas in 3D Revit models (e.g. stairs), where common design mistakes occur, and most of the time these mistakes cannot be found out with traditional viewing of the model. VR brought another layer on students' understanding of the construction design and showed them the importance of eliminating design mistakes early in the project. Most of the students have met with the virtual punch-listing concept for the first time in these classes, and became aware of their roles as CMs to monitor this process.

As the industry continues to use VR technology, it is believed that VR will become an inevitable part of the CM education. Future studies have room to focus on how General Contractor (GC) companies use VR for specific purposes, so that future graduates can be well equipped with this new and emerging technology.

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Effectiveness of Building Information Modeling (BIM) Technology for Pre-Service/District School Administrators

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ABSTRACT

This study is to assess the understanding of Building Information Modeling (BIM) technology for pre-service and current district school administrators in North Carolina whose additional responsibilities include the administration, planning, design, and construction of educational facilities. Pre-service administrator is defined as *a period of guided, supervised training by a mentor who facilitates a progressive learning system to encourage advanced levels of management (Kaufman,2013).* The goal and objective of pre-service training is *an opportunity to experience the demanding and rewarding task of assuming major administrative responsibilities(Kaufman,2013).* A school administrator *is responsible for making recommendations regarding hiring or the purchase or acquisition of any property or services by the local school district.* (State of New Jersey Department of Education 2017) Furthermore, this study will seek to understand how BIM technology can be introduced into pre-service education curriculum and professional development training for district administrators.

Keywords: BIM, Education, School Administrators, School Districts, Pre-Service Administrators, Curriculum, Training, Facility Management

1. INTRODUCTION

Before an educational facility is constructed, most school administrators are asked to participate in the design stages. Once an educational facility is constructed and occupied, administrators are tasked with operating and maintaining the building. School administrators need to be well informed about the building operation and maintenance under their direct supervision.

School administrators at the Pre-Kindergarten through 12th grades are asked to manage the planning, design, construction, maintenance and operation of their respective educational facilities. No longer are educators and administrators asked to just prepare lesson plans and develop curriculum. They are now held responsible, in part, for the planning, design, decor and construction of an educational facility. The dilemma then, for the designated administrator is how to manage the design, construction and renovation of a building.

When school administrators and central office personnel are given the responsibility of managing a new building design, construction or capital improvement project, administrators are handicapped when it comes to offering informed building design and construction suggestions. *School*

administrators play integral roles in ensuring schools function smoothly. They are involved in nearly all aspects of their school's operation. School administrators at the elementary, middle, and high school levels include principals, assistant principals, and other professionals who help operate schools, either on the school's campus or at the school district's central office. (Learn.org 2018)

According to the 2016 report released by the Center for Green Schools entitled "State of Our Schools: America's K-12 Facilities", our school buildings and grounds are not keeping pace with the overall needs of the stakeholders. It is estimated that between 2012 and 2024 enrollment in North Carolina will escalate by 13.1 percent with an increased enrollment of 199,435 more students. The cost of this increase directly affects the school administrators' ability to offer students an equitable education without the estimated $476 million needed to facilitate the learning environment which includes facility management and upgrades. Schools buildings are the cornerstone to the educational success, health, and economic vitalization of the communities. Many school facilities are overcrowded and unable to accommodate the increases in student enrollment. Administrators need to be able to forecast and make projections for their perspective schools. (Centerforgreenschools.org 2017)

Using BIM technology will allow administrators the flexibility to explore several options in decision making about various aspects of building operations, maintenance, facility space usage, and staffing/hiring.

The State of Our Schools report also identified these key strategies for addressing the structural deficits in K-12 public education infrastructure:

- *Understand public school facilities conditions and provide communities access to accurate data about school facilities,*
- *Engage in education facilities planning using best practices from across the country and support local communities in proposing creative and practical plans to improve their public school facilities and*
- *Support new public funding to provide what is needed to build and maintain adequate and equitable school facilities and leverage public and private resources to extend a community's investments, utilizing a new generation.* (Centerforgreenschools.org 2017)

As school administrations educational and training programs struggle with new changes in education, the new reality of added responsibilities and competency in all aspects of facility management becomes ever prevalent to the pre-service training of administration interns. In most curriculum for school administrators there is a lack of concentration on facility management and new construction management. In many states, particularly North Carolina, the new standards for licensure as a principal include facility management as a component of required competency however, more training is needed to perfect the use of technology for decision making such as BIM that could make the total experience more meaningful and assist with increasing administrators knowledge about building space usage, facility management, heating and air conditioning, furniture placement and grounds utilization.

Unfortunately, school safety has become a major school administrator and law enforcement concern directly related to previous and present school violence and shootings. The reality for school

administrators is that the need for better building management requires use of better technology to safe guard schools. There are many inhibitors or barriers to making the school building the highest priority such as funding and community support. However, armed with the knowledge and the ability to use a tool such as BIM technology for decision making allows administrators to plan for the future.

2. METHODOLOGY

The Institutional Review Board at North Carolina A&T State University reviewed and approved the Building Information Modeling survey for this study. This was an on-line survey collecting data with Survey Monkey. Prior to emailing the survey, letters were sent to each school district requesting permission to survey their personnel. After receiving district approval of the survey, surveys were emailed to administrators in three North Carolina school districts. The main purpose of the survey was to determine the knowledge and usage of Building Information Modeling (BIM) technology by school administrators and pre-service administrators. The survey questions focused on a variety of BIM concepts and pre-service and administrators' basic knowledge of BIM technology as it relates to their new responsibilities of facility planning, development, maintenance, operations and renovations. Refer to Appendix A for the complete survey.

The responses from this survey were analyzed and used for statistical projections regarding future course development, training, workshops and certifications for administrators. "*The basic premise of Building Information Modeling (BIM) is to use and share the digital model of a project as a source of information for all participants, in order to simulate and analyze potential problems during the project's life-cycle, from conception to operation. BIM is a relatively new technology praised by all participants in the Architecture-Engineering-Construction (AEC) industry for its innovative tools, and the promise of a high return of investment and productivity increase.*" (Pena, 2011).

3. FINDINGS

The findings of this survey provided useful information and documentation for the need for BIM technology training, workshops and certifications of pre-service and school administrators.

The findings from this survey provides table and statistical information to assist pre-service and school administrators with the needs assessment to incorporate BIM technology into the credentialing of pre-service and administrators. The cost associated with the efficiency of building design, construction, maintenance, operation and safety is directly related to the skill and educational level of those involved that manage and operate buildings.

This Building Information Readiness Survey (Exhibit 1) was sent to school administrators at three North Carolina school districts. Although this survey was sent to several NC school districts, the response rate was very small. These findings document the need for BIM technology training. The results of the survey reveal that the majority of the respondents had little to no BIM knowledge and building design, construction, maintenance and operation experience. Our BIM survey revealed several important descriptive facts included in the following tables 1 through 5:

Table 1
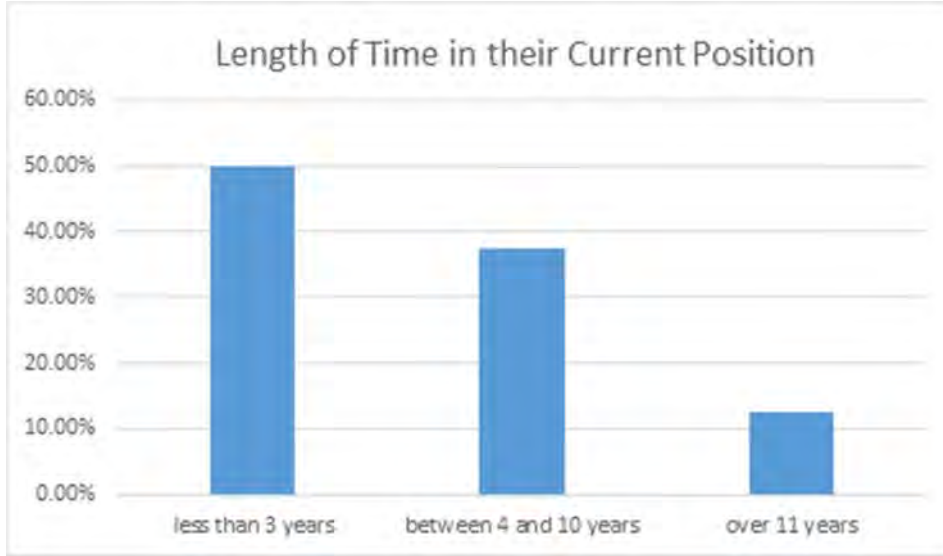
Length of time in educational settings can be an important variable. Table 1 shows the length of time the survey respondents have been in their current positions. 50% of the respondents have been in their positions for less than 3 years. 38% of the respondents have been in their current positions between 4 and 10 years. A smaller percentage, only 12%, have been in their current positions for over 11 years.

Table 2
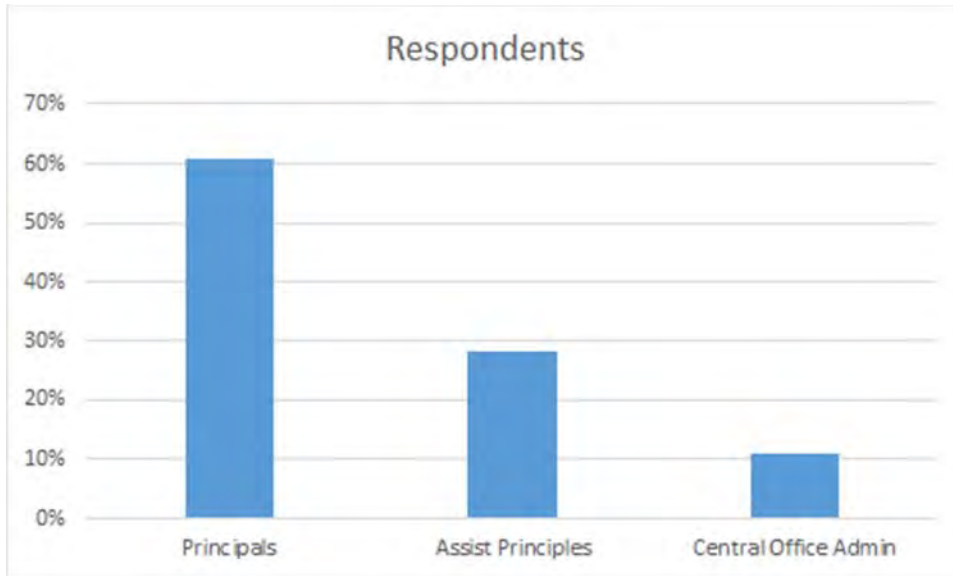
The decision-making process for developing budgets and needs assessments for schools can be associated with the management style of the institution. These decisions can be initiated or developed by principals, assistant principals or central office administrators. Table 2 shows the current positions of the survey respondents. 60% of the respondents were principles, 29% were assistant principals and 11% were central office administrators.

Table 3

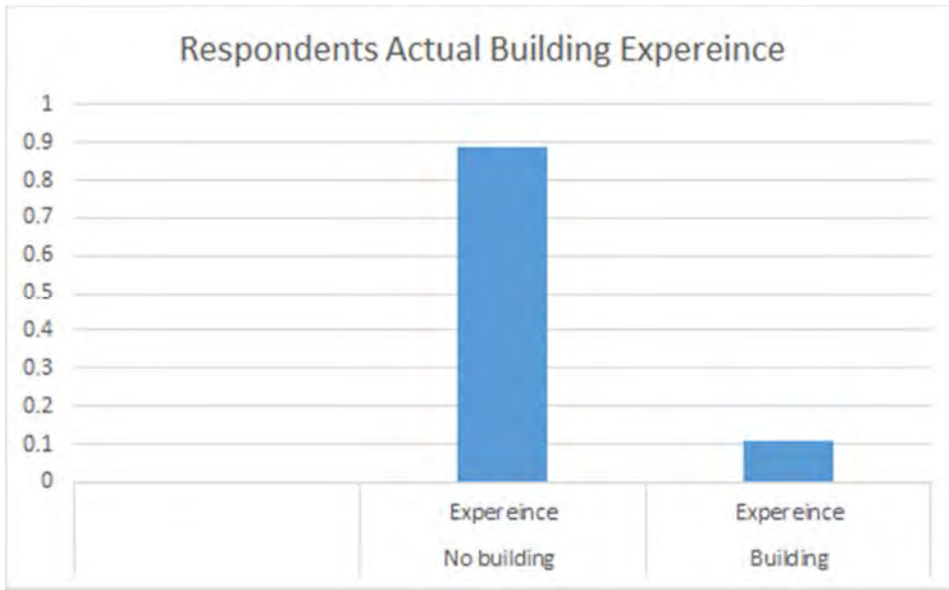## Respondents Actual Building Expereince

Table 3 looks at the respondent's actual level of building experience. This variable becomes important when decisions need to be made relative to new construction, modifications and renovations. 89% of the respondents in the survey have no building experience, while 11% had some prior building experience.
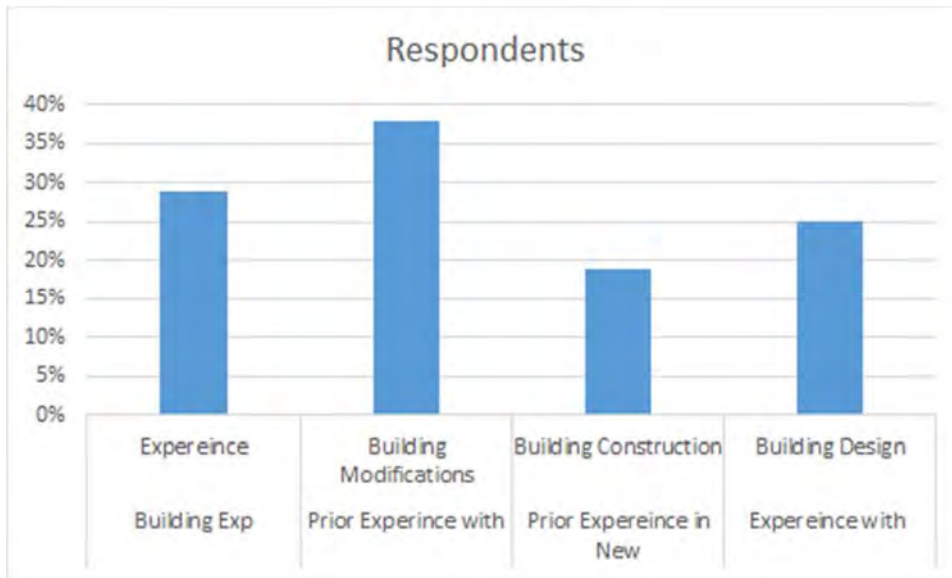
Table 4

Respondents

Table 4 is a bit more specific in that it looks at the specific type of building experiences that each survey respondent had. 40% of the respondents had more building experiences with building modifications. Approximately 25% had experiences with building design while 19% had experience with building construction.

Table 5

Remolding and Renovation Expereince
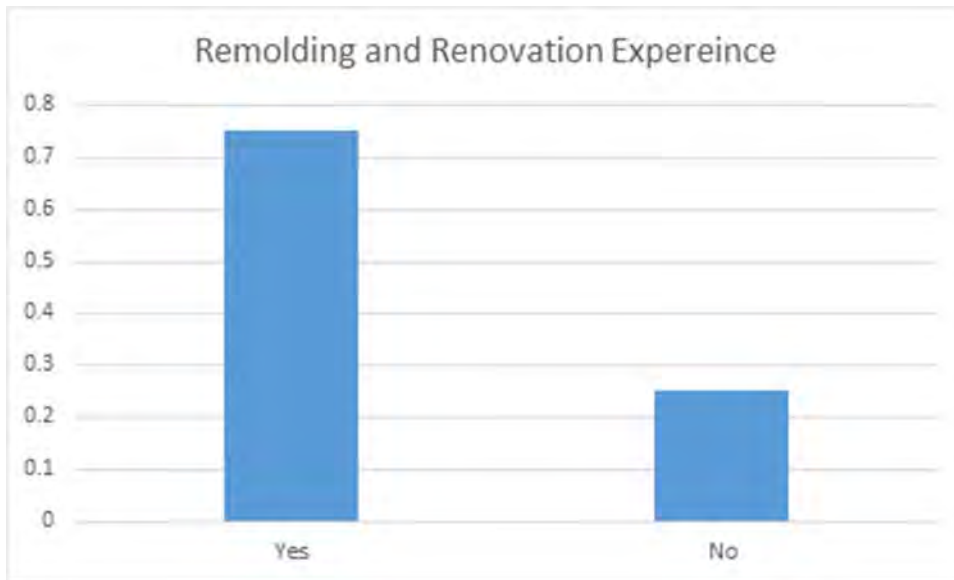
Table 5 shows the percentage of survey respondents who have been involved with remodeling and or renovation experiences. 75% of the respondents have had remolding and or renovation experiences. 25% have had no experiences with remolding or renovation.
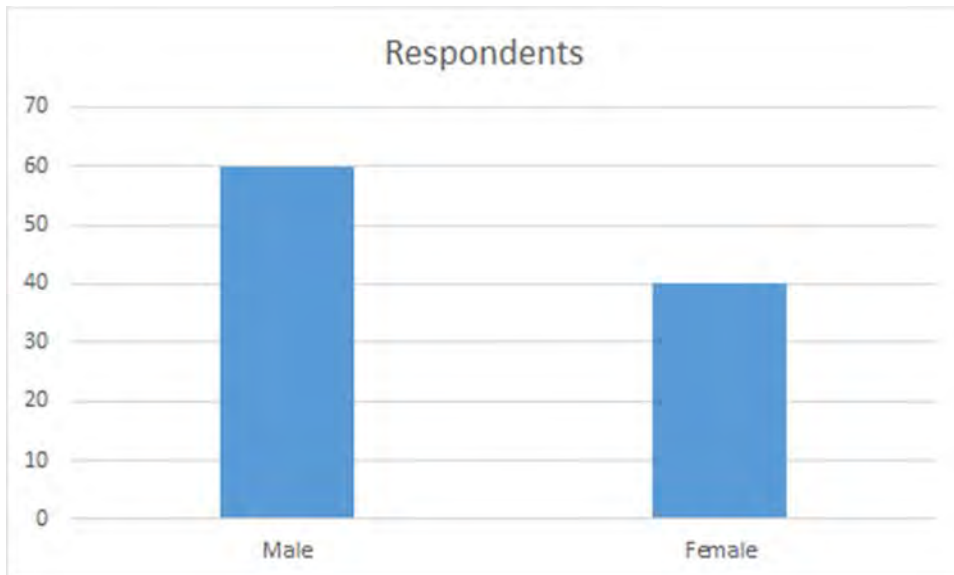
Table 6

Respondents

Table 6 shows the percentage of males and females respondents. There were 60% male and 40% female.

The probability of a successful remodeling or renovation project from this group of respondents is only 1.14%. An interesting finding was that 38% of the respondents had previous experiences with building modifications and renovations while only 3% of the respondents had any building or construction experiences using BIM technology.

Another interesting finding was that 75% of the respondents had previous experiences with building modifications and renovations while none of the respondents had any building or construction experiences using BIM technology. The probability of a successful remodeling or renovation project from this group of respondents with less than 3 years of experience is only 12,5%. This is not a favorable statistic.

4. CONCLUSIONS AND FUTURE WORK

Further studies on this topic are needed to analyze the exact needs of pre-service and administrator duties and responsibilities with respect to building design, construction, maintenance, operation and safety. BIM Certificates specifically designed for pre-service and school administrators may also be researched.

The findings from this survey can be developed into a needs assessment model which will assist BIM technology educational and professional development training. The following advantages can be realized from this model for school districts and pre-service administrators:
   a. Assessing the number of employees who are in need of BIM technology and training
   b. Designing BIM training programs which address specific needs
   c. Developing instructional material for teaching BIM technology
   d. Developing interest in BIM technology for economic building efficiency
   e. Creating BIM workshops to address school safety
   f. Creating an additional skill set for current administrators
   g. Documenting the need for a Certificate Program in BIM for school administrators
   h. Collecting information useful in estimating the cost for BIM technology training.

District administrators have varied backgrounds including education, technology, business, economics, etc. For example, there are several costs savings that could be realized by educational districts if they seek employees who are trained and have experience in using BIM technology. Grant proposals would aid BIM technology education in a collaborative effort to strengthen existing curriculum and develop new curriculum, education programs, and certificates which address BIM technology.

Developing a Center for BIM technology training specifically for pre-service and school administrators is suggested from this survey data. The BIM Center can bridge the technology gap for school district administrators who are currently involved with building design, maintenance and planning for future buildings. Offering seminars and webinars for current and future administrators is a way to re-tool these administrators.

Exhibit 1 (Building Information Modeling Survey)
1. How experienced are you with BIM (Building Information Management) Technology?
2. Have you had any special training using BIM technology?
3. Do you have building construction experience?
4. What level of experience have you had with the following building construction issues?
5. How long have you been in your present position?
6. What is your gender?
7. Have you ever been involved in the financing of school construction projects?
8. Which category best describes your current position?
9. 9. Are you familiar with BIM estimating tools?
10. .Do you know about BIM facility and Asset Management tools?
11. Which BIM applications are you familiar with?
12. Are you familiar with the term "Integrated Project Delivery?
13. How do you currently manage the construction of a school project?
14. Identify which of the following Benefits of BIM technology you are familiar with.
15. Which of the following BIM information would you want to have to effectively administer the construction of a school: Select all that apply?
16. Have you heard of 4D simulation/visualization BIM models to support construction planning so that you can "SEE" in real time the actual "virtual construction" of a project?
17. Did you know that 4D models allow you to link a project to a construction schedule that provides you with start and end dates/times for every component.

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BIM IMPLEMENTATION AT THE CONSTRUCTION COURSES IN THE ARCHITECTURAL ENGINEERING IN THE UNITED ARAB EMIRATES UNIVERSITY.

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Abstract. The implementation of BIM in the Architectural Engineering and Construction (AEC) curricula is a must to provide our students with the skills that AEC industry is demanding all over the world. This paper explains the evolution of the Construction II "Building Construction Components" course (BCC) in the United Arab Emirates University (UAEU). Here we introduce the assessment process implemented to understand the motivation, satisfaction and performance of the students; some of the conclusions of this assessment, and the changes made at the course level to improve the BIM introduction and students' performance and experience.

Keywords: BIM, AEC, Curriculum, Higher Education, Mixed Methods, Enhanced Learning, User Centered Evaluation, Motivation, Satisfaction, User Profile.

1. INTRODUCTION

The evolution of a curriculum towards BIM is a very complex issue. The first and most important factor is the ambiguity of how BIM will fit both industry and academia. It is known that the industry, governments and academia are incorporating BIM to the AEC working environment, but is a slow process with lots of difficulties and no common framework. This leads to the current situation, where every institution is doing BIM by its own, without standard, common learning outcomes or any encounter point.

There are efforts to create standards, assessments and certifications, but all of them are still evolving and not mature enough. For instance, we can find the Academic for Interoperability Coalition (AIC) where this paper is submitted, Building Smart Associations all over the world, and many conferences and seminars trying to improve and figure out the future of BIM. Meanwhile the industry is using BIM and improving its use, by standalone trial and error system, where each company try its best or hire a consultant to fulfil the BIM law requirements; this is quite sarcastic because BIM is meant to be a collaborative working environment.

This research paper explains the introduction of BIM at the Construction II course (Building Construction Components) in the Architectural Engineering (AE) department at the UAEU, and its following modifications. These modifications are done based on the assessment procedure that is being developed in my PhD thesis, by quantifying the motivation, satisfaction and performance of the students, and using qualitative data to have a better understanding of the results.

2. BACKGROUND

2.1. INFORMATION AND COMMUNICATION TECHNOLOGIES (ICT) IN HIGHER EDUCATION

Information and Communication Technologies (ICT) are changing the way people interact in our society; our lives and working environment had changed totally due to the introduction of ICT. Few people remember how

difficult it was 30 years ago to collaborate, communicate or accessing papers, database and information. Nowadays every one of us can access almost everywhere more information than what we are able to understand, comprehend and use.

The introduction of this technology on the Academia is not a simple task. On this direction we can find several scholars [1-3] who wrote about problems and failures that faced the introduction of ICT in academic curricula. Different types of studies have been conducted to investigate the implementation of ICT including: studies about teaching methodology and course design [4,5]; studies about the difficulties that we might face when implementing ICT tools in academic courses [6,7], and studies about the so called "good teaching practices" [8-10].

Utilization of ICTs in academia is a very common practice. The evolution and the change on the representation tools in AEC curricula has affected the nature of the presented information. As Ibrahim and Krawczyk stated [11] the earlier generations of CAAD software like AutoCAD only represented the geometrical properties of the architectural elements; while the introduction of Building Integration Management/Modeling (BIM) added the value of integrating the information and graphics within the building model.

In new building models specifications and properties for the design evaluation, collaboration, analysis and production processes are all embedded information, which can describe materials specifications, code requirements and any other data associated with the building model as Kocaturk explained [12].

2.2. BIM WITHIN AEC CURRICULUM

In the Studies carried out by Taylor and Barison [13,14], it is stated that BIM should not be introduced just as a skills course, but rather, should be embedded into background knowledge. We can observe in the data provided by Barison[15] that BIM is introduced within Architecture curriculum mainly in Design Studios, Digital Representation and Construction Management Courses, while in Engineering it is implemented as a BIM specific course. This is a very important point, because it can define the way it should introduced, and the final purpose of it.

[6] Kymmell mentioned that the first two years of BIM introduction will be consumed in the practice of individual skills of modelling and analysis, after that period, one can begin to learn teamwork and collaboration and finally comprehend the interaction with third parties.

The research conducted by Barison [15] about the BIM implementation in the AEC curriculum, has shown that each school is working individually, and there is no common agreement about how to introduce BIM in the curriculum. As stated in the introduction, we can find that AIC, Building Smart and Governments are working in order to create standards and assessment procedures to implement BIM at the industry and academia, but there is still a lot to do in this regard and this study is working towards this issues.

2.3. UNITED ARAB EMIRATES UNIVERSITY (UAEU), ARCHITECTURAL ENGINEERING (AE) PROGRAM BRIEF HISTORY.

The United Arab University (UAEU) is a French model based university founded in 1976 as one of four federal institutions of higher education (UAEU, Zayed University, Higher Colleges of Technology, College of National Defense), each of which serves a distinct mission and student population. UAEU is a comprehensive federal university, and is widely recognized as the flagship institution of higher learning in the United Arab Emirates.[16].

The currently ABET accredited Architectural Engineering (AE) program was founded in 1981. In 2012, the department identified Building Construction/Construction Management as its synthesis/design focus area, with building structures at 'application level' and building mechanical and electrical systems both at 'comprehension level', according to ABET attainment levels requirements. In 2014, the program addressed the implementation of BIM in the courses of Design Studios, Building Construction and in an advanced elective course of "BIM: Modeling and Simulation". Thanks to these changes, it is highly expected the Graduation Projects will be improved in quality and the graduated students will become an asset to the AEC industry of the country which is moving forward to the BIM technologies. To even further reinforce these benefits, a new BIM skills course at the early stages of the curriculum will be added, beginning next fall 2017 semester.

3. CASE STUDY

3.1.   'BUILDING CONSTRUCTION COMPONENTS' COURSE (BCC)

3.1.1. FORMER COURSE

Building Construction Components (BCC) Course is the intermediate Building Construction Course in the AE program at the UAEU. At this stage, the students learn the building construction components properties, specifications and application methodologies in order to be able to create their own details for their projects. During the BCC Course we introduce the students to different types of floor systems, interior and exterior wall systems, false ceilings, building joints, vertical circulation, and openings.

This course is primarily oriented around lectures, open class discussion, information research and detailing drawing and specification assignments. The course is organized around a series of interrelated instructional topics. A significant portion of the course material is technical information that requires frequent class discussions and small group interactions. We target students' collaborative skills, research ability and detail design as main elements of this course.

The Course has four main parts: lectures where each subject is introduced by the professor, research about products available in the region, their specifications and application methodology; in-class discussion about the lecture and research findings; and finally detail development by sketching and AutoCAD, each of the students are required to develop their own details for their project, using one of the products available in the market.

Table 1. Former bcc course schedule.

Topic	Hours*	
	Lectures, Theories & Group Discussions	Practical Lab/Studio Applications
Week I: Introduction to Course (Syllabus + Revision) Internal Finishes: Plastering & Paint	2	2
Week 2: Internal Finishes: Floorings	2	2
Week 3: Internal Finishes: Demountable Partitions	2	2
Week 4: Internal Finishes: Suspended Ceilings	2	2
Week 5: External Finishes: Plastering + Cladding	2	2
Week 6: External Finishes: Metal & Glass Curtain walls	2	2
Week 7: Q1 (Internal and External Finishing)	2	2
Week 8: General Revision & Open Questions Session	2	2
Week 9: Midterm Exam (Date is subject to change)		
Week 10: Joints in Buildings		
Week 11: Openings: Doors and Windows Components	2	2
Week 12: Service Components: Ducting, Floor Trench, Floor and wall Chase	2	2
Week 13: Q2 (Openings)	2	2
Week 14: Vertical Circulation: Steel Staircase	2	2
Week 15: Vertical Circulation: Elevators, Escalators and Conveyors in Building Construction Drawings	2	2
Week 16: General Revision & Open Questions Session	2	2
Final Exam: (Date to be Confirmed)		

The students' evaluation:

- Assignments and presentations: 40%
- Class Participation: 10%
- Mid-Term Exam: 20%
- Final Exam: 30%

Main assignment grading criteria:

- Understanding; well-defined problem and clear design intent based on literature review, establishment of needs, and case study analysis.
- Application: Selection and integration of appropriate construction system, its components, and relevant construction methods.
- Standards and Building Codes: Application of Building Standards and Building Codes.
- Calculation: Relevant to the selected construction system/components.
- Building Construction Drawings: Technical and graphical expression of building materials, structural system(s), and construction methods.

3.1.2. FIRST APPROACH TO THE BIM INTRODUCTION AT THE BCC

The process to introduce BIM in the academia is a difficult process, where we have to deal with several obstacles that kymmel [6] identified and categorized into three groups: difficulties in learning and using ICT tools software; misunderstanding of the process, and issues related to the circumstances of the academic environment.

Due to the academic environment circumstances, where some professors all over the world do not continue developing their ICT skills, or they just don't want to modify their teaching procedures, we found reasonable to try a s first stage, of BIM introduction, where we decided to adopt the simplest option, which most faculty will find it easily to introduce.

We stick with the course as it is, and split the lab sessions in two sessions. The first one will follow the same conventional approach and assignments will be done typically as the former course. The second part will introduce BIM concepts and Revit tool to create a 3D model of the building and its details that we are developing at the course. This approach provides at the same time the traditional 2D learning environment, along with a 3D BIM one. We assume (and we will evaluate) that this 3D environment provides visual engagement, better comprehension and motivations towards the building construction knowledge.

In order to understand if this is a valid way to introduce BIM based on Revit at the construction course, we created our own methodology based on the experiments of Fonseca, Ernesto and all the Gretel [9,17-20] group which more than twenty publications at the ISI level using this assessment methodology.

3.1.3. ASSESSMENT METHODOLOGY

The assessment procedure is developed in three different steps:

- A pre-test and post-test questionnaire designed to evaluate the students' motivation and satisfaction about the course and BIM. These tests were presented and published at the HCI 2016 conference in Toronto [21]. These tests are conducted in both the BCC course, where we introduced BIM to understand its impact into the students' performance, and in Construction III course in order to follow up with the students' motivation and usage of these skills in a course where BIM is optional.
    - The results of our analyses show the students increased their motivation towards BIM and Revit as the tool used to develop their projects and to improve their future. Meanwhile, they lost some confidence to improve their grades.
- A students' performance evaluation. This methodology is submitted and will be explained deeply at HCI 2017 and will be published in Lecture Notes from Springer. In this step, we evaluate all the courses of building construction for different outcomes.
  For Building Construction, I course, which has not changed throughout the whole study, we can evaluate the skills towards building construction courses of each group of students, (waving) their performance to assume that our different groups have the same level or not.
    - The current results show consistency on the grading performance of the different groups of students. This means that we can use the different groups of students to evaluate the variance on the grading to the changes done at the following building construction courses.
  For Building Construction II (BCC) course where we implemented BIM, we compared the performance of the students' groups who did the course before and after BIM introduction.
    - The new configuration of the course, split the students in two different groups, a very good one and a very bad one with students who dropped the course or failed. This issue created a very significant decrease in the grading performance of the group.

Understanding the reasons behind this finding will be one of the main objectives of the interviews.

And finally for Building Construction III Course, we evaluated how much the introduction of BIM within the previous course (BCC), affected the students' performance at this level.

- o It has been found out that there is insignificant decrease on the students' grading (around 10 %).

- Student's interviews after they finalized all their three building construction courses. At this stage we look for the reasons about the data obtained and the possible solutions to improve the BIM implementation.
  - o There are two main reasons from the students' opinion for the grading drop. Lack of previous skills, and the use of both AutoCAD and Revit at the same time which got some of the students confused.
  - o On the other side all of the students feel that both tools are necessary during the course, but not at the same time. They pointed out that Revit gives them speed and comprehension, while AutoCAD gives them freedom to develop their own specific details.

3.1.4. ASSESSMENT CONCLUSIONS

From the analysis of the data obtained, we have several interesting conclusions. As we introduce more assignments and a new tool overlapping the existent once at the initial course, the load of course increased exponential and also confuse some of the students, splitting the class into very well defined groups; those who could handle it and get great grades and the rest who drop or failed the course, letting no place for gradual distribution of the grades as should be expected.

It is surprising that the motivation towards the new tool (Revit) is high, while the opinion about it to improve their grades is neutral with a grate variance. The students complained about their lack of previous skills to succeed in the course, they would like to focus the course in Revit while 75% thought that they also need AutoCAD for detailing due to freedom and flexibility, but only 25% thought that both tools should be used at the same time in the course.

2 students out of 3 interviewed finished their assignments in AutoCAD even if they were supposed to be done in Revit, but even though they want to learn and they think that with the proper skills it will improve the way they work and the results.

For a deeper review of the assessment, we published a paper Universal Access in the Information Society Journal in 2017 [22], with all the statistical analysis ,discussion and deeper conclusions

3.2. BCC COURSE IMPROVEMENT DUE TO THE ASSESSMENT

In order to adapt the BCC course to address the comments of the students and to meet learning process objectives that the building construction cluster at the department agreed upon, we re-designed the course activity schedule [Table 2]. We have to say that the academic environment, creates a big pressure to isolate the BIM, trying still to continue with their course, without modifying it. This pressure leads to a strange situation where the details are developed individually instead of creating them as part of the BIM model. So we can observe that first, we will introduce the students into the construction knowledge and detailing as always have being done before, and finally, we will introduce BIM concepts and Some Revit skills in order that they can begin their own projects into a better-comprehended BIM environment.

Table 2. Current BCC course schedule.

Week	Session Topics	
Number	1st Session	2nd Session
Week 1 Unit 1	Introduction to the BCC Course (Syllabus + Revision)	**Unit 1 - Lecture 1:** Internal Finishes: Plastering & Paint
Week 2 Unit 1	**Unit 1 - Lecture 2:** Internal Finishes: Floorings	**Unit 1 - Lecture 3:** Internal Finishes: Suspended Ceilings
Week 3 Unit 1	**Unit 1 – Assignments:** Assign 1: Group Research for Internal Finishing [In class – Submission by the end of the class]	**Unit 1 – Assignments:** Assign 2: Individual CAD drawing for Internal Finishing [Start In class]

Week 4 Unit 1	Unit 1 – Assignments: Assign 2: Individual CAD drawing for Internal Finishing [1st Draft Submission by the end of the class]	Unit 1 – Assignments: Assign 2: Individual CAD drawing for Internal Finishing [Final Submission]
Week 5 Unit 2	Unit 2 - Lecture 4: External Finishes: Ext. Plastering + Cladding	Unit 2 - Lecture 5: External Finishes: Metal & Glass Curtain walls
Week 6 Unit 2	Unit 2 – Assignments: Assign 3: Group Research for External Finishing [In class – Submission by the end of the class]	Unit 2 – Assignments: Assign 4: Individual CAD drawing for External Finishing [Start In class]
Week 7 Unit 2	Unit 2 – Assignments: Assign 4: Individual CAD drawing for External Finishing [1st Draft Submission by the end of the class]	Unit 2 – Assignments: Assign 4: Individual CAD drawing for External Finishing [Final Submission]
Week 8 Unit 3	**Mid-Term Exam [in Internal & External Finishing]**	Unit 3 - Lecture 6: Joints in Buildings
Week 9 Unit 4 BIM	Unit 4 - Lecture 7: Service Components: Ducting, Floor Trench, Floor and wall Chase	**Intro to BIM in BC:** Revit Model for Building Structure (a)
Week 10 Unit 5 BIM	Unit 5 - Lecture 8: Openings: Doors and Windows Components	**Intro to BIM in BC:** Revit Model for Building Structure (b)
Week 11 Unit 6 BIM	Unit 6 - Lecture 9: Vertical Circulation: Elevators, Escalators and Conveyors	**Intro to BIM in BC:** Revit Model for Building External/Internal Finishing (a)
Week 12 Unit 6 BIM	Unit 6 - Lecture 10: Vertical Circulation: Steel Staircase	**Intro to BIM in BC:** Revit Model for Building External/Internal Finishing (b)
Week 13 Unit 6 BIM	Units 5&6 – Assignments: Assign 5: Individual CAD drawing for Openings & Steel Stair [Start In class]	**Intro to BIM in BC:** Revit Model for Stairs and Elevator Shafts (a)
Week 14 Unit 6 BIM	Units 5&6 – Assignments: Assign 5: Individual CAD drawing for Openings & Steel Stair [1st Draft Submission by the end of the class]	**Intro to BIM in BC:** Revit Model for Stairs and Elevator Shafts (b)
Week 15 Unit 6 BIM	Units 5&6 – Assignments: Assign 5: Individual CAD drawing for Openings & Steel Stair [Final Submission]	**Intro to BIM in BC:** Revit Model Rendering & Documentation
Week 16 BIM	Final Revision	**Intro to BIM in BC:** Final Revit Model Submission
Final Exam [date/time as announced]		

4. CONCLUSIONS AND FUTURE WORKS

Based on the results, and at a first overview of the collected data about the currently adopted BIM implementation approach, we have noticed that courses where BIM are to be implemented, should be re-design entirely. This means that such courses should be conceptualized as a whole progressive process where the students evolve the building model and its details as their knowledge grows.

We also have to state that it is better for the courses where their students have no proficiency with the BIM skills, to avoid the use of more than one ICT tool at the same time.

As a future research possibility, the AIC meeting is a great opportunity to improve this assessment process with the collaboration of the members of this association and to create a bigger database of BIM courses' evaluation that can lead us ultimately to standard conclusions about the best practices to introduce BIM into AEC curricula, and those practices which we should avoid. Creating not only learning outcomes as was suggested in the last meeting, but also a framework of how BIM and also ICT skills courses for BIM should be implemented, can be a great asset to fight against the establishment and re design the courses in order to fit properly BIM knowledge.

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THE COBIE ACADEMY: CONTINUING EDUCATION SUPPORTING OPEN-BIM IMPLEMENATION

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ABSTRACT

The transformation of the design, construction, and facility management industry is managed in different ways worldwide. In the United States, there are three major forces driving industry transformation. First, software vendors are vertically integrating by adding features aimed at solving design and construction information exchange problems. Second, owners are requiring a variety of building information deliverables often based on proprietary technological choices. Third, groups of stakeholders are developing multiple, possibly incompatible, approaches to standardizing the exchange of electronic building information.

To support the establishment of objectively testable and contractable open Building Information Modeling (BIM) requirements, the authors have developed a program of continuing education courses for the National BIM Standard - United States (NBIMS-US) Version 3.0, Chapter 4.2, Construction Operations Building information exchange (COBie) standard. This paper describes the context, content, and lessons learned from creating and operating three university-hosted COBie courses during their first year of operation.

Keywords: BIM, NBIMS-US, COBie, Continuing Education

1. INTRODUCTION

The predominate style of Building Information Modeling (BIM) technology implementation in the United States can be characterized as a combination of "middle-out" and "bottom-up" approaches. The "bottom-up" approach, as defined in Succar (2015), is used by technologists within individual companies who can demonstrate design and construction cost savings. During design, anecdotal evidence suggests that three-dimensional drafting reduces construction drawings costs by as much as 60%. As a result, the primary users of building information modeling technologies during design are former CADD draftsmen. During construction, a variety of evidence suggests that field-changes stemming from shop-drawing coordination can be eliminated by detailed and intensive subcontractor modeling combined with regularly scheduled look-ahead planning.

Seeing possible benefits from BIM, building owners and industry associations have begun parallel journeys to establish BIM requirements in design and construction contracts. For public agencies, requirements diverge due to the expected benefit anticipated from BIM technology. For example, the General Services Administration BIM requirements were driven by a need to control cost overruns. For the Corps of Engineers, BIM requirements were driven by the need to execute the largest construction program since World War II. At the Department of Veterans Affairs, there was an acknowledgement that the major cost of federal infrastructure occurred during the operational phase of the project.

As is the case with US government agencies, US professional and trade associations have also been working with minimal coordination. The American Institute of Architects is seen by many industry leaders to be primarily concerned with limiting liabilities imposed on "design intent models" and ensuring model

property rights are properly managed. The Association of General Contractors (AGC) publication of "Levels of Development" (LoD) defines the granularity of geometric representations needed in BIM files to ensure that proper geometric coordination can be accomplished. However, the specific decision of which LoD is needed for a given exchange is left to each project team to define. AGC's agcXML specification defines routing of business-process exchanges, not information about building objects and properties. The only group to develop standards that are accreditable by the American National Standards Institute (ANSI) is the buildingSMART alliance. Under the auspices of the National Institute of Building Sciences, the buildingSMART alliance published consensus standards that included participation by all sectors of the US construction industry. Unfortunately, the buildingSMART alliance is now de-authorized as the US chapter of the buildingSMART international for lack of international dues contribution. As a result, the international standing of the output of several millions of US tax paper dollars that went into NBIMS-US V3 are in question.

The US "middle-out" and "bottom-up" implementation approaches have resulted in a wide variance in the requirements for and application of BIM technologies in the US. A significant difficulty faced by any project team is determining whether the people, processes, and technology applied to a given project are qualified under the unique requirements of each individual project requirement. For most owners, the delivery of electronic building information, including BIM files, represents an uncheckable and ultimately unusable deliverable. The shoe-boxes shown in the left-hand side of Figure 1 provide a photograph from 2013 showing the "BIM deliverable repository" of a major US government construction contracting agency.

Figure 1. Shoebox-Formatted BIM Files

US public construction law requires that contracts not include proprietary products or services. Today, many public contracts contain either explicit or implicit proprietary specifications for BIM software. While standard data exchange formats have been used to solve construction management information exchange problems for decades (East 1993), the same cannot be said for BIM software exchanges. One large US government construction management agency narrowly avoided major litigation over the inclusion of proprietary software requirements in their contracts. While that agency and some others now allow BIM files to be created by multiple vendors, the quality of the BIM deliverables cannot be objectively and automatically tested.

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Performance-based standards for the delivery of building information comprise the primary technical content of NBIMS-US, V3 (East 2016a). These standards, including COBie, allow anyone to implement a testable, format-neutral contracted information exchange. For at least one major US government agency, the decision to mandate COBie is being stymied by the lack of a consistent understanding and application of NBIMS-US by project managers, designers, builders, and facility managers. While using open-standard building data was cited as the most important way to improve the value of BIM, half of industry survey respondents indicated that they could not move forward due to lack of training (Young 2008).

2. COBIE RESOURCES

An essential aspect in the development of rules for evaluating NBIMS-US V3 technical standard submissions, including COBie, was that each balloted item provide a minimum set of implementation resources. This information was required to demonstrate that a submission to NBIMS-US V3 had or could become a "standard in practice" and not simply a "standard on paper." For COBie, the following implementation support materials and tools were produced:

- Technical Standard (bSa 2015)
- Commentary or Instructions (East 2012)
- Contract Technical Provision (East 2014a)
- Quality Control Testing Software (Bogen 2015)
- How to Books and Manuals (East 2016b)
- Example Files (East 2014b) (East 2017)
- Training Videos (East 2015)
- Social Media Forum (LinkedIn 2013)
- COBie Case Studies (East 2011)
- COBie Business Case Calculator (East 2013)

Despite the wide range of free resources representing over a decade of work by Dr. East and his team of designers and engineers, there remains significant misunderstanding about the purpose, requirements, and use of COBie in the US. The need to promote a common understanding of COBie was the major motivating factor in creating a university-sponsored continuing education certificate comprised of three courses.

3. THE COBIE ACADEMY

3.1 Core Competencies

Key to the establishment of a COBie educational program was the recognition that the key capabilities or "competencies" (Succar 2013) are required of a successful COBie professional. According to one recent study of university BIM courses, these underlying competencies "are not yet covered" (Sacks 2013).

The first of these competencies is to understand the nature of the transformation taking place in our industry. The fundamental change our industry is undergoing is to make explicit the information buried in the convention of construction drawings. This is difficult since the scaled engineering drawings (including floor plans, elevations, and sections) we use have been our primary communication tool since the Italian Renaissance. The reason to begin with this change is that understanding of this fundamental shift changes students' focus from the technology tools they use today (or tomorrow) and places focus on the information that needs to be exchanged among project team members.

Since the schema for expressing information currently on construction drawings creates a file that can be defined by standard (i.e. ISO 16739), the next competency is the understanding of how information can be efficiently structured. While it is not necessary to turn a BIM operator into an object-oriented database

administrator, it is necessary for the qualified COBie professional to have a basic vocabulary about building objects, relationships, and properties. With this basic vocabulary, anyone using open-standard building information will be able to conduct and understand COBie quality control and quality assurance activities. Even the simplest change to the tools we use has compounding effects on how we work. There is an initial change to be made to learn the tool and an ongoing awareness of how to conduct that new way of working. For example, the addition of powered hand drills on construction sites still requires training on extension cord tripping hazard mitigation and ground fault circuit safety.

As we begin to consider information as just another tool of work, we will also change how we work because of that tool. For COBie as a life-cycle information exchange standard, the change required must take into account not only the current worker but also the worker's interaction with information from other employees, partners, and stakeholders. Therefore, the next competency is a basic understanding of the how the COBie pieces fit together during the project life-cycle. The sources and uses of specific building information are identified. The way that information is already captured (and repeatedly lost and recaptured) in our current document-centric construction administration process is illustrated. The goal of the COBie Academy is not the training of management consultants, but helping the COBie professional to identify costs and benefits resulting from the use of their new COBie tool.

3.2 Expected Benefits

Despite efforts to provide a complete set of resources for COBie learning, practitioners indicated that they were overwhelmed by the volume and depth of available information. This frustration is consistent with lessons from artificial intelligence research where a key difference between the expert and novice is a well-organized catalog of subject information. The first expected benefit from the COBie Academy was to help the novice begin their journey to becoming a COBie subject matter expert by understanding the organization of existing COBie information.

Another anticipated benefit from the COBie Academy is to provide a common baseline for COBie knowledge throughout the industry. This baseline includes not only the technical knowledge of the COBie standard, but also knowledge about the impact of contracted information exchanges in daily practice. With the baseline established, an acceleration in the adoption of COBie is anticipated. One final benefit can be expected for the individual and their company. Successful completion of the COBie Academy courses can also be used as a marketing tool to demonstrate competency.

3.3 Organization

The COBie Academy is organized into sets of courses for developing COBie Subject Matter Experts (SME), and additional courses for clients and project managers. The three courses leading to minimum COBie SME capabilities were the first courses to be released to the public. The content of the three courses is based on the content of previously held University of Florida 3-day in-person workshops. The three courses are competitively priced at under half the estimated total cost of the on-site workshop.

Each COBie Academy course has a consistent outline for units and pages. Every course unit has a set of instructional pages that clearly identify all learning objectives followed by an assessment. Instructional pages are organized so that each page has a balanced amount of work. In each assessment, question are matched to the original the learning objective. For knowledge-based learning objectives, automated assessments are used. For learning objectives that require higher skills, such as application, analysis, or evaluation, students submit assignments for grading by the instructor. These graded assignments also help the instructor to provide enriched, differentiated learning by commenting on deeper or related topics identified by the student's solutions.

COBie Academy courses are self-paced. This means that some students may take a break in their learning when their work schedule demands it. Direct instructor interaction when students have not visited the course in a given period of time has helped busy working students return and complete the course. To

help students double-check their knowledge across the each course, comprehensive exams recaps previous unit assessments.

3.4 Outcomes

In the year since the release of the first course, building industry professionals from six countries have participated in the COBie Academy. These countries are the United States, United Kingdom, Ireland, Portugal, Norway, and Philippines. Student profiles have been varied including designers, contractors, owners, and software developers. Mandatory post-course evaluations have provided favorable to very favorable ratings across all evaluation categories. Many users have taken the time to add additional text comments. A sample of written course evaluation comments are noted below:

- "(the alternative) of going through endless websites links becomes a nightmare."
- "I like how it was laid out."
- "wider concepts of database design have greatly enhanced my understanding of COBie and the wider concepts of BIM."
- "the experience of actually filling out a partial COBie file helped me solidify my understanding of what is required and helps to better appreciate the ability to have software do most of the work in the real world."
- "The course provides a strong foundation."
- "Having the chance to be in contact with (the instructor) was worth the course."

This is not to say that the courses were perfect. As different types of learners with different professional expertise have taken the courses, minor clarifications to assignment instructions were needed. In all but one case, written discussion boards provided sufficient communication "bandwidth" to resolve the matter. The one exception was a discrepancy between a stated minimum assessment criteria and the actual calculation applied for the assessment. Ultimately, live "office hours" were not required to resolve the matter.

4. KEY LEARNINGS

A key lesson learned was that a significant amount of instructor time is required to understand how to translate the features provided by the learning management system used for the courses into an effective on-line course. Each learning management system has its own way of approaching the organization of content, assessments, and prerequisites. Although some iteration will be needed, understanding the organizational tools provided by the learning management system before starting work should reduce the overall time required to produce the course. Anyone new to a given learning management system should begin with the learning management system training. The objective of that training should be to understand how to create a consistent organizing paradigm relevant to the course content.

After determining the organizing principals of the course, all course content outside the learning management system, in a word processing file, before loading into the system. This is needed to allow easy changes to content and minor reorganization that occur during course creation. Updating information in the learning management system is much more difficult than simply updating a word processing file. Subsequent to the drafting and review of the course content, the material may be transferred to the learning management system.

Our COBie Academy courses were developed and checked as follows. First was the initial drafting and review in a word processing file. Second was a review of the course content by the COBie Academy's senior academic advisor, in the word processing file. Of critical importance at this stage, was to replace US-English phrasing that might have added difficulty for English as a second language speakers. After

editing the course content in the world processing file, the course was loaded into the learning management system and tested by the course author. Before releasing the content to the public, the complete course, including the final completion certificate program, was beta-tested.

In most on-line courses there is a need to establish the order in which lessons are to be accomplished. Learning how to set the order of the course pages and modules and maintaining a consistent outline numbering scheme across all course content took some time and effort to complete. Unit assessments, assignments, and the mandatory course evaluation serve as milestones. These milestones were to be completed at a specific level of proficiency before the student was allowed to proceed to the next milestone. In developing the assessments, caution was used when creating individual questions and "question banks" to ensure that slight changes individual questions and/or changes to the pool of possible questions could be made after the course is live. Understanding the interaction between a specific assessment, question banks, and the related policies for retries and assessment duration required some time and effort.

Another lesson learned was that the up-front time spent on precise organization of hand-graded assignments, including detailed student instructions and published rubric, aided the student in understanding the learning objectives for that assignment and the expectations for success. To date, only one conference call regarding student assignment grading has been required due to a typographic error on the written assignment policy page.

Currently, it is difficult to determine how long each course takes to complete. Metrics provided by a web-based learning management system only show the amount of time for the student's browser session. This means that if the student starts the course in the morning and then takes a phone call and forgets to close the browser tab unit the close of the day, the learning management system records the entire work day duration as "activity time." Having a measure of "engagement time" not just "time logged in" would be helpful in balancing courses and units. Evaluation of different student's engagement time against assessment scores would also be of value.

5. CONCLUSION

An essential element of the continuing education offered by the COBie Academy can be described by the term "joyful learning." In the COBie academy, we help students meet learning objectives by providing multiple opportunities to interact with assessments and sufficient time to complete each assessment. This has been key to helping working professionals stay engaged with the course content and kept part-time learners from failing to complete the courses. Our efforts at providing a well-organized set of learning content has been successful in helping students orient themselves to our on-line course offerings. As a result, student-instructor interactions have been focused on enriching course content as prompted by individual student discussion questions or assignment results. Based on our experience with the COBie Academy to date, it is clear that this learning platform provides an essential bridge between the general education needed by students working toward a degree and the targeted knowledge necessary for professionals to begin to implement contracted information exchange standards.

6. FUTURE WORK

While the current courses each provide a certificate of completion, the COBie Academy does not anticipate providing a knowledge certification testing. Such a certification has been requested by one large US federal government agency to allow them to move forward with plans to mandate COBie deliverables. In support of their goal, the authors are currently helping an established US professional organization to create and administer a COBie certificate program.

With the current three courses, and the upcoming certification, a consistent level of knowledge can be established within our industry. Additional training modules for the COBie Academy are planned to support COBie enterprise implementation and specific computer software processes. Finally we are investigating

the requirement to be listed as a provider of certified professional development units. This would allow existing training budgets to be used for those interested in completing the COBie Academy.

ACKNOWLEDGMENTS

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THE CONTRIBUTION OF BUILDING INFORMATION MANAGEMENT TO STRUCTURAL ENGINEERING

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ABSTRACT

It is noted worldwide that, the construction industry is faced with challenges of mismanagement, miscommunication and low quality products. Further, the construction players are investing their projects in dangerous sites and significant challenges with respect to site coordination and collaboration between the different disciplines. The introduction of Building Information Modeling (BIM) technologies can positively contribute to the structural engineering industry. BIM contributes to improved problem solving, development of innovative ideas as well as creation of complex designs. BIM as well enables structural engineering students to improve on structural design documentation as well as minimize errors during the design phase. The current research paper describes the benefits of implementing BIM to the construction industries in Botswana and other Africa countries. In addition, challenges to the adoption of BIM to the construction industry are discussed and strategies to address the constraints are proposed. A qualitative phenomenological approach was used to conduct the study and a thematic analysis facilitated data analysis. Findings indicate that BIM technology can help the construction players improve communication, coordination and collaboration in management of construction projects. Also, BIM enables structural engineers to improve on visualization and simulation of problems and enhance consistency of data.

BIM software has made life easier in structural engineering by helping engineers visualize, design, analyze, document and build projects more efficiently, accurately and competitively. The collaboration of BIM tools such as the Autodesk tools, Revit architecture, Advanced Steel, Revit Structure, Revit MEP, Bentley System and CSI tools such as SAP 2000 has helped structural engineers overcome construction challenges such as clash designs, delays and project costs overruns. In conclusion, BIM tools should be highly advocated in structural engineering to help improve the design and structure of buildings and architects.

Keywords: Construction, building information modeling, technology, strategies, constraints, construction projects.

1. INTRODUCTION

The construction projects can be considered by their nature to be uncertain, risky and complicated. These attributes are evident in remote construction projects which have unique problems caused by factors such as remoteness of the project site itself that also contributes to loss of control over management and communications [1]. The aspects of little managerial skills as well as lack of human resource and infrastructural input contribute to challenges in construction projects. Coordination and communication have been the main challenges in remote and poorly managed construction projects [1]. The conventional management methods have been found to be defective in handling such problems which forced scholars to suggest approaches such as advanced computer based management system that ensures effective information management and communication.

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The construction industry has long been observed to contribute to the economy of a country. However, the construction industry is faced with issues such as poor quality of work, dirty construction sites, occurrences of accidents, delays and dangerous sites conditions. The advent of ICT and increased technology innovation such as Building Information Modeling (BIM) has helped manage most construction projects and contribute to the success and productivity of the construction industry [2]. The BIM technology has been observed to be suitable for both risky and complex construction industries. The BIM has been applied in various countries such as United Kingdom, Malaysia, Australia, Hong Kong and Denmark among others. In addition, BIM adoption in the Middle East countries is also rising. Countries like Dubai, UAE are increasingly integrating BIM in their construction industries due to the increased development of the countries' economy. However, BIM adoption in Africa is low as most of the countries are in their developing states. Despite the increased awareness of BIM in Nigeria, the adoption is still low due the constraints in the implementation of both process and technology [3]. The implementation of BIM in South Africa is a challenge due to constraints in personnel inadequacies in terms of training, education and skills development. Figure 1 and 2 demonstrates the adoption of BIM in European countries and Middle East countries.

Country	2013	2015
United Kingdom	28%	66%
Germany	37%	72%
United States	55%	79%
Brazil	24%	73%
Australia	33%	71%
France	39%	71%

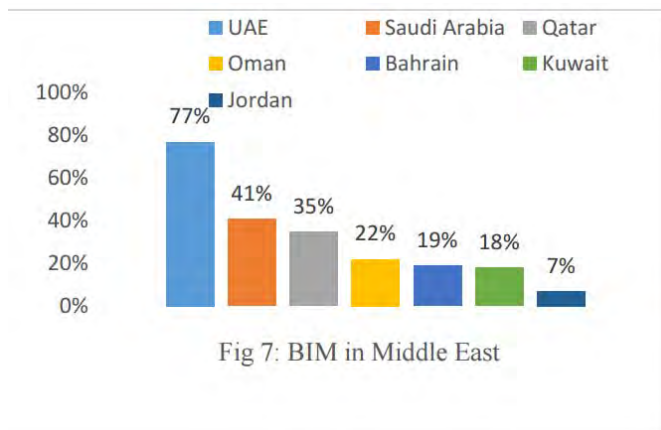Figure 1. BIM implementation in European countries. Source: [3]

Figure 2. BIM adoption in Middle East countries. Source: [4]

Reference [2] describes that the Malaysian government is advocating for the implementation of the of the BIM in construction projects due to its benefits of facilitating solving problems in the construction industry such as preventing disputes between construction players, minimizing project delay as well as decreasing construction cost. BIM has helped structural engineers to stay competitive and keep pace with today's economy. BIM has helped structural engineers to better handle and visualize components as well as ensuring data accuracy and reduction in drafting errors [5].

Business Information Modeling is described as "digital representation of physical and functional characteristics of a facility that serves as a shared knowledge resource that forms a reliable basis for decisions during its life cycle, from inception onward" [6]. BIM involves the characteristics of collaboration between distinct stakeholders at varying phases of facility lifecycle to insert, extract, update or modify information in the model to reflect the roles of that stakeholder. BIM combines different threads of

information into one operating environment thus, reducing different documents needed in the site [6]. The BIM is observed as an incorporation of software tools and techniques in the lifecycle of building and construction process. BIM focuses on enabling viewing and visualizing of buildings in 3D entities. The rapid technology advancement has led to the adoption of BIM in the construction industry including emerging Smart Building Environments (SBE) that incorporates embedment of smart objects such as sensors and actuators leading to intelligent interaction between humans and computing and communication technology in day-to-day activities [7].

The BIM software is based on Object Oriented Programming. The presence of new 3D tools is allowing structural engineers and designers to create models for documentation and coordination. The BIM software helps in developing buildings in 3D dimensions that utilize the X, Y and Z dimensions [5]. The Autodesk Revit is considered as the market leader in building and construction that utilizes BIM. The Autodesk Revit is greatly compatible with civil engineering software such as SAP2000, ETABS and Robot Structural Analysis. Revit allows the user to develop walls and assign attributes to it such as exterior texture among others (Bhusar & Akhare 2014). Figure 3 demonstrates the use Revit architecture in modeling.
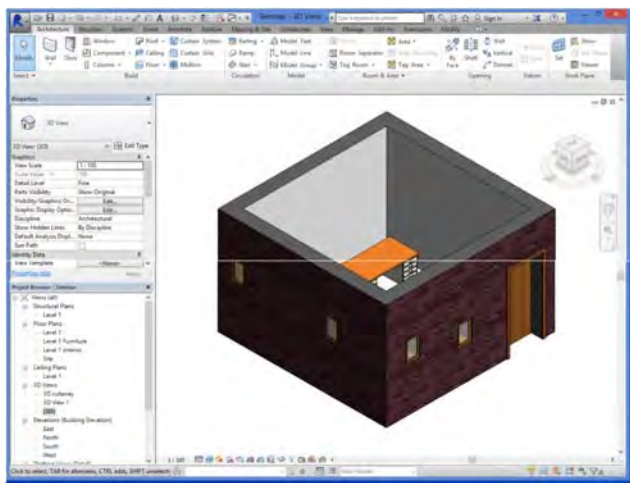

Figure 3. Use of Revit architecture in modelling of buildings. Source: [5]

1.1 Problem Statement

The construction industry is facing huge challenges forcing structural engineers to improve quality, value and productivity. Challenges in the construction industry include delays, production of low quality products, cost overrun as well as dependence on old technology [8]. In addition, challenges in poor management and miscommunications have resulted in low quality drawings and architects. Also, issues such as inadequate project pre-planning and uncertainty in project process integration contributes to misinterpretation and miscommunication that lead to misguided and inappropriate decision making process [1]. There has been slow adoption of BIM technologies in the construction industry due to challenges of its implementation. The adoption of BIM in Botswana is still a challenge due to constraints in technology and people. Local companies owned by Botswanans are not familiar with BIM however, only few international companies know a little about BIM. There is need for the awareness of adoption of BIM among structural engineers. Increase in training activities on the use of BIM tools will contribute to the increase in the adoption of BIM and its contribution to the structural engineering. Moreover, several international companies have adopted BIM and given testimonials on its importance and contribution to positive results.

1.2 Purpose

The purpose of conducting this study is to develop a framework and a plan for initiating Building Information Modeling to the Botswana's structural engineers. Botswana is among the developing countries

with minimal integration of technology in the construction industry [9]. The initiation of the BIM in the construction industry will aim to boost the production and quality of products and services in the construction industry and contribute to structural engineering in Botswana.

1.3 Research Questions

1. What benefits does the Building Information Modeling have to the structural engineers in Botswana?
2. What are the constraints to the adoption of the Building Information Modeling among structural engineers in Botswana?

2. MATERIALS AND METHODS

2.1 Research Methodology

The research methodology provides framework that helped the researcher to structure and execute the data collection and analysis process. The research approach used was the qualitative research method. Qualitative research method was chosen as it focuses on exploring and interpreting a phenomenon. In addition, qualitative research focuses on non-numerical data [10]. Qualitative research study focuses on theoretical findings and discoveries as well as deals with a small number of non-representative samples [11]. The design also used was the phenomenology research design that focuses on describing people's perceptions about their surrounding environment. The phenomenology as well describes human experience of the world people lives in [12]. The study thus, used primary qualitative data selected from structural engineers in Botswana.

2.2 Population and Sampling

The target population is identified as a defined whole accumulation of units from which sampling takes place [13]. The target population of the study was structural engineers in the building and construction industry in Botswana. The sampling process that entails extracting a sample from the population used was the purposive sampling. Reference [14] indicated that purposive sampling is suitable for the phenomenological qualitative research where participants are expected to meet specific criteria during the selection moment. The criteria used in this study were that the structural engineers must have worked in the construction industry for more than 3 years in Botswana and managed a team of at least 5 people. The purposive sample considered to sample 3 structural engineers.

2.3 Procedures

Interview processes were used for the collection of information as it helps in exploring details from participants and encourages participants to express their own thoughts and feelings [15]. The participants were given an informed consent that stated the purpose of the study and the contributions of every respondent to the study. The consents were sent via email and respondents invited to attend to interviews via emails and phone calls. The interviewer controlled the interviewing process.

2.4 Data Analysis

Data was analyzed by use of thematic analysis. Thematic analysis concerns itself with identifying common themes among various participants [16]. The themes were identified and categorized manually based on researchers informed knowledge. Thematic analysis helped to categorize related information and the contributions of Building Intelligence Modeling to construction industry was identified.

2.5 Ethical considerations

The ethics of confidentiality and anonymity of participants was adhered. The ethics were achieved by not including personal details in the research study. In addition, biasness was minimized when reporting and interpreting the data.

3. RESULTS

This section focuses to present the results from the interviewed respondents. The first section focuses to present the overall demographic characteristics of respondents while the other section discusses the objectives of the study. The results indicate that sample consisting of three participants two were males while one was a female structural engineer. The mean age for the respondents was 43 years with the minimum age of 35 years and the maximum age of 52 years. In addition, the mean years of work experience was seven years with the minimum of 4 years and the maximum of 10 years of work experience.

3.1 Research Question One

The research question focused to assess the benefits of Building Information Modeling to the structural engineers in the construction projects in Botswana. The results indicate that the participants were aware of Building Information Modeling and had implemented in their projects. Additionally, the participants viewed the Building Information Modeling as a digital representation of building project and work flow that helps in designing buildings. The representation and workflow is facilitated by use of software package. The participants added that BIM facilitates collaboration to enable project success. The participants indicated that BIM have numerous advantages that facilitate the progress of construction projects.

The main theme emerging in this question is that BIM have facilitated improved communication and collaboration among project team members. Effective communication and collaboration among team members results in efficient handling and sharing of tasks that facilitates success of the project. The participants added that BIM have helped their construction projects by lowering of production costs as well as total reduction in cost of other infrastructures. BIM have facilitated provision of quality products, services and operations. One of the participant described that using the 3D architecture in BIM have facilitated provision of quality drawings, architects and buildings as compared to the old technology. The participants demonstrated the necessity of BIM to structural engineering field as to help engineers reduce drafting errors as well lower designing cost. Also, participants indicated that BIM enables structural engineers improve on visualization and simulation of problems and enhance consistency of data. BIM software has made life easier in structural engineering by helping engineers visualize, design, analyze, document and build projects more efficiently, accurately and competitively. The collaboration of BIM tools such as the Autodesk tools, Revit architecture, Advanced Steel, Revit Structure, Revit MEP, Bentley Systems and CSI tools such as SAP 2000 has helped structural engineers overcome construction challenges such as clashes in designs, delays and project costs overruns.

3.2 Research Question Two

The research question identified the constraints hindering the adoption of Building Information Modeling among structural engineers in the construction industry in Botswana. Participants gave various responses although themes were identified from the responses. The main theme addressing the constraints to BIM adoption was inadequate training and skills in operating the Business Information Modeling. The training constraints have resulted in slow adoption and awareness of the BIM technology. Structural engineers lack Revit training which is considered as essential in the construction industry. In addition, participants indicated constraints to BIM adoption was inadequate infrastructural resources and finances for funding implementation of BIM projects. One of the participants indicated that inadequate finances have resulted to challenges in purchasing BIM tools such as Revit Architectural. The training courses available are inadequate and are also expensive to enroll in. The participants called for immediate intervention to the constraints by the government of Botswana.

4. DISCUSSION

The section discusses the results of the findings in relation to the research questions. There were two research questions which focused to discuss the benefits of the Building Information Modeling technology to the construction industry and also the constraints to the adoption of Building Information Modeling. The participants first described Building Information Modeling as a digital representation of workflow of

building designs and projects that is facilitated by software packages. The findings are confirmed by several scholars [6] [7] [17]. The participants indicated that Building Information Management has helped them excel in the building and construction industry. BIM has been attributed to have numerous benefits including facilitating communication and coordination of team members in the construction projects [2] [6].

In addition, BIM technology integration in the construction industry has helped in reducing construction costs and also facilitated in engaging in risky ventures. Reference [2] indicated that BIM technology has enabled construction players to venture their projects in dangerous sites and also engage in risky ventures. BIM has also enabled reduction of infrastructural costs. Reference [7] indicated that BIM technology through the integration of 3D architecture has facilitated the improvement of quality of architectural designs and buildings. Participants indicated that BIM help in reduction of design and drafting errors as well lower designing cost. Moreover, BIM enables structural engineers improve on visualization and simulation of problems and enhance consistency of data [5].

The study also assessed the constraints to BIM adoption of construction players whereby inadequate training and skills to operate BIM was the main challenge. The findings are consistent with several studies [8] [2]. Moreover, participants described constraints to BIM adoption as inadequate finances to purchase BIM tools. Similar findings were observed by [2].

5. CONCLUSIONS AND FUTURE STUDY

There is recent increase in challenges in construction industry such as mismanagement, miscommunication and low quality products. In addition, construction players are investing their funds on projects located in dangerous sites, occurrence of accidents, increase in delays, and experiencing poor coordination and collaboration which requires intervention. Structural engineers indicated increased benefit associated with BIM integration in the building and construction industry. BIM has facilitated effective communication, collaboration and coordination of team players which have resulted to success of projects. In addition, with the integration of 3D architecture in BIM, the quality of products, designs of buildings and architects is also increasing. Additionally, BIM has enabled structural engineers improve on visualization and simulation of problems and enhance consistency of data. The collaboration of BIM tools such as the Autodesk tools, Revit architecture, Advanced Steel, Sost-X, Revit MEP, Bentley System and CSI tools such as SAP 2000 has helped structural engineers overcome construction challenges such as clash designs, delays and project costs overruns. However, despite the increased benefits of BIM in the construction industry, the pace of adopting BIM is very low due to the challenges of adopting BIM that is attributed by structural engineers viewing BIM as disruptive technology that transforms construction industry to a new direction. The adoption of BIM to eradicate traditional methods is facing huge challenges such as making construction players understand how BIM offers more benefit compared to 2D drafting, education and training as well as process of upgrading technology.

6. RECOMMENDATIONS

The increased constraints to BIM adoption are hindering its adoption rate in the construction industry, the progress of construction projects and in overall economic conditions which thus, requires adequate intervention. The participants described several intervention measures that would help in increasing adoption of BIM. The participants indicated that the government should heavily intervene by providing training opportunities and courses and also providing funding and finances to support BIM projects. Similarly, the researcher plans to intervene on the issue by proving training courses in Building Information Modeling. This can be achieved by the researcher advancing on the skills by enrolling in short training courses in Revit Structure, Robot Structural, ETABS/SAP2000 as well as programming languages such as Python and Dynamo.

7. ACKNOWLEDGMENT

8. REQUEST FOR TRAINING BY THE AUTHOR

Similar initiatives are conducted in Malaysia whereby the Malaysian government is giving grants to undergraduate students to obtain training on BIM. The government ensures that undergraduates receive training in using BIM tools such as Revit Architectural, Revit Structural and Navisworks and are awarded BIM certificates [2]. The author thus, focuses to enroll in short training courses to advance the skills and knowledge about BIM tools. The author therefore, plans to enroll in training webinars at Graitec whereby the university in which the author is attached will help in developing a budget to enroll in BIM training.

REQUIRE BELOW WORKSTATION

HP ZBook Studio G4 Mobile Workstation (ENERGY STAR)

7th Generation Intel® Core™ i7 processor

16 GB memory; 512 GB SSD storage

15.6" diagonal 4K display

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ACADEMIA MEETS AECO INDUSTRY REALITY: A COLLABORATIVE BIM COORDINATION EXERCISE IN AEC EDUCATION

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ABSTRACT

Learning styles and teaching techniques are an often debated concept in which many schools of thought exist. However, in the Architecture, Design and Construction (AEC) industry, as a whole, the belief in experience as the most valuable asset of an individual is quite pervasive. Furthermore, it stands to reason that the ability to gain hands on experience can be invaluable to industry professionals, both aspiring and existing, especially as they work to adapt to the emerging technological workflows which are driving the future of the industry. The ability to provide experiential learning to students and industry professionals helps provide a solid foundation which moves beyond conceptual learning and enables the application of such knowledge through the development of a broader knowledge foundation. To accomplish this, a collaborative learning exercise focused on the BIM coordination process was designed and executed in a graduate level BIM course. The designed Collaborative Coordination Exercise (CCE) provided benefits to not only the students, but to the instructors and industry partner who were an integral part of the exercise as well. By leveraging the cloud based Autodesk BIM 360 suite of products, which are emerging as industry leading platforms, each participant was able to gain meaningful experience with industry workflows.

The BIM 360 products provide project teams with a range of options for project collaboration which differ from the traditional ways of conducting business. The CCE provides bilateral benefits to the students and industry professionals who participate through the use of these products in a collaborative environment, which otherwise wouldn't exist. The primary academic goal of the CCE was to expose a class of construction management graduate students to real-world collaborative BIM experiences which they will face as they begin their careers in the AEC industry. Furthermore, the industry partners were able to work in a no-risk environment to train additional staff or test workflows they would otherwise not be able to attempt on a live project. Overall, the ability to work synchronously in a connected collaborative BIM environment through a CCE provided benefits which break down the traditional asynchronous stereotypes placed upon learning, while enriching the students overall learning experience and creating meaningful partnerships with industry professionals.

Keywords: BIM, VDC, Coordination, BIM 360, Cloud, Collaborative Exercise

1. INTRODUCTION

The Architecture, Design and Construction (AEC) industry continues to see pervasive growth in the role of technology with each passing year. As the role of various technologies continues to grow so do the expectations for the knowledge students enter the workforce with.

College students studying in AEC degree programs are expected to learn more than ever before, while developing a foundation of experience from "real-world" sources. This is especially true in the construction industry where experience is often regarded as one of the most valuable assets someone can have. To this end, educators work to provide students with a conceptual foundation as well as the opportunity to gain experience. However, this is often a difficult task to accomplish from a classroom setting, especially related to Building Information Modelling (BIM) workflows.

The inherently collaborative process of BIM based coordination and project management is nearly impossible to re-create with group projects or assignments within the classroom alone. While meaningful modeling experience can be provided more readily, the role of most students leaving an AEC program of study will be in the management space and not modelling. To address this, the researchers designed and executed a collaborative learning exercise for a graduate level BIM course, focused on the BIM coordination and management process. The Collaborative Coordination Exercise (CCE) provided benefits to not only the students, but to the instructors and industry partner who were an integral part of the exercise as well. One of the goals for the CCE was to establish a relationship with an industry partner who would provide project scenarios and information founded in real-world experience. Furthermore, potential bi-lateral benefits of such a relationship were explored to ensure the CCE was a beneficial experience for everyone involved. To accomplish this, a collaborative environment was established using the cloud based Autodesk BIM 360 suite of products, which are finding increased use throughout the AEC industry. The use of such industry leading technology, coupled with a carefully crafted learning environment and exercise requirements, created meaningful experiences in multiple ways.

The primary academic goal of the CCE was to expose a class of construction management graduate students to real-world collaborative BIM experiences which they will face as they begin their careers in the AEC industry. For the industry partners, the ability to work in a no-risk environment to train additional staff or test workflows was an opportunity they would not be able to attempt on a live project. Following the CCE, the students were asked to complete a debrief assessment of the exercise in order to reflect upon their experience and provide meaningful feedback for the continued improvement of the exercise itself. Finally, the developed CCE was presented at Autodesk University 2017 and made available as a resource for educators and industry professionals to implement. Overall, the ability to work synchronously in a connected collaborative BIM environment through a CCE provided benefits which break down the traditional asynchronous stereotypes placed upon learning, while enriching the students overall learning experience and creating meaningful partnerships with industry professionals.

2. BACKGROUND

Construction technology, and specifically BIM processes, have become a standard within the AEC industry. According to McGraw Hill (2012) approximately 71% of practitioners in the AEC industry make use of BIM processes in their business. This number continues to grow as the industry continues to develop new ways to improve project efficiency and performance leveraging a wide range of construction technologies. This increased utilization of construction technologies leads to a parallel demand for qualified professionals and effectively educated students entering the industry. Due to this, educators work to develop new curriculum and pedagogical techniques to better prepare students for an increasingly technological industry. Specific to BIM and Virtual Design and Construction (VDC) processes it is understood that while most students will not be involved with physical modeling, they will be expected to manage such processes and as such need to have both a foundational understanding of model development as well as a grasp of higher level

management theory (Lee et al. 2013). Furthermore, it has become increasingly important for educators to focus on BIM process and management skills, as opposed to technical modeling skills (Wang and Leite 2014). This shift has been studied and is validated by research which reports that the industry is looking for employees with higher level management skills, especially from the graduate level (Lee and Yun 2015; Sacks and Pikas 2013).

The inclusion of BIM and VDC courses into AEC curriculums has become all but a necessity for academic institutions, with a range of thoughts related to how this should be best accomplished. Research studying this reported that 78% of architecture and construction schools surveyed, a total of 67, had integrated BIM into their curriculum in some way (Joannides et al. 2012). Barison and Santos (2012) established three distinct level categories at which this integration takes place, introductory, intermediary and advanced. Each defined level provides a different experience, with introductory courses focusing on basic technical software knowledge, intermediate courses introducing management and data analysis tools, and advanced courses expanded this knowledge to interdisciplinary study while simulating true project environments (Barison and Santos 2012). One aspect that is hinted at in these categorizations is the shift toward increasingly real-world, or simulated real-world, learning experiences.

2.1 Experiential Learning Exercises

Experiential Learning Theory (ELT) is a field of study which is seemingly appropriately applied to an industry such as AEC, where experience is so highly regarded among professionals. Kolb (1984), one of the founders of ELT thought describes ELT as different from the traditional rationalist and cognitive learning theories which focus on the acquisition, manipulation and recall of knowledge. The primary "traditions" of ELT are described by Kolb (1984) through the following three statements:

1- Learning is best conceived as a process, not in terms of outcomes

2- Learning is a continuous process grounded in experience

3- The process of learning requires the resolution of conflicts between dialectically opposed models of adaptation to the world

These concepts are furthered by the establishment of four distinct abilities which an effective learner should possess. These abilities are; concrete experience, reflective observation, abstract conceptualization, and active experimentation (Kolb, D.A. 1984). Thus ELT theory suggests that learners should have new experiences related to what they are learning, which they then analyze and reflect upon. Upon reflection they should then be able to integrate their observations and experiences into new theories which they can leverage to solve problems. In addition to the foundational concepts of ELT, it was further proposed that learning is not a singular process but is instead more of a map of learning territories, termed "learning spaces", which must be considered in concert with the learners "Life Space" or learning environment (Kolb, A.Y., Kolb, D.A. 2005). In this way, ELT is more than just a singular expression of providing one with "experience" in the traditional sense, but is rather the inclusion of experience within the overall learning process inclusive of many aspects of how someone learns.

The concept of ELT is one which offers intriguing insight into how pedagogical techniques could be altered for added benefit, and is especially applicable to AEC education. This area of experiential learning study is extensive and there exists a great deal of critiques, counter-critiques, and reviews, which began with the work of Dewey, Lewin and Piaget over a century ago. One such critique assess the theoretical foundation from which Kolb's ELT is based and surmises that it is an inappropriate and over-simplified interpretation of the work by Dewey (Miettinen, R.

2000). Such work makes it clear that the concept of experiential learning, while not universally agreed upon at the theoretical and conceptual level, does appear that the majority of work agrees that creating meaningful experiential learning experiences can provide benefit.

3. COLLABORATIVE BIM COORDINATION EXERCISE

The Collaborative Coordination Exercise (CCE) was designed as an in-class activity focused on the BIM coordination process which is becoming commonplace in commercial and industrial workflows. It was designed for integration into an advanced graduate level BIM course at the University of Florida using Autodesk BIM 360 Glue, Team, Docs, and Collaboration for Revit. The selected course meets weekly for a single 3 hour time block and is a semester long course which typically runs a total of 15 weeks. It is an upper division course in a construction management program, focused on the utilization and management of BIM and VDC technologies. Students are expected to have a basic understanding of construction practices, as well as, basic computer/technological proficiency. During the course students complete seven classwork assignments, based on standard plans designed specifically for the course, as well as one semester long group project developing an as-built model of local buildings. The primary focus for the individual assignments is on best practices, theory, and BIM execution, while the group project focusses on team collaboration and BIM workflows over the life of a project. Essentially, the core components of skill building and concept application drive the two sets of activities which make up the backbone of the course. The designed CCE bridges the gap between skill building and application related to connected BIM services and processes as they exist in the industry.

The CCE is conducted in three stages and great care was taken to consider the learning outcomes and objectives for both the students and industry partners. Furthermore, the outlined activity is intended to be able to adapt to a multitude of other needs based on the particular academic and industry partnerships. The three stages of the CCE outlined below were preceded by a pre-planning stage in which the academic and industry partners worked to prepare a meaningful exercise based on the specific skill sets and needs of the given semester. During this stage the CCE team; compiled documentation for an existing building project provided by the industry partner, determined the student groups sizes and focus areas of the building, prepared the models while introducing coordination errors, developed exercise specific prompts for the students, established a schedule and anticipated deliverables, and finally prepared the BIM 360 workspace in Glue, Team and Docs for the students. The pre-planning stage for the CCE took place over the course of approximately six months leading up to the actual execution of the activity itself. The CCE was executed over the span of three class periods, 1 hour in the first, 3 hours in the second, and 1 hour in the third, in consecutive weeks. Furthermore, the CCE was conducted in the state-of-the-art VDC lab run by the Center for Advanced Construction Information Modeling (CACIM) at the University of Florida. The lab space has 18 computer terminals with dual screens and all the required BIM software for the students use. In addition, it has a projection wall which was used as the presentation space, where the industry partner was able to remotely share their screen and participate via a video conference call, akin to real-world coordination meetings.

3.1 Stage 1: Coordination Kickoff & Modelling Meeting

The initial part of the live exercises was the chance for everyone to understand the expectations for the exercise, establish roles and collectively plan for the next stage. This stage was accomplished in approximately 1 hour and is depicted in Figure 1 (A). The instructors divided the students into their work groups, assigned project roles, and exposed students to what would be

taking place the following week. The students were divided into groups of six, with four acting as the architect and two acting on behalf the structural engineer. The two structural engineers were in charge of the structural model for their given project area and the architects were responsible for the interior partitions and ceilings in the architectural model. This division required the teams to work together as each of their assigned building systems interact with one another. Prior to this, the students had been given instruction on the use of the BIM 360 products and were provided access to the CCE models and documents through those platforms during this period.

The industry team conducted a BIM coordination "kickoff meeting", setting expectations as would occur in a real meeting of this sort, and reviewed each discipline's models, with the students. Following this meeting the students were given a QA/QC assignment in which they were expected to review their models and make any corrections based on the design drawings prior to the coordination meeting in phase two. This was the student's opportunity to coordinate their "internal" efforts for accomplishing the assigned task and to speak with the course instructors who were operating as "owner's representatives" and could provide any clarification they needed. The students leveraged BIM 360 Team to access the models and Collaboration for Revit for simultaneous access and communication as they worked.

3.2 Stage 2: Coordination Meeting

During Stage 02 of the CCE project teams were expected to participate in a three-hour BIM coordination meeting. All project stakeholders, e.g. the roles everyone assumed, were present and logged into the live model through Collaboration for Revit, hosted on BIM 360 Team. Model and design coordination took place in the BIM 360 glue environment and was navigated by the industry partner, acting as the project manager, via a live video conference. The project teams worked to correct mistakes and make changes live during this session, depicted in Figure 1. B & C, with periodic breaks for updated models to be pushed to BIM 360 Glue. The coordination report was updated at multiple stages during the exercise to demonstrate progress and to allow for continued effort by all stakeholders to occur. All project team members were expected to manage their assigned building areas and to actively participate in the problem identification and solving process with the industry partner. As an added challenge the MEP model, being managed by the industry partner, was updated half way through the session. This simulated the updates received by MEP subs which can greatly impact the coordination process. A coordination timeline was developed which clearly identified the times which each group would be actively coordinating and when updates had to be made to the live project, making it possible to accomplish a great deal of coordination in the span of three hours. The coordination process experienced in this stage of the CCE simulated a longer, comprehensive review meeting focused on solving problems and making live updates to expose students to the kind of meeting they will experience during their career. Following the activity students were assigned a debriefing survey to reflect upon the experience.

3.3 Stage 3: Final Coordination Review & Debrief

In Stage 03 of the CCE a brief coordination meeting was held to review final changes and to discuss the next steps should coordination continue, as it would in industry. This was the project team's opportunity to review each other's work and have a discussion about the coordination process as a whole. The discussion was facilitated by the course instructor and industry partners with the goal of inspiring an appreciation for the collaborative BIM coordination process. Furthermore, everyone was able to share lessons learned and discuss how the use of the BIM 360 suite of products impacted the process. Prior to the start of Stage 03 everyone wrote a debrief statement where a concise review and reflection of the experience was shared and was used to help

shape their individual contributions to this discussion. This was the student's opportunity to gain valuable insight into the world of connected BIM and project coordination from the perspective of an industry partner who operates in the technological world every day.
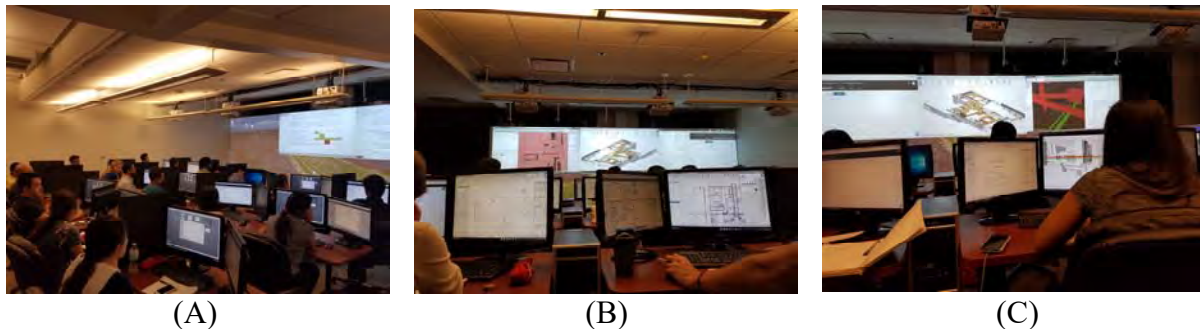

(A)   (B)   (C)
Figure 1. In-Class Collaborative BIM Exercise

4. RESULTS AND DISCUSSION

The CCE proved to be a challenging undertaking which was well worth the effort and provided benefits to everyone involved. The exercise was well received by the students who participated and proved to be a great addition to their overall experience in the graduate BIM course. In the debrief survey one student stated "It's refreshing to partake in a real-world modeling process that was led by industry professionals who are skilled, experienced and willing to demonstrate how their daily work was conducted step-by-step." and another said ""…for those students who had not experienced the coordination process this was immensely valuable." when asked their opinion on the exercise. These sentiments were found throughout the anonymous debrief survey submissions and were a positive sign to the researchers that the CCE was a valued addition to the course. In addition to student benefit, the industry partner found the exercise to be of great help as they explored new software platforms and workflow strategies. Furthermore, they were able to test new processes without the restrictions of a live project and in a collaborative environment.

The debrief survey provided additional information in relation to the students prior experience, as well as the students perception toward the suite of BIM 360 software packages. Based on the responses, 71% of the 17 students who completed the survey stated that prior to this activity they had never participated in a BIM coordination meeting. When asked to rank the four BIM 360 platforms used in the study in order of perceived usefulness to the AEC industry, it was found that Collaboration for Revit was ranked as first by 9 of the 17 respondents. BIM 360 Docs was the package ranked fourth the most frequently and the full distribution of this is depicted in Figure 2. Interestingly, when asked which was the most beneficial and which was the most challenging, Collaboration was selected the most frequently 99 out of 17) for each. AS Collaboration for Revit is the platform which enabled the teams to work simultaneously in a model it is not surprising that it was found to be beneficial and as it requires a number of steps to save and sync models it is also challenging to novice users. It should be noted that the other platforms, Docs, Glue and Team, serve different purposes and all stem from the model itself. Due to this the information collected should not be used to exclude any of these platforms from integration into a course. Rather it is clear that the ability to collaborate simultaneously and access information live from a cloud based platform is something which the students responded positively to.

A second beneficial observation of the CCE was that the students were actively engaged and showed genuine interest in the process. Due to the fact that this was an experiential learning

endeavor the instructors focused on providing the tools and prompts to the students while maintaining distance to allow them to problem solve on their own. Unprompted, the students began to make use of the lab space they were put in to coordinate their efforts, and leveraged the BIM 360 platforms in different ways. Figure 3. Shows the students reviewing their assigned building areas and working at their computer terminals during phases one and two of the CCE respectively. The researchers were pleased to see the students self-motivate and demonstrate willingness to work in an unfamiliar technological environment. This extended to the coordination portion of the activity as well where students were asking well thought out questions to the industry partner and were sincerely engaged in understanding the process as well as how the problems they encountered would be solved in a real-world scenario. The overall plan for the CCE proved to be successful and suggestions for improvements were solicited from the students and industry partner in order to continually improve the exercise moving forward. The CCE proved to be a valuable addition to the advanced BIM course and provides an experience for students which they would otherwise go without. The appreciation the students gained for the coordination process is a valuable addition to their education and provides an invaluable opportunity for interaction with industry professionals who provide insight into an increasingly technology driven industry.
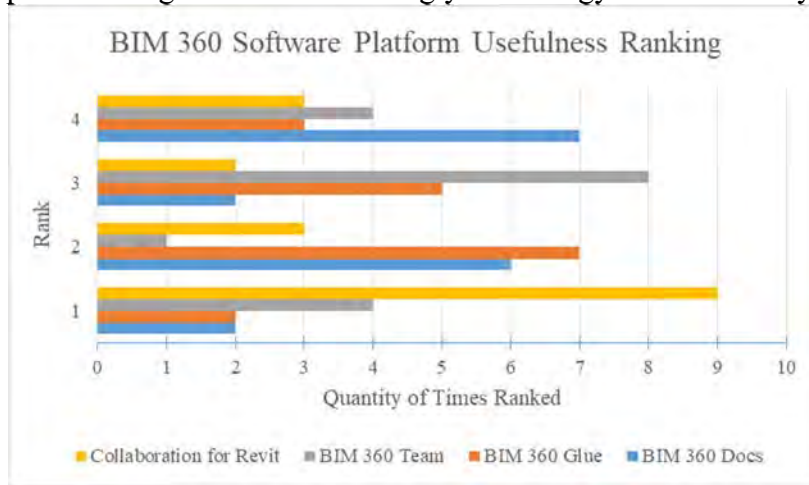
Figure 2. BIM 360 Usefulness Ranking Chart
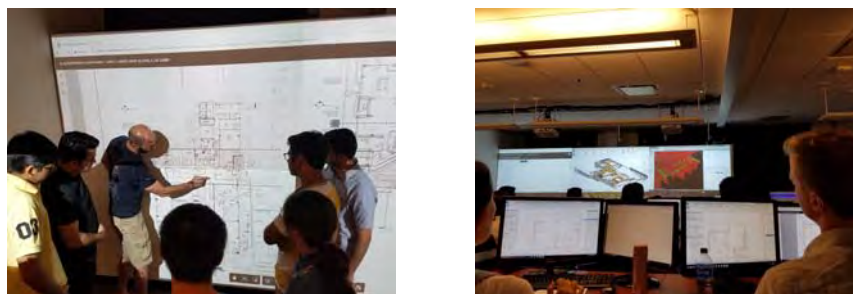
Figure 3. Collaborative BIM Exercise Examples

5. CONCLUSIONS AND FUTURE STUDY

The benefits of an interactive, synchronous BIM based coordination activity cannot be overstated. Students gain a firsthand understanding of the complex process while developing a respect for the roles of each member of a project team which they will someday be a part of or manage. The ability to assume the role of a specific team member and see the problem from a new

perspective, with a tangible goal in mind, forces the students to think critically and apply their knowledge of BIM processes in a real-world scenario. Furthermore, the ability to utilize the technology, concepts and intangible skills, such as communication and negotiation, which will be crucial in their careers, is a great asset to their education. The CCE affords them the opportunity to make mistakes and step out of their comfort zone, where instructors and peers can offer insight and guidance toward success. Overall, the ability to work synchronously in a connected BIM environment provides benefits which break down the traditional asynchronous stereotypes placed upon learning while enriching the students overall learning experience. Beyond student benefits, the industry partners were able to work in a no-risk environment to train additional staff or test workflows they would otherwise not be able to attempt on a live project. The bilateral benefits discovered for students and industry professionals through the CCE can continue to evolve and grow as the individual needs of the academic and industry partnership change. Whether the person participating in this exercise has never experienced connected BIM enabled coordination or simply wants to expand their understanding and experience to new areas, the focus on experiential learning creates meaningful experiences which encourage further thought and skill development. Moving forward, the goal is to expand this framework of industry and academic partnership while evaluating the impact it may have on student learning outcomes and career preparedness.

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BIM Curriculum Development

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Ever since the mid-eighties when CAD (Computer Aided Design) began to revolutionize how we design our buildings, forward thinking people have had a vision of a virtual construction world where we not only design in three dimensions but also schedule and estimate that same project from the information already assembled in the 3D electronic model. The potential benefits to all stakeholders were hard to overestimate. So what is the current progress of this vision and how do we, as college professors, deliver the best preparation for our students who will undoubtedly enter an industry that will continue to exploit the potential of what has come to be known as: BUILDING INFORMATION MODELING (BIM). This paper presents the process of our Undergraduate Construction Management program identifying the importance of BIM education for our majors and the initial steps we have taken in that direction.

Key Words: Building Information Modeling (BIM), Computer Aided Design (CAD), Schedule (4D), Estimate (5D), Sustainability (6D), Facility Management (7D)

History

John Brown University's Construction Management program consists of 3 full-time faculty and 60 students on average and is ACCE accredited. The first 2D Computer Aided Drafting was introduced in 1987. Then the program progressed to using Graphisoft's ArchiCAD but switched to Autodesk Revit in 2008. BIM technologies were already being used by many of the advisory board member companies and it became apparent that graduates needed as much experience with BIM as possible.

Introduction

The very first CAD (Computer Aided Design) systems began their development in the U.S. Air Force in the 1950's. They progressed for the next three decades without affecting the construction industry to any great extent until the founding of Autodesk in April of 1982. Autodesk's idea was to create a CAD program for the price of $1,000 that could run on a personal computer (PC). The following year, 1983, the first versions of AutoCAD were marketed in Germany and France (Bozdoc, 2006 [1]).

With the application of computer aided design and drafting to the building process, the inevitable move toward including more and more information in our electronic building models was assured. Those who were CAD designers in the 90's remember the regular promise of full 3D design capability in new softwares only to be disappointed by the glitchy limitations and painfully long screen regeneration times. Just being able to design in full 3D easily, with any speed, was the only goal many architects and designers could imagine. But, as the softwares that made 3D design easier kept developing, so did hardware configurations that could process that

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information without the long time lags of the 90's and early 2000's. As we realized 3D design ability on simple PC work stations, the idea of attaching even more information to the components in the model didn't seem as counterproductive because of continually improving processing speeds.

Visionaries saw the potential and teamed with IT personnel to start adding information that would let us schedule (4D) and estimate (5D) directly from the information we had already created in our 3D models. The idea that the electronic drawings could also give us accurate schedules and estimates was incredible, to say the least. Further additions of Sustainability (6D) and Facility Management (7D) round out the current applications of Building Information Modeling (BIM) by non-profit organizations, private, government and municipal agencies who are all trying to maximize the advantages of BIM in their practices. The chart below fleshes out sub-categories under the 5 main areas of BIM.
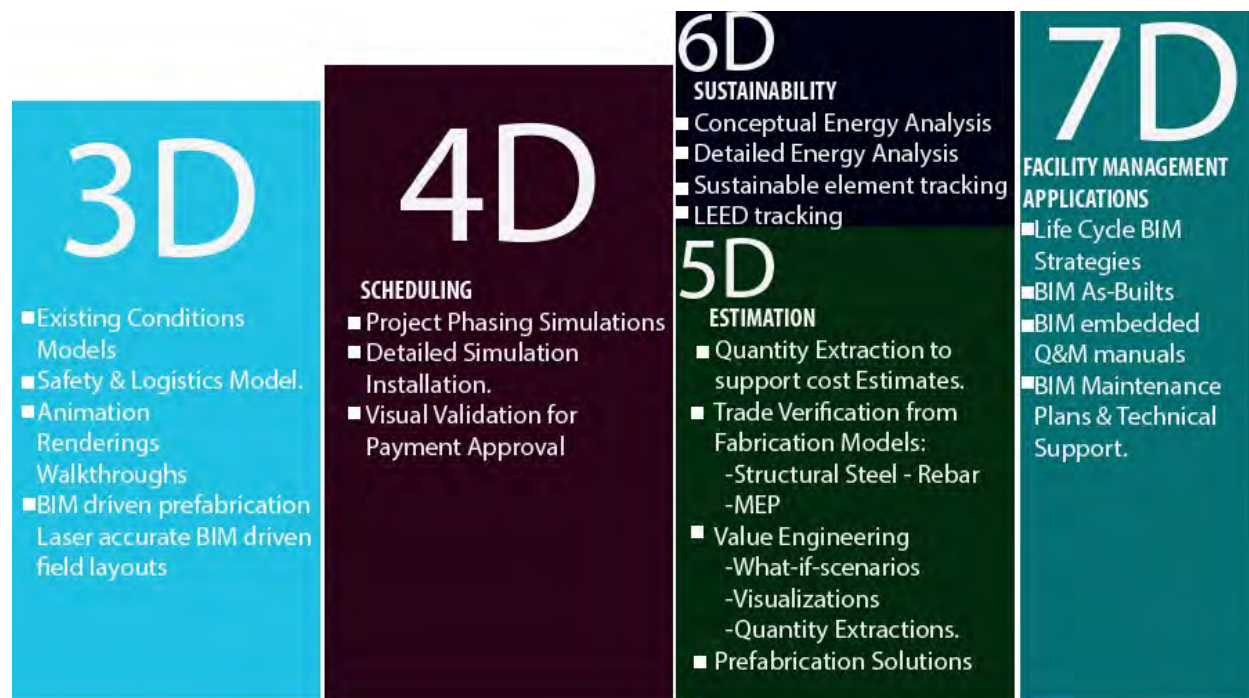
"'Expect the use of 4D and 5D building information modeling (BIM) technology to flourish in the future', Turner Construction's Treighton Mauldin told a group of construction professionals attending a webinar that WPL Publishing held April 17, 2012. He sees 4D, which addresses scheduling, and 5D, which involves estimating, 'taking off because they bring all of the aspects of a plan, an estimate, a model, and a schedule into one environment that can be easily monitored and managed and communicated to the rest of the team, which is a huge benefit, and it really starts to eliminate errors in communication, miscommunication, and, in the end, makes people more money (Rizer, 2012 [2]).'" These comments are typical of large commercial companies that plan on maximizing BIM in the future.

2

Before a program creates specific BIM training for their students, they need to answer the following questions;

Is BIM really here to stay?
"BIM Adoption Expands from 17% in 2007 to over 70% in 2012, According to New McGraw-Hill Construction Report (Malangone, 2012[3])".

Is BIM just happening in the U.S.?
Building and Construction Authority (BCA); **"Singapore, 1 August 2013** - There has been significant progress in promoting Building Information Modeling (BIM) in Singapore. The adoption rate has gone up from 20% in 2009 to 65% today" (Press Release, 2013 [4]).

With confirmations like this that the growth rate is fast (about 10% per year) and almost the same in both the U.S. and on the other side of the world, we know our students need to be as familiar as possible with BIM technologies as they enter their careers. We also know we have to be asking the right questions as we set out to create curriculum that meets that goal. The body of this paper will state those questions and the progress JBU has made in implementing what we have discovered and learned so far.

What does our client (industry) need?

When the author first started talking about BIM to his students he made sure they knew what the acronym meant and that it was about clash detection and attaching scheduling/estimating information to the electronic model. This provides information in the planning stage rather than having to wait for the architect to finish the working drawings and then schedule/estimate and look for clashes the architect didn't identify during the design process.

In a job interview in 2008 a JBU graduate was asked what he knew about BIM and he said, "Oh, Building Information Modeling?", and went on to repeat some of the basic facts accurately. He was offered a job in their newly formed BIM department. That made it abundantly clear that the construction industry was eager for students with Building Information Modeling knowledge.

In a recent survey of our industry advisory board, they said they want our graduates to know about BIM. They usually say BIM is a great tool but they don't quite know how it's done. HR personnel are challenged in how to write job descriptions for these new positions. "'To start your formulation of Job descriptions your firm needs to ask and answer, how do you and your management team plan to deploy VDC-BIM on projects? Some firms look at BIM as a drafting activity meant to provide project teams 3D modeling services. Taking this view they would create a BIM department that would likely be staffed with specialized CAD users. Alternatively, other firms focus on integrating 3D technology into each project teams' management skill set. Thus the development of Job descriptions would be different for each management strategy.

The distinction between the specialized CAD manager approach versus a project management that is specialized in model management requires a unique job description for each position (Cousins, 2010[5]).'" This quote is from an article written by an HR professional who also did short interviews with BIM managers from 4 respected commercial construction companies. The conclusion is drawn that the better the student's ability in Autodesk Revit, the better they will be able to adapt to whatever system of using the electronic model for BIM in their respective companies.

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The action plan for our program was for the instructor to get better at Autodesk's Revit since there are three classes that require the use of Revit in the program. BIM applications will make more sense when people have some level of mastery of Revit. Just as AutoCAD became the industry standard in the 2D drafting world, Revit is already the standard in the 3D/BIM world and will only solidify its position as time goes on.

Where does BIM curriculum fit into an undergraduate program?

The introductory class using Revit (CM 1223 - see below) uses a text written by a designer from Minnesota named Daniel Stine. In it he reviews hand drafting methods and then launches into a preset exercise of drawing the plans for a residence. The class is split in half and the students alternate doing plan reading exercises one lab a week and the Revit chapter assignments on the other. Senior CM students work as Teaching Assistants and lead the plan reading assignments while the instructor focuses on the students doing the Revit lessons. The following is a link to a PDF copy of the syllabus from the spring semester, 2015. It includes a schedule of each lab period: http://www.jbu.edu/majors/construction_management/presentations/ This format is a very good way to get students right into the nuts and bolts of the software (Stine, 2015 [6]).

The following JBU classes are the ones that directly involve using Autodesk Revit software. They were the initial classes considered for alteration to accommodate dedicated BIM training. CM 1223 starts the process of Revit acquisition and CM 3613 furthers it with a residential project students design themselves (This is something they may legitimately do as professionals).

After consideration, the course that was chosen to be altered was CM 3623 (next page). This is the first JBU course catalog with the new references in the description to BIM design principles and software. These concepts have been incorporated into this class for the past three years but the course description change has only now, in the current year, gotten into the school catalog.

The reality is that, unless JBU grads go on and become licensed architects, they will never legally do the full design of a commercial building and that's what the original course described them doing until this catalog cycle. This has been one of the first steps toward BIM integration into the entire construction management curriculum.

CM 1223 Graphic Communication Skills   **Three hours**
The study and practice of communicating ideas through manual and digital means. Emphases include the development of lettering and sketch abilities, communication through construction documents, an introduction to construction assemblies and an overview of three-dimensional model based design, and construction documentation. Two three-hour laboratory periods per week. An additional fee associated with this course.

CM 3613 Architectural Design I   **Three hours**
The design, development, and presentation of an architectural program for a residence. Introduction to design principles and their influence in the development of a project is addressed. The architect, contractor and owner working relationships are emphasized. Two three-hour laboratory periods per week. An additional fee associated with this course. Prerequisites: CM 1223 and junior standing, or consent of instructor.

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CM 3623 Architectural Design II   **Three hours**
An introduction to commercial design principles combined with principles of Building Information Modeling (BIM). The course will include an exercise in commercial design presentation and an introduction to BIM software and theory. An additional fee associated with this course. Prerequisites: CM 3613 and junior standing, or consent of instructor.
(Course Descriptions, 2015 [7])

After the above course description change in 2015 the program here has continued to improve and refine this class to the extent that the new course listing below has taken the place of **CM 3623** in the new JBU 2017-2018 catalog. The description follows:

CM 3723 Building Information Modeling   **Three hours**
An introduction to the application of Building information Modeling (BIM) as it relates to managing construction projects. Software experience with 4D CAD and clash detection will be explored. Course includes a semester project and presentation. An additional fee associated with this course. Prerequisites: CM 3613 and junior standing.

                                                    Offered Spring semester

What are the standard forms of BIM being used?

Once a program establishes the need for BIM training and dedicates at least part of a semester to it, what should they teach? The educator will find that more curriculum options have surfaced in the last couple of years that make it easier to design a course of study in BIM. In the Master of Engineering Technologies program at Pittsburg State University tutorial exercises are required in two softwares that are emerging as BIM applications in the construction industry. This has great appeal to construction companies that are late adopters of the technology. It also has strong appeal to educators who want to give their students comprehensive BIM exposure along with educating themselves. The JBU class was altered to include: DProfiler and Synchro. The feedback has been very encouraging as several former students have seen these softwares being used by their employers and were glad they were familiar.

"**DProfiler** is a unique BIM program that integrates 3D macro modeling and cost estimating. With this powerful program you easily build a model of your conceptual design and generate an accurate cost estimate without extra time or effort. An excellent marketing tool, with DProfiler you can give clients an impressive preconstruction package.
DProfiler features: DProfiler videos: http://www.beck-technology.com/products/destini-profiler/

- 3D Modeling with easy importing from CAD programs

- Cost Estimating with integration from Excel, RS Means databases, and Timberline

- Energy Analysis

- Google Earth integration
(Beck, 2012 [10])"

DProfiler 3D model scaled on a 2D drawing

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1	B20A0-8I	Brown Field Excavation - HARBORcenter Area	4d	12:00 AM 5/	12:00 AM 5/
2	B2201-8I	Shore/Form PT Deck - HARBORcenter P2 Are	8d	12:00 AM 8/	12:00 AM 8/
3	B2202-8I	Shore/Form PT Deck - HARBORcenter P2 Are	6d	12:00 AM 8/	12:00 AM 8/
4	B2308-8I	Shore/Form PT Deck - HARBORcenter P3 Are	1d	8:00 AM 9/2	12:00 AM 9/
5	B3CA0-8	FRP Slab on Metal Deck - HARBORcenter Co	2d	8:00 AM 3/1	5:00 PM 3/1
6	B2100-8!	Interior Masonry - HARBORcenter Stair 1 Shai	10d	8:00 AM 3/1	5:00 PM 3/2
7	B3CD0-8	FRP Slab on Metal Deck - HARBORcenter Co	2d	8:00 AM 3/1	5:00 PM 3/1

Synchro model with integrated schedule

"**Synchro PRO's** real time visualization capabilities change the way projects are planned- the ability to see into the future, to communicate clearly and to create a shared understanding amongst the entire project delivery team, enables performance on a much higher level. Safety, productivity, quality, reliability and cost competitiveness all increase. As the industry works to close the skills gap, to effectively and successfully utilize new purpose built, digital technology, the Synchro Project Delivery Team is here to support the companies and people who are working hard every day to deliver great projects (Synchro, 2016 [11])."

Standardized BIM is trying harder to emerge in places other than the U.S. it seems. "'Although the number of project teams using BIM tools increases each year, the transformative potential of these tools remains checked by barriers that impede the information exchange among participants and across different software platforms. Getting the most out of BIM will require an open exchange of information, which in turn requires defining and implementing common protocols and standards. But who wants this arduous task?

In the United Kingdom, the answer is simple: the government. By 2016, all British government building contracts will require "fully collaborative 3D BIM," according to the country's 2011 Government Construction Strategy. The NBS National BIM library—yes, such a thing exists— already contains thousands of both generic and proprietary BIM objects. (These objects are virtual building components containing performance parameters and physical attributes that can be placed in digital building models.) Singapore, Finland, and Norway also have national BIM standards, and China has one in the works (Shapiro, 2014[8]).'" They have also produced a video about the status of BIM in the UK (National BIM Library, 2013 [9]).

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Other resources I have found to help introduce BIM

Reid Johnson (reid.johnson@autodesk.com) has been available to teach mock coordination meetings (via Go-To-Meeting) focusing on clash detection in the CM 3623 course using the autodesk cloud at no charge. There are 6 hours of lab time dedicated to these meetings and it has received great student feedback.

The challenge of grading can be met by allotting an appropriate amount of points for participation and engagement during the actual contact time and some questions on the final that can only be answered by engagement in the original exercise or remedial experience.

Conclusion

First of all, students need to have the highest level of proficiency possible in the 3D software package they will most likely be using in their new jobs. That software should be the current version of Autodesk's Revit.

Because so many companies, especially early adopters, developed their own hybrid systems using softwares like Navisworks, or writing their own, there haven't been many standard protocols for educators to look at to create BIM curriculum. That is changing, however, and several new tools are being offered by Autodesk in specific disciplines like Construction Management: https://academy.autodesk.com/curriculum/construction-management. In addition, DProfiler and Synchro tutorials, along with videos and classroom experiences in mock coordination meetings will continue to be some of the best ways to introduce BIM to construction management students.

The author hopes to start a connection with as many other undergraduate professors as possible so the group could go forward developing really effective BIM curriculum together. All universities can prepare students to hit the ground running in this new paradigm called Building Information Modeling.

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FRAMEWORK OF INTERACTIVE WEARABLE AND CARE MANAGEMENT SYSTEM FOR ELDER PEOPLE

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ABSTRACT

The United States is experiencing a significant shortage of qualified workers who are capable of managing, supervising and providing high-quality services and supports for older adults. This deficiency threatens care for people with serious disabilities and vulnerable older adults. This research examines the framework of interactive wearable and care management system facilitated by BIM and Internet of Things (IoT) to fulfill the growing demand for the workforce of care-providers. The research seeks to answer the question whether the proposed framework can improve the employee satisfaction and engagement in elderly living facilities through the implementation of innovative technology and management strategy. Specifically, the research studied a Continuing Care Retirement Community (CCRC) in central Illinois to collect data about the care management process, needs, expectations, and features of future workforce for the senior care industry. The authors analyzed the survey data collected from 146 employees range from ages 16 to 72 and with different backgrounds of education, socioeconomic class, race, gender, and ethnicity. The five areas for improvement include workload distribution, communication, wage, conflict resolution, and opinion report system. The framework design targets on the five areas of the analysis results and provides a solution to the workforce shortage problem.

Keywords: BIM, Smart Homes, Internet of Things (IoT), Long-Term Care, System Framework

1. INTRODUCTION

With the advancement in technology, people have the desire to use technology for comfortable living. For example, Internet of Things (IoT) is gaining more recognition and acceptance in all sectors. This has paved the way for the senior care industry to adapt to IoT and Building Information Modeling (BIM) leading to the solution of their workforce deficiency problem. The United States is undergoing a significant shortage of, and a growing demand for, qualified workers who are capable of managing, supervising and providing high-quality services and support for older adults. Many issues are fueling this national workforce crisis. The population of adults age 65 and older will increase from 47.8 million in 2015 to 88 million in 2050 (Muenz 2007; Toossi 2002). The U.S. Department of Health and Human Services estimates that nearly 70% of people who reach the age of 65 will ultimately need some form of long-term care (Favreault and Dey 2015; Haskell, et al. 2007). The nation will need 2.5 million long term care workers by 2030 to keep up with the growth of America's aging population. Many long-term care facilities struggle with turn-over and staffing, which is not uncommon for the senior care industry. The impact of this staffing crisis to providers include high costs to recruit and train new workers, concerns about access, and quality decline, because shortage of workers means consumers have difficulty in accessing quality care. Staff shortages often cause hardships for workers who remain on the job, including increased workloads, high patient-to-staff ratios, as well as higher rates of accidents and injuries, all of which can have an impact on quality of care.

The objective of this study is to determine what the staff satisfaction factors are and how an organization can use this knowledge to make service improvements and increase employee satisfaction, which possibly have a positive effect on retention. Particularly, the research examines survey data to ultimately predict the dependent variable of overall employee satisfaction. Based on the understanding of the care management process, needs, expectations, and features of future workforce, this paper presents a framework of interactive wearable and care management system

(IWCMS) facilitated by BIM and Internet of Things (IoT) for care providers. This study intend to develop an intelligent system that can deliver help for workload monitoring and distribution, communication, conflict resolution and data report system in a smart home environment. Smart home technology offers flexibility of remote control, which means that care providers have the option to monitor and assist customers or patients on round-the-clock attention without being there physically.

As smart home technology continues to gain acceptance and more related devices come to the market, the research on how it could be used to help older people still lacks attention. There are a lot of benefits and ease that smart home technology can bring to people with serious disabilities and vulnerable older adults. Smart homes encourage independent living at homes for elderly and disabled people which improve the quality of life (Olawumi, et al. 2017). There are lots of benefits that comes with owning a smart home. This explains the increasing rate at which homes are adopting this technology. According to IHS Markit (2016), 80 million smart home devices were delivered worldwide, a 64% increase from 2015. Digital technology becomes increasingly embedded in the architectural fabric of buildings. It is believed that soon homes will be intelligent enough to distinguish between occupants and guests or patients and care providers.

Many homes have more than three smart devices, including smart phones, smart televisions, and smart watches. Smart homes offer its owners the opportunity to control these devices remotely with just a click from any mobile device and the aid of a third party application. However, these applications may come with confusing interfaces which makes it difficult for the app users to know which devices are on or off. In addition, the implementation of the IWCMS requires more complicated functions than the simple control of smart devices. The design of the IWCMS needs the thorough understanding of the current operations and processes associated with care management system and using a mobile application to control a smart home. Some companies have introduced programming framework for third-party developers to build apps that realize smart home operations. For example, *Samsung's SmartThings, Google's Weave/Brillo* and *Apple's HomeKit*. The *Samsung SmartThings* app is a widely used smart home application and has a growing set of apps (*SmartApps*). Compared to other frameworks, such as *HomeKit* and *Vera*, it has the greatest number of apps and is able to support up to 132 different devices from major manufacturers of smart devices. In addition, *SmartThings* shares important security design principles with other frameworks (Fernandez, et al. 2016; Rushing 2017). These features make the *Samsung SmartThings* framework ideal for this research.

The research question is whether the proposed framework can improve the employee satisfaction and engagement in elderly living facilities through the implementation of innovative technology and management strategy. Specifically, the research studied a Continuing Care Retirement Community (CCRC) in central Illinois to collect data for the framework design of the IWCMS. The methodology design and collection of the survey data started from September 1st to December 10th, 2017. The data from 146 surveyed range from ages 16 to 72 and with different backgrounds of education, socioeconomic class, race, gender, and ethnicity. The demographic data show the diversity of the sample group and help to validate the generalizability of the research. This research confronts with some limitations, including that only one facility is being surveyed. With thousands of long term care facilities in the country, one facility may or may not have similar satisfaction results. Another limitation is that this survey is only one "snap shot" of satisfaction with one's job which can be greatly influenced by a recent, temporary situation and may not be a good indication of overall satisfaction. One assumption is that employees are being honest with their responses.

2. BACKGROUND

Smart homes present opportunities for comfortable living and prolong independent. Several smart home programming frameworks are able to support third-party app development and provide enormous benefits to users (Fernandez, et al. 2016). For example, Samsung SmartThings framework sustains a broad range of devices including smart TVs, motion sensors, fire alarms, and door locks. It allows users to monitor and control their home devices and appliances remotely through smartphones. SmartThings hosts the application runtime on a proprietary, closed-source cloud backend. Fernandez, et al. (2016) performed a static source code analysis of 499 *SmartThings* apps (called *SmartApps*) and 132 device handlers, and carefully crafted test cases that revealed many undocumented features of the platform. Their research produced two key findings. First, they discovered that although SmartThings implemented a privilege separation model, two fundamental flaws were found in the design that led to significant overprivileged in *SmartApps*. Once installed, a *SmartApp* was granted with a full access to a device even if it specifically requires just limited access to the device. The other flaw detected was that SmartThings didn't sufficiently protect sensitive information such as lock codes. Possible security attacks include secretly planted door lock codes, stole existing door lock codes, disabled vacation mode of the home, and induced fake fire alarms. These don't require physical access to the home, which

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makes the vulnerabilities dangerous. It is prudent to have a stand-by app purposely for keeping an eye on the smart homes.

Current research on smart homes includes security issues on protocols and devices. Denning, et al. (2013) described a set of rising threats to smart homes due to the rapid introduction and acceptance of smart devices. For instance, there are threats of direct compromise as well as eavesdropping of various smart home devices. The nature of attacks include illegal physical entry, data destruction, and privacy violations (Denning et al., 2013). The Federal Trade Commission (FTC) addressed the risks introduced by the Internet of Things (IoT). According to the FTC Staff Report in 2015, a variety of potential security risks regarding smart home devices could be exploited to harm consumers by the following actions: (1) Enabling unauthorized access and misuse of personal information; (2) Facilitating attacks on other systems; and (3) Creating risks to personal safety." (Staff 2015) Researchers reviewed existing standards, collections and guides of best practices for smart home implementations (Christiaens, 2015; Olawumi, et al. 2017). The data transmitted via wireless interfaces in smart home environments usually go through the main security component of ZigBee network (Olawumi, et al., 2017). Researchers recognized the link between security and privacy and outlined the difficulties of keeping certain information truly private to prevent smart devices from leaking information (Weber 2010). Jakkula and Cook (2008) used data available from smart sensors and machine learning to detect irregularity and automatically duplicates behavior for individuals. They were able to know exactly what the occupant was doing inside their smart homes. This research considers the entire smart home environment and focus on the framework development of the IWCMS.

There is an alarming shortage of nurses in geriatric care in the United States, Israel, Europe, and many other countries (Haron, et al. 2013). The Israel Ministry of Health's Nursing Division decided to investigate the readiness of current nursing students to work in geriatrics. The study had the goal of gathering student nurses' (in their final year of school) views on geriatric nursing as a career path and identify the different factors that influence their views. They found that the non-influence of training program content was the key finding and recommended that most efforts to recruit nurses to the field should be invested in making geriatrics more attractive by improving the pay and expanding the authority of geriatric nurses to the level of Clinical Nurse Specialist (CNS), which would provide an attractive career growth opportunity. The research study related to the following variables: (1) "Having the opportunity to do what I do best every day." (2) "Leaving work feeling good about the work I did." (3) "Being part of a team that is producing meaningful results for the organization." (4) "Believing they personally make a difference here." It is important for nurses to feel like they have the opportunity to use their skills. This study alludes to nurses wanting to have meaningful results and making a difference.

For future care providers, a lot of them are the Millennials who care greatly about wanting to make a difference and have a meaningful job. According to Branscum and Sclaraffa (2013), nowadays the Millennials (born 1981-1999) are graduating from college and starting their careers. Most likely, working in senior care facility will be their first interaction (outside of family) with older adults. Branscum and Sclaraffa (2013) attempted to understand these stereotypes, focusing on perceptions of Millennials on Baby Boomers. They hoped to figure out if the Millennials follow historic trends of holding negative stereotypes of older generations and determine ways that society could use to alleviate this. Individuals born between the years 1981-1999 completed the survey. There were 336 surveys completed in total, 46 males and 290 females, mostly Caucasians. The selection of participants was through "convenience" and "snowballing". Most of the participants were traditional students at a midsize university (University of Louisiana). Overall the results indicated that Millennials did indeed have negative attitudes toward older adults. The R-A (Respect and Appreciation) subscale has the highest Mean score, followed by I-I (Irritation-Intolerance), then S-C (Social Connectedness). The findings about the characteristics of the Millennials include: (1) Millennials are not loyal to their employers. Having friends at work may lower the chance of leaving a job. (2) Millennials care greatly about wanting to make a difference and have a meaningful job. (3) Millennials want to grow and learn more than other generations. (4) Millennials care about doing a good job and want constant feedback from supervisors.

Researchers noticed that employees' job satisfaction could affect the care quality provided (Haron et al. 2013; Branscum and Sclaraffa 2013; Walker 1999). The areas that employees are dissatisfied with can provide suggestions to system design for the IWCMS. Walker (1999) performed a study to determine if there is a difference in job satisfaction between certified nursing assistants (CNAs) in a nonprofit and a for-profit nursing facility. CNAs with high levels of turnover impact the quality of care. The job satisfaction of CNAs is the greatest impact on turnover (Walker 1999). The influencing factors studied include demographic factors such as age, level of education, marital status, salary, length of employment at current position, length of employment in the field, and number of sick days used in the last 6 months. Walker (1999) also collected data in regards to whether the CNAs' attitudes about their job, values of work, and perceptions of the work correlated to their levels of satisfaction? Whether the satisfaction level of the CNAs related to the type of facility they are employed at? This study was limited to a small sample of CNAs

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employed in the two skilled nursing facilities in the western New York area. The literature review suggests that CNA job satisfaction can be influenced by the lack of opportunity available at a nursing facility. This lack of opportunity causes an added stress to the CNAs, which may cause them to jump from job to job in search of higher wages and recognition. The level of job satisfaction depends on interpersonal relationships, management style, CNA achievement, responsibility, salary, working conditions, and administrative policies. Low pay is a substantial reason why job satisfaction among CNAs is very low. Non-profits and for-profits differ especially in competitive wages. Those who work for non-profits may believe and trust in the organization more so than those who work for for-profit businesses. There are stereotypes of for-profit agencies to be corrupt or "money hungry", so trusting the leadership and believing the organization is following its missions can be important to general trust and loyalty.

3. METHODOLOGY

The design of this study is an online survey provided to all employees through the existing online education system called "RELIAS". Employees are required to do monthly training to maintain compliance with the training rules and regulations of the industry. This organization chooses to do that training online and has been using the system "RELIAS" for over five years. The link to the survey was inserted into the RELIAS training module for that month and employees were prompted to take the survey. Reminders to take the survey were also posted on bulletin boards, on the internal television and via internal emails. 29 factors were considered in the survey. The factors were presented in the form of statements and participants responded on a Likert Scale with the following options: A=Strongly Disagree, B=Disagree, C=Neutral, D=Agree, E=Strongly Agree. Table 1 shows the details.

Reliability and validity of this specific survey cannot yet be tested as the turnover rate of the employees that have taken this survey may not be analyzed for another year, three years, five years or more. In a number of years, the number of employees that left voluntarily from their position can perhaps be aligned with the satisfaction results to determine if the survey results were valid. For example if an employee receives poor satisfaction scores and voluntarily leaves his/her job within 6 months, the survey results would be valid. Alternatively, if an employee receives high satisfaction scores and is still employed in 5 years, one could deduct that the results were valid. The challenge with employment is that there are many other factors besides satisfaction that would cause one to leave their job such as relocation, health, retirement, and job performance. Fig. 1 shows the demographic data.

4. DATA COLLECTION AND ANALYSIS

Located in Urbana, Illinois, CCRC is a non-profit retirement community that has been operating for nearly 40 years. Their mission is to offer senior adults exceptional services and living environments designed to engage the mind, spirit, and body in wellness and community. It is the only facility to offer continuous care in the area. Offering continuous care implies that the organization delivers its residents housing facilities on the same site until they pass away or decide to relocate. In order to provide this amenity, the organization has two contrasting campuses for residents: the Village and the MB Health Center. The Village is a resort-style independent living facility for active seniors, while the MB Health Center provides individualized assisted living and nursing care. Residents are able to transfer from the Village to the Health Center whenever they feel the need for living assistance. These spaces, and the 28 acres of land they exist on, are what allow the facility to provide the unique continuous care that it does. CCRC currently employs nearly 300 individuals, yet its only funding comes from resident fees and reimbursements from insurance providers. Its main competitors for staffing are the local hospitals and clinics, and the local nursing homes and retirement communities. Though the organization faces tremendous competition (especially from the local hospitals), their 5-Star Medicare rating and exceptional reputation have aided in the organization's ability to stay operational. The data was collected online via survey and was measured by summarizing scores and determining the averages for responses to the questions. The scores were compared to a previous survey for the same or similar questions.

The average response for all respondents on a given factor is based on a rating scale (i.e., from strongly disagree to strongly agree). While the survey is conducted using a 1 to 5 rating scale, to calculate the mean score, each response is multiplied by 20 and reported using a scale that ranges from 20 to 100. It is important to understand that the mean scores are not percentages. A mean score of 87.8 for overall satisfaction does not mean that 87.8% of respondents are satisfied, but rather the average response among respondents for overall satisfaction was 87.8 on a 20 to 100 scale, or 4.39 on a 1 to 5 scale. Table 1 also shows the satisfaction by department. The first number listed next to the factor is the overall score for reference. The numbers following are departments in the following order: Administration, Dietary Services, Environmental Services, CNA, licensed practical nurse or registered nurse (LPN/R), and Ancillary Services. The department with the highest score is bolded in green for each factor and the lowest is bolded in red for each factor.

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Table 1: Data Analysis

| Satisfaction Factor (*highest % is bolded*)	A	B	C	D	E	Mean	Adm	Diet	Env	CNA	LPN/R	Anc
Overall, I am satisfied with my job.	1.4%	2.1%	8.9%	**43.8%**	**43.8%**	85.3	**91.9**	82.7	**76.0**	85.3	90.4	78.3
I would recommend CCRC as a great place to work.	2.8%	2.8%	4.8%	39.3%	**50.3%**	86.3	**95.0**	86.7	77.3	84.2	90.0	**76.7**
I think I will be working at CCRC in three years.	3.6%	3.6%	16.5%	**41.7%**	34.5%	80.0	85.8	76.0	**70.7**	78.3	**86.4**	84.0
I believe CCRC is living up to its mission and goals.	1.4%	2.1%	7.5%	**44.5%**	**44.5%**	85.8	**93.1**	89.3	**73.3**	82.6	87.8	83.3
At work, my opinions count.	3.5%	10.5%	18.9%	**39.2%**	28.0%	75.5	**86.3**	77.3	**60.0**	72.8	74.5	70.0
CCRC cares for its employees.	1.4%	7.5%	11.0%	39.7%	**40.4%**	82.1	**93.8**	84.0	**68.0**	78.4	80.0	80.0
At work, I have the opportunity to do what I do best every day.	1.4%	6.9%	10.4%	**45.8%**	35.4%	81.4	**88.4**	77.3	**74.7**	78.9	87.0	80.0
I trust the leadership of CCRC.	2.1%	6.2%	14.6%	**40.3%**	36.8%	80.7	**89.0**	77.1	**68.0**	82.1	81.7	75.0
I feel I'm part of a team that is producing meaningful results for the organization.	0.7%	4.9%	12.0%	**45.8%**	36.6%	82.5	**90.0**	82.9	**67.1**	80.0	84.5	83.3
I feel I personally make a difference here.	1.4%	4.1%	11.7%	**46.9%**	35.9%	82.3	**86.3**	84.3	**72.0**	81.1	85.2	80.0
I often leave work feeling good about the work I did.	2.1%	2.8%	9.0%	41.7%	**44.4%**	84.7	89.0	80.0	77.3	85.8	**90.9**	**75.0**
I have friends at work.	1.4%	1.4%	11.9%	**53.1%**	32.2%	82.7	**88.1**	86.7	**72.0**	80.5	84.5	80.0
I know what is expected of me.	1.4%	2.8%	2.8%	**48.3%**	44.8%	86.5	90.0	84.0	**74.7**	90.0	**90.9**	81.7
My Supervisor offers positive recognition for a job well done.	3.4%	8.3%	11.7%	**42.8%**	33.8%	79.0	82.5	74.7	**70.7**	78.4	**86.1**	72.7
This last year, I have had opportunities at work to learn and grow.	1.4%	4.2%	14.6%	**41.7%**	38.2%	82.2	88.1	84.0	**74.7**	80.0	**81.7**	80.0
The physical safety of employees is protected.	1.4%	2.1%	2.8%	**55.2%**	38.6%	85.5	88.1	88.0	**73.3**	85.4	**89.6**	85.0
Staff issues, including conflicts, are resolved fairly.	5.7%	7.1%	22.7%	**41.8%**	22.7%	73.8	**79.3**	77.1	**60.0**	73.5	73.6	71.7
The workload of my team is distributed fairly.	4.2%	16.2%	16.2%	**45.8%**	17.6%	71.3	**80.0**	67.1	**57.3**	66.5	76.5	74.5
I am given the necessary tools and equipment to do my job.	2.1%	4.8%	4.8%	**56.6%**	31.7%	82.2	**86.9**	76.0	**74.7**	85.9	82.6	75.0
I believe our employees provide residents with the best possible care.	1.4%	5.5%	7.6%	**44.1%**	41.4%	83.7	**92.5**	81.4	**74.7**	81.1	87.0	78.3
I have respect for my Supervisor.	2.8%	4.1%	5.5%	40.7%	**46.9%**	85.0	88.8	84.0	**72.0**	**89.5**	87.8	72.7
I am given training on all the important parts of my job.	2.1%	5.6%	9.9%	**50.7%**	31.7%	80.8	81.3	81.4	**66.7**	**88.1**	83.5	70.9
My performance review is completed and shared with me on time.	2.9%	7.2%	15.2%	**45.7%**	29.0%	78.1	82.0	82.7	73.3	74.4	**83.6**	**72.0**
Communication is good at CCRC, both on my team and with other teams.	5.6%	13.2%	18.8%	**41.7%**	20.8%	71.8	77.4	76.0	**54.7**	69.7	**80.0**	65.0
I am paid a competitive wage compared to similar positions in the industry.	4.9%	13.2%	20.8%	**38.2%**	22.9%	72.2	73.8	73.3	**52.0**	**80.5**	69.6	70.9
I have confidence in my Supervisor's ability to lead.	3.5%	4.9%	10.4%	**41.0%**	40.3%	81.9	84.4	85.3	69.3	85.4	**87.0**	**69.1**
I am comfortable going to my supervisor with concerns.	3.5%	11.1%	5.6%	35.4%	**44.4%**	81.3	**86.3**	81.3	**69.3**	83.2	84.3	74.5
My supervisor asks for employee input with problem solving.	2.1%	9.3%	10.0%	**45.0%**	33.6%	79.7	86.0	70.7	76.0	77.1	**86.1**	**72.7**
I can handle the amount of work I am asked to do.	2.8%	2.8%	12.4%	**51.7%**	30.3%	80.8	**87.7**	81.3	**66.7**	80.5	83.5	76.7
I read the employee newsletter every month.	5.6%	7.0%	15.5%	**47.2%**	24.6%	75.6	**88.8**	74.7	78.7	68.1	69.1	81.8
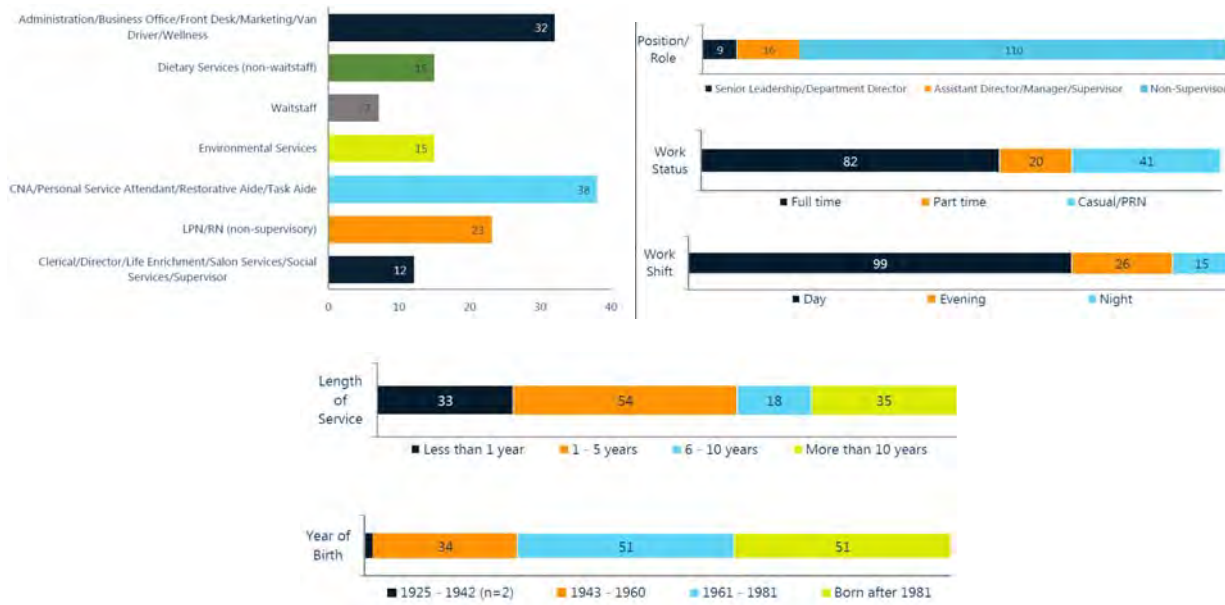
Figure 1: Demographic data

The top five highest and lowest scoring items, which may indicate the five areas in which the organization is doing well, and the lowest may indicate the five areas in which the organization could make improvements. The variables with the highest scores are the following ones: (1) I know what is expected of me = 86.5; (2) I believe CCRC is living up to its mission and goals = 85.8; (3) The physical safety of employees is protected = 85.5; (4) I have respect for my Supervisor = 85.0; (5) I often leave work feeling good about the work I did = 84.7. The variables with the Lowest Scores are the following ones: (1) The workload of my team is distributed fairly. 71.3 (2) Communication is good at CCRC, both on my team and with other teams. 71.8 (3) I am paid a competitive wage compared to similar positions in theindustry.72.2 (4) Staff issues, including conflicts, are resolved fairly. 73.8 (5) At work, my opinions count. 75.5.

5. FRAMEWORK DESIGN

Although many definitions exist for a framework, it is simply a basic structure which explains a system or concept. The foundation for the framework considered for this study includes the Framework for Improving Critical Infrastructure Cybersecurity (Sedgewick 2014) and Control Objectives for Information and Related Technology, or COBIT (ISACA 2018). These frameworks provide recommended best practices for governance and control process of information systems, cybersecurity and technology. Analyzing the COBIT and NIST frameworks provided a better insight into the security standards that has been put in place to protect critical infrastructures.

The Samsung SmartThings app is a widely used smart home application. Other reasons for choosing *SmartThings* is because has a growing set of apps (*SmartApps*). Compared to other frameworks such as *HomeKit* and *Vera*, it has the greatest number of apps. Again, SmartThings has support for 132 devices from major manufacturers of smart devices. In addition, SmartThings shares important security design principles with other frameworks (Fernandez, Junk and Prakash, 2016). This made the Samsung SmartThings framework ideal for this research. Fig. 2 shows the framework.

6. CONCLUSION

Based on the highest scores, the organization might assume that it communicates expectations well to its employees. Because employees believe the organization lives up to its mission and goals might be a strong indicator of retention as the opposite would inspire distrust and animosity towards the organization. Believing that the organization follows its mission may elicit feelings of pride for employees. The organization protecting the safety of employees is an important factor for believing the organization cares for its employees. Having respect for the supervisor is important for satisfaction as it can be challenging to accept assignments in a relationship that lacks respect. Finally, leaving work

feeling good about the job they've done is an important factor in satisfaction overall. Based on the lowest scores, having the workload distributed fairly is an area of improvement. This may also be a conspiracy theory of employees as their perception may be that workload is unevenly distributed, when in reality that may or may not be true. Another low scoring factor is communication. This factor would need more analysis as there is not enough information about what type of communication. Employees believing that they are paid a competitive wage compared to similar positions in the industry is another low scoring factor. This perception should inspire the human resources department to do an analysis on wages and benefits for similar industry positions and perhaps rework the organizations compensation program. This is another factor that could be considered an inaccurate and misguided perception. Staff issues, including conflicts, are resolved fairly was another lowest scoring factors. One way to improve this could be training supervisors in conflict resolution and mediation skills. And finally, the factor of believing their opinions count could be improved by inviting more front-line staff to decision making meetings, involving front line staff in work groups and overall empowering staff to make their own decisions on issues that are safe for them to do so.
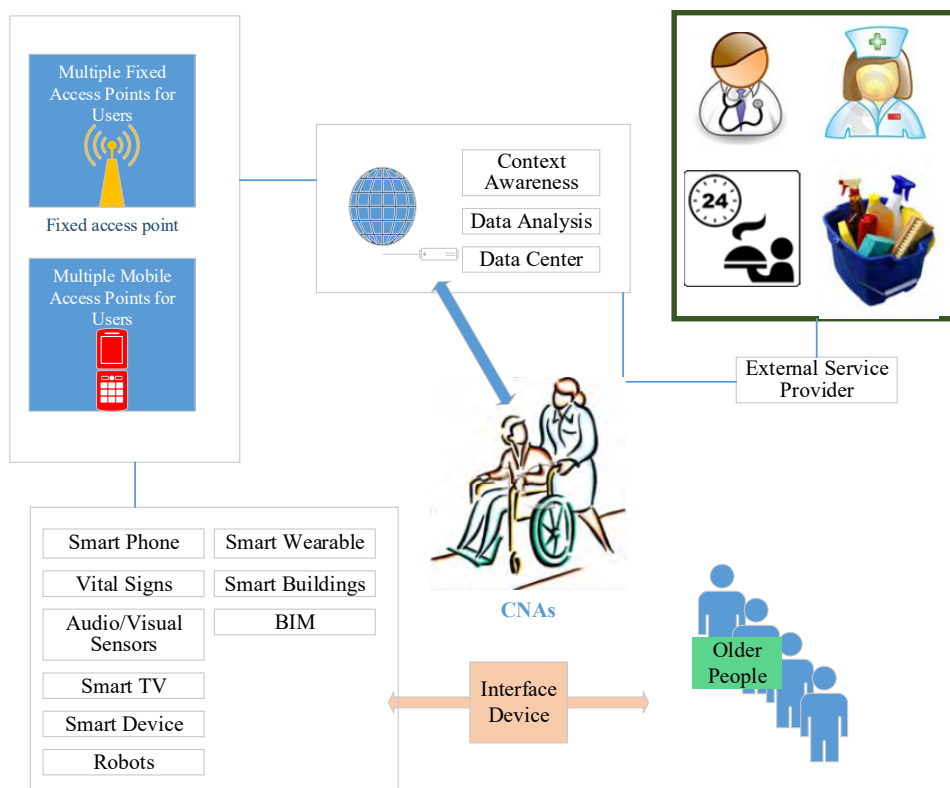

Figure 2: Framework of Interactive Wearable and Care Management System (IWCMS)

An interesting piece of the results is the separation of satisfaction based on department. Administration had the most amount of highest scores with 17 factors scoring the highest and CNAs and RNs combined ranked highest for 13 factors. Environmental Services had the most amount of lowest scores with 24 factors scoring the lowest. In comparison to the previous survey, of the 18 similar factors studied, 15 factors had increased scores and 3 factors had a lower score. This suggests that the organization is headed in a positive direction in relation to staff engagement and satisfaction.

The students observed that after 1970s, with the acceleration of population aging, the society faced the elderly population expanding and the increasing demand of the elderly. In Bloomington-Normal, the aging population is spread out with 23.8% from 45 to 64, and 10.2% who were 65 years of age or older. A high quality senior living facility is becoming more and more important to this area. The suitable living facilities for the elderly are not only to reduce or eliminate the potential safety problems of the elderly when in use, but can make up for the elderly both physical and mental functions decline. It provides the basic security communication outdoor activity. The students in the BIM class used the collection of information, reference gerontology, environmental psychology and other related knowledge, extended the living facilities design principles, and designed the methods that were suitable for elderly people to use. Through the comparison of the apartments for the aged group in Bloomington-Normal area, and

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interview the group of people who use the living facilities with their personal feelings and experience, the ISU students identified both indoor and outdoor living facilities planning and design deficiencies. They summarized the common problems existing in the apartments for the aged group. Their final designs combined with the lifestyle needs of the elderly to provide some reference for scientific research design of living facilities for the elderly apartments, and put forward some reasonable suggestions for planning and construction of Bloomington-Normal area of apartments for the elderly.

Based on the findings of the ISU students, this research then constructed a framework for geriatric engineering design using BIM technology. The research finds out that there are 3 factors crucial to the success of ergonomic design practice for geriatric consideration. 1) The development and verification of the framework and the subsequent interpretation of results are critical to the success of the design. 2) A revised genetic algorithm (GA) is applied to search for an optimized solution by iteratively trying to improve a candidate solution in regards to a given measure of quality. 3) The profile captured and sketched in user feedback, together with ergonomic design and geriatric considerations, can contribute to the setup of the framework. This framework will be brought to design environment to integrate all design activities and benefit the geriatric study with a new design procedure. Due to the use of BIM technology in this research, the result framework can be easily adopted to parametric rules or as design constraints in practical implications.

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HOW TO INTEGRATE EXPERIENTIAL LEARNING FOR ARTIFICIAL INTELLIGENCE IN BIM CURRICULUM

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ABSTRACT

Building Information Modeling (BIM) is not a single piece of software or model, but a new form of information processing and collaboration, with data embedded within the model. One of the top technologies that will affect BIM in near future is Artificial Intelligence (AI) and machine learning. The Architecture, Engineering and Construction (AEC) is well placed benefits from the advent of AI through BIM. To understand AI with BIM, its potential impact, provide a broad research of some of the applications of AI and machine learning, gain skills and experiences with smarter tools and the impact that these tools might have in the short and long terms in AEC is important to develop and integrate an experiential learning environment for AI in BIM Curriculum. The aim of this study is to (1) understand the new data sources and AI technologies and their use in AEC; (2) learn how BIMs are used with new AI data sources and technologies; (3) outline an experiential AI-BIM learning module through a roadmap to execute it in the BIM curriculum; and, (4) discuss AI-BIM environment, tools and industry support for experiential learning in terms of these technologies. Some in-class practices in Introduction to BIM and Construction Management with BIM courses at Armour College of Engineering at Illinois Institute of Technology (IIT) and outcomes will be shared.

Keywords: Artificial Intelligence, Mixed Reality, Augmented Reality, Virtual Reality, BIM

1. INTRODUCTION

Data sources in construction are exploding. Mobile devices and apps like BIM 360 Field are capturing and storing thousands of photos on typical projects. Drones, scanners, wearables and other construction management apps are adding to the mountain of data collected as a by-product of their use. To bring structure to our interpretations of these growing data streams, machine learning solutions are being applied to sort, filter, and surface insights so that projects can find the information they're looking for and make better decisions. The photo and video recognition for management of construction images, as well as predictive analytics in terms of highlighting high risk quality and safety issues are early practical examples.

The ever-increasing prevalence of building information modeling (BIM) solutions represents a promising step towards AEC modernization. The 3D modeling capabilities, enhanced information sharing, and data insights delivered by the most advanced BIM software are incredibly useful; however, the most forward-thinking AEC firms are also beginning to explore the ways in which BIM can be leveraged to even greater effect using virtual reality (VR), augmented reality (AR), and mixed reality (MR) technologies.

As spaces have become increasingly complex, more stakeholders are involved in the design process than ever before. Unsurprisingly, this can be problematic from an efficiency standpoint — when designs are being modified by multiple parties simultaneously, it increases the likelihood of clashes and inconsistencies by a significant margin. 2D renderings and drawings are limited for communication and

prone to wrong interpretation and loss of data. AI technologies used with BIM help (1) clarify communication and facilitate collaboration; (2) eliminate confusions stemming from inconsistency; (3) solve problems with team focusing; (4) detect and realize the clashes for proactive decisions in pre-construction and on site; (5) optimize built environment and increase building performance; and, (6) detect and decrease safety risks (Scott, 2016).

According to the CGarchitecture's worldwide (28% of the companies located in the US) and Industry Survey (Autodesk University, 2017), AI technologies (VR/AR/MR) in AEC is generally used by *architectural visualization companies* (35%), *architectural firms* (20%), *engineering firms* (5%), *building contractors* (3%), *academics and students* (4%). The use of AI in *production* is increased 3% from 2016-2017 (69%) to 2017-2018 (72%). The use of AI in *research and development* is reported as 78% for 2017-2018 and 77% for 2016-2017.

These technologies are considered highly important for architectural design and collaboration in terms of the survey results. The use of the AI with building information models in architectural design are seen in general for scale judgement or tracking, spatial reasoning, accessibility, design projection, production and collaborative design purposes. According to the experts' opinion, as it is shown in Figure 1, building for VR is an extension of what AEC is already doing. VR replaces the existing world with a virtual one. AR supplements it with digital objects of any sort. MR integrates digital objects into the existing world making it look as if those are really there (Rosenberg, 1992).
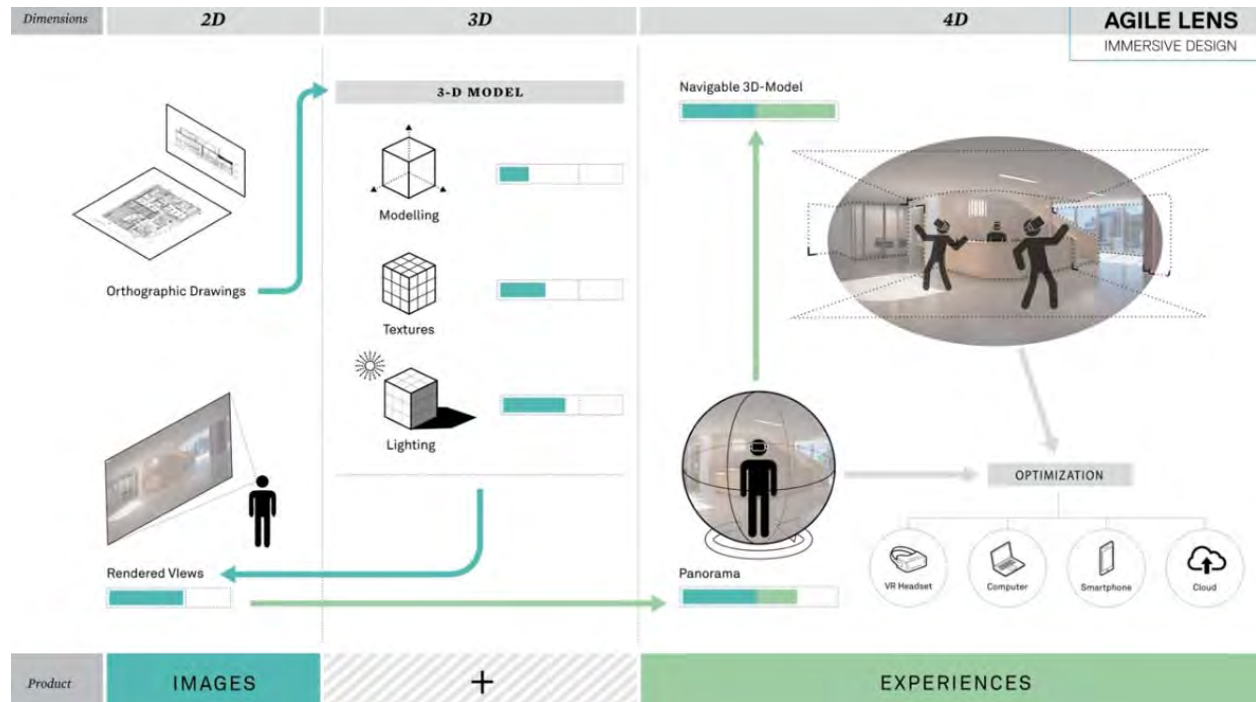

Figure 1: Building for VR (Autodesk University, 2017)

3-D models and BIM are more than just geometric representations of buildings – they are also a repository for a wealth of information. Throughout the design and construction phases of a project, we create and capture information that is extremely valuable to an owner for use in operating their building. Finding best ways to store and extract this data is a huge issue. The sheer number of discussions, classes and casual mentions at AU about extracting data from building information models (BIM) to leverage for operations was staggering, and a clear marker that the industry has recognized the need for better tools and processes to benefit owners.

2. MACHINE LEARNING AND ARTIFICIAL INTELLIGENCE

Over the past several decades, the relationship between human input and computer input has been well explored. It even has a widely studied discipline known as human computer interaction or HCI. Human input happens through a variety of means including keyboards, mice, touch, ink, voice, and even Kinect skeletal tracking. Advancements in sensors and processing are giving rise to a new area of computer input from environments. The interaction between computers and environments is effectively environmental understanding, or perception. Environmental input captures things like a person's position in the world (e.g. head tracking), surfaces and boundaries (e.g. spatial mapping and spatial understanding), ambient lighting, environmental sound, object recognition, and location.

One of the top technologies that will affect BIM in near future is machine learning. Machine learning explores the study and construction of algorithms that can learn from and make predictions on data without being explicitly programmed. The increased roles of machine learning — in which algorithms are used to learn from and make predictions on data — and artificial intelligence (AI) are making waves for the construction industry.

Artificial Intelligence (AI) is the theory and development of computer systems able to perform tasks that normally require human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages. It is a branch of computer science dealing with the simulation of intelligent behavior in computers. It depends on the capability of a machine to imitate intelligent human behavior. It is first coined in 1955 (Merriam-Webster, 2018). Whereas human brains are naturally creative and great at pattern recognition, artificial intelligence can process information faster and simulate many outcomes based on an array of inputs.

2.1 New data sources and AI technologies

Virtual Reality (VR):
VR is the computer-generated simulation of a three-dimensional image or environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors. It is an a artificial environment which is experienced through sensory stimuli (such as sights and sounds) that is created with software and presented to the user in such a way that the user suspends belief and accepts it as a real one. It is first known use is in 1987(Merriam-Webster, 2018)..

VR replaces your view with a simulation in some way or another. In today's world, VR is found within headsets. The tools involve looking into a headset with lenses that look at a virtual screen. The virtual screen has a stereoscopic view which the eye adjusts to see as a 3D image. The headset tracks where you are looking and reflects those movements in the virtual display. Interaction is also possible with controllers of various types. VR aims to make you feel completely immersed in another world and blocks everything else out.

Augmented Reality (AR):
AR is the technology that superimposes a computer-generated image on a user's view of the real world, thus providing a composite view. It is an enhanced version of reality created by the use of technology to overlay digital information on an image of something being viewed through a device (such as a smartphone camera). It is first known use is in 1992 (Merriam-Webster, 2018).

AR is any sort of computer-based system that overlays data on top of your current view of the world, while continuing to let you see the world around you. It is more likely to be used regularly in day-to-day life. Technically, it does not need to be purely visual data either — you can augment reality with sound too. AR headsets overlay data, 3D objects and video into your vision. They do not need to do so in a way which necessarily makes them emulate real world objects.

Mixed Reality (MR):

MR is the merging of real and virtual worlds to produce new environments and visualizations where physical and digital objects co-exist and interact in real time. It takes place not only in the physical world or the virtual world, but is a mix of reality and virtual reality, encompassing both augmented reality and augmented virtuality (Milgram and Kishino, 1994) via immersive technology. MR is a form of AR that is somewhere between VR and AR. MR works towards integration of augmented reality with your perception of the real world with virtual objects that aim to look as if they are really placed within that world. It locks their position according to real world objects.

Virtual Fixtures platform developed at the U.S. Air Force's Armstrong Laboratories in the early 1990s is the first immersive mixed reality system, providing enveloping sight, sound, and touch. A *virtual fixture* is an overlay of augmented sensory information upon a user's perception of a real environment in order to improve human performance in both direct and remotely manipulated tasks. Developed in the early 1990's by Louis Rosenberg at the U.S. Air Force Research Laboratory (AFRL), virtual fixtures was a pioneering platform in virtual reality and augmented reality technologies. The term mixed reality was originally introduced in a 1994 paper by Paul Milgram and Fumio Kishino.

It is made possible by advancements in computer vision, graphical processing power, display technology, and input systems. MR headsets can do simpler augmented reality things, too — like showing notifications and simple data in a way that is locked to your display, rather than the world. It is the bringing of virtual objects in a more realistic way into the user's view that gets it into mixed reality territory. Some MR tools include eye tracking — potentially allowing for the headset to know where you are looking and adjust the view accordingly. The application of mixed reality goes beyond displays but also includes environmental input, spatial sound, and location.

The combination of computer processing, human input, and environmental input sets the opportunity to create true mixed reality experiences. Movement through the physical world can translate to movement in the digital world. Boundaries in the physical world can influence application experiences, such as game play, in the digital world. Without environmental input, experiences cannot blend between the physical and digital realities.

2.2 Use of BIM with AI and new technologies

VR with BIM: Presence

In a VR experience, the user is immersed in an environment completely detached from their physical surroundings, and there is minimal interaction between the real and virtual worlds. The user has total control over their virtual environment and is free to manipulate any element of it as they see fit (Viatechnik, 2018). The affordances of VR over traditional methods are practiced with scale, presence, design options and decisions by communicating with simple VR sketches.

AR with BIM: Utility

AR superimposes digital information within a user's field of vision. It is the integration of digital information with the user's environment in real time. Unlike VR, which creates a totally artificial environment, AR uses the existing environment and overlays new information on top of it.

MR with BIM: Flexibility

MR bridges the gap between the virtual and the physical worlds. Users can manipulate and interact with objects in both environments. The potential applications of MR tech in an AEC context are numerous. Mixed reality technologies enable AEC firms to leverage their growing data streams into increased construction worksite efficiency. MR ensures that everyone involved in executing a project plan remains on the same page throughout its entire lifecycle (Microsoft, 2018).

MR is particularly useful for

Technological advancement is what has enabled MR experiences. There are no devices today that can run experiences across the entire spectrum; however, Windows 10 provides a common mixed reality

platform for both device manufacturers and developers. Devices today can support a specific range within the mixed reality spectrum, and over time new devices should expand that range. In the future, holographic devices will become more immersive, and immersive devices will become more holographic. Often, it is best to think what type of experience an app or game developer wants to create. This model is shown in Figure 2.
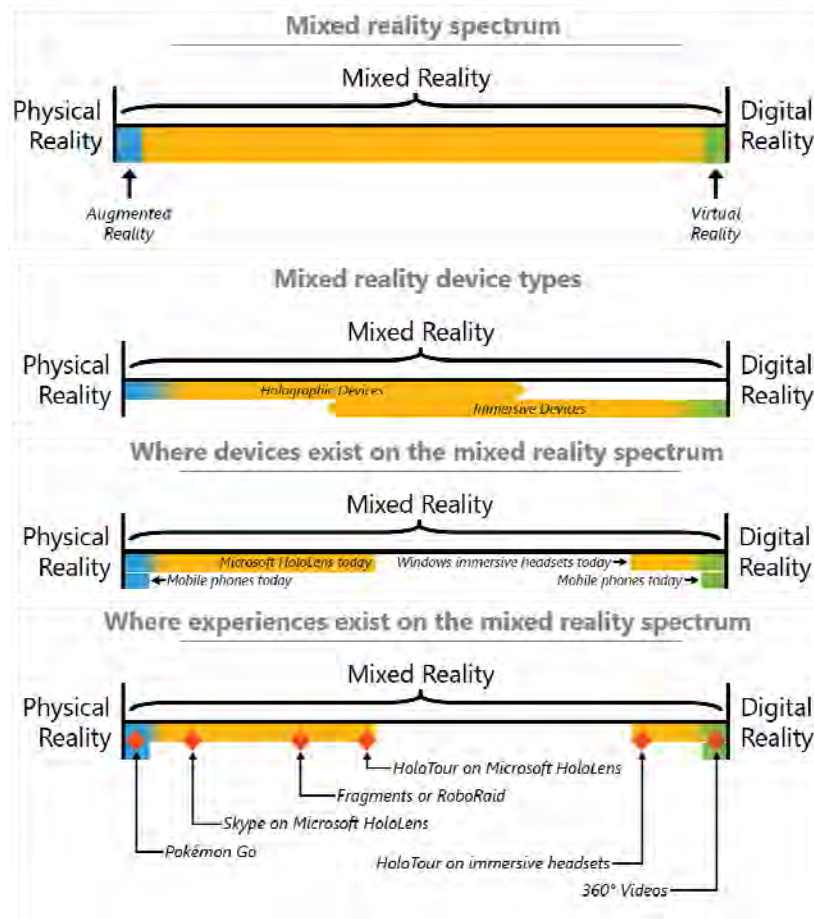

Figure 2: Mixed Reality Spectrum (Microsoft, 2018)

The energy issue plays an important role in the design and operation of buildings where careful long-term decisions can significantly improve the performance of buildings and thus reduce their consumption of energy. Building Energy Modeling (BEM) is a process in the design phase which one or more building energy simulation programs use properly adjusted Building Information Models (BIMs) to conduct energy assessments for the current building design. The core goal of BEM is to inspect building energy standard compatibility and seek opportunities to optimize proposed design to reduce structure's life-cycle costs.

New technologies, including Big Data, analytics, and artificial intelligence will make energy management, facilities maintenance and smart building solutions easier to use, manage and control than ever before. The best energy management system or smart building solution is only as good as its weakest link.

Visualization is the apparent means by which modern smart building solutions and managed services can present information in an easy-to-understand format for new and experienced facilities managers. Prediction of equipment failures with a third party collecting more information, the system itself grow smarter. This is artificial intelligence in facilities management. The system learns from past issues or successes and leverages analytics to determine the best course of action to attain the desired result.

3. BIM WITH AI IN CLASS PRACTICES

The increased use of BIM has brought about new roles such as the BIM specialist, manager, coordinator, leader, champion, trainer, consultant, expert, technologist, etc. The BIM professional's competency could cover technology, process, commercial, and personal skills. Those skills define the professional's role depending on the entry conditions into the construction industry and the qualifications and background of the professional.

The Department of Civil, Architectural and Environmental Engineering incorporated BIM into its curriculum through the introduction of three course offerings: (1) EG 430 -Introduction to BIM, the senior level elective in the Engineering Graphics Program; (2) CAE 573 - Construction Management with BIM, a graduate level elective in the Construction Engineering and Management Program; and (3) CAE 515 – Building Energy Modeling.

The BIM Learning Modules created for Department of CAEE at IIT targets improving BIM software skills (ability to create, understand and interpret building information models), for whole life cycle processes, respectively collaborating and coordinating with models; and, performance modeling and optimizing the design and use in an integrated-communication environment, and stimulating students' interaction with BIM professionals. Gaining the momentum of three different BIM learning modules, this program helps students to understand the plurality in the construction professions.

3.1 Experiential Learning

BIM Learning modules are planned and created to cover the abilities and deliverables expected from or realized by the students (as future design and construction professionals), organizations and projects when using BIM tools and workflows. These modules are based on the experiential learning which is defined by Felicia (2011) as the process of learning through experience, and is more specifically defined as "learning through reflection on doing". Early in the 1970s, the theory was proposed by David Kolb who was influenced by the work of other theorists including John Dewey, Kurt Lewin, and Jean Piaget.

The experiential approach adopted to BIM-enabled learning (1) allows the students to experience a BIM learning modules namely collaboration module, coordination module and performance and optimization module; and (2) helps them to learn how BIM and BEM tools and Building Performance Analysis (BPA) methods integrate with each other.

Experiences in integrating BIM in terms of learning by doing into a graduate and undergraduate level courses and an undergraduate immersive research program at IIT are briefly presented and discussed through AI knowledge and practice including *hands on lab-sessions* and activities by industry support.

3.2 BIM Learning Modules with AI

Collaboration Module

The primary competencies AI can be practiced in Collaboration Module include: (1) design review, (2) design authoring, (3) structural analysis, (4) MEP engineering analysis, and (5) energy analysis. In addition to those primary knowledge areas secondary competencies such as (1) phase planning, (2) quantity take-off and cost estimation, (3) sustainability evaluation, (4) existing conditions modeling, and (5) code validation can be considered.

Coordination Module

The primary competencies AI can be practiced in Coordination Module include: (1) 3D coordination, (2) phase planning, (3) cost estimation, (4) site utilization planning, and (5) 3D control and planning. In addition to those primary knowledge areas secondary competencies such as (1) field / space manage tracking, (2) record modeling and its use in facility management, (3) sustainability evaluation, (4) existing conditions modeling, and (5) digital fabrication can be considered.

Performance and Optimization Module

The primary competencies AI can be practiced in Performance and Optimization Module include: (1) Sustainable Design and Building Life Cycle, (2) Energy Analysis Models/EAMs and Simulation, (3) Building Science and Equations of Modeling, (4) Software and Tool Selection, (5) Environmental Strategies and Baselines, (6) Building Components Performance, (7) Building Energy Systems Optimization: and (8) Simulation Comparisons and Interpretations. In addition to those primary knowledge areas secondary competencies such as (1) Resilient Design Strategies, (2) Facility Management, Sustainability and Enabling Technologies, (3) Sustainability Evaluation, and (4) Existing Conditions Modeling can be considered.

3.3 Hands on lab-session

Danielle Dy Buncio, President/CEO of VIATechnik, talked about BIM, VDC (Virtual Design and Construction) and VR (Virtual Reality) projects during a workshop session of Construction Management with BIM (CAE573) course at Illinois Institute of Technology (IIT). Armour College of Enginering studens enjoyed practicing VR technologies in class in Summer 2017. Another session which is shown in Figure 3 is held in Introduction to BIM (EG430) course in Spring 2017.

Figure 3: VR experience and presentation, by Anton Dy Buncio, and Cansu Donmez, VIaTechnic, 2017.

Feedbacks shared after the sessions are very helpful for future directions of adoption of AI skills to the BIM curriculum. One of the students of CAE573 stated that:

"I believe having Danielle Buncio to our class to present VR uses in the construction fields was a very beneficial experience to many students. While I have had some experience with VR in the past, it was nice to be able to hear about the real benefits it proposes to the future of the construction industry. While it is clear that VR and BIM require very different models in consideration of the information that lies within them, it was very interesting to see how directly these models can still correlate in regards to the same project.

Thank you Danielle for your informative and fun presentation. It is great to see entrepreneurs like yourself striving to bring progress to an industry with one of the slowest rates of technological advancement. I believe once the industry starts to see and understand the benefits of these technologies, it will not only provide huge benefits to clients and design/construction companies alike, bit will increase the rate of technological advancement in the entire industry." Samuel Pavlovcik, ALA, NCARB

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4. CONCLUSIONS AND FUTURE WORK

As the industry continues to digitalize, data-driven, reality-altering technologies provide paradigm-shifting in and transmogrified reality functions and, by many indications, pay for themselves rather quickly. This is the future of construction, and it's those AEC firms who are willing to embrace change and innovation that are ultimately going to win out in the end. This also means that there is a need to think creatively about training and recruiting – the skills and backgrounds that made a great construction manager yesterday will be vastly different by 2020.

The AEC industry is on a precipice of change, and in order to truly forge ahead we need the ideas and energy of the next generation. A key challenge is attracting and retaining talent in an industry that has been historically slow to change and adapt new technology. There is a need to establish and improve BIM knowledge, skills and experience of current engineering professionals. To sustain the momentum of BIM, effective workforce development that aims to balance the supply-demand equation in the labor market is essential. For many, experience with BIM begins in academia. The challenges reside in the classic gap between academic focus on disciplinary principles and the industry needs for specific application proficiency.

An academic framework informed by BIM research, BIM professionals and other industry stakeholders is a prerequisite for delivering BIM education in universities. The rising market demand for competent BIM professionals would eventually force companies to adjust their recruiting practices through enhanced and more proactive collaboration with BIM educators. Critical steps to be taken via an academia industry partnership for a continuity to improve BIM education in universities with more direct input of established BIM professionals to bridge the gaps between theory and empirical experience.

Advanced training of current workforce through competency and skill based programs leads to mastery and performance improvement. Furthermore, a safer industry attracts more workforce. The IIT strategy relative to BIM by using the learning modules approach is successful and expected to help architecture, engineering, and construction professionals to be prepared for the needs of the industry in the future. Efforts should continue and expand to provide exposure, skills and opportunity to students.

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NET-ZERO AND BIM: THE CURRENT STATE AND FUTURE NEEDS

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ABSTRACT

The construction of buildings consumes enormous amounts of energy, clean water, and materials. Improving the ways buildings are designed, built, operated, renovated, and recycled can significantly reduce the use of resources. To address this issue, a number of sustainability initiatives have been adopted. The term "green building" came into use in the 1990s, but the practice of sustainability in the building construction industry can be traced back much further in time. In recent years, the topic of "net-zero energy building" has drawn increased attention as a measure to counter the negative impacts the building construction industry is creating in terms of energy consumption and greenhouse gas emissions. With the goal of net-zero energy for all new Federal buildings by 2030, Net-Zero has become a part of the United States policies on energy efficiency in buildings. On the other hand, the emergence of BIM as a design and visualization tool is considered as an important addition to the construction industry. BIM digitally represents physical and functional characteristics of a facility, acts as a shared knowledge resource, hence form a reliable basis for decisions during the life-cycle of a facility.

Based on literature review, this paper evaluates the current state of both green building and net-zero building, as well as their criteria. The different approaches for net-zero building are detailed in this paper. The role of BIM in attaining the net-zero goals is discussed to identify future needs in this field. In addition, this paper discusses the inclusion of net-zero in curriculum to ensure graduates are prepared with the knowledge and skills necessary for net-zero projects. Hence the paper provides a useful reference for both industry practitioners and academics.

Keywords: Net-Zero, green building, BIM, curriculum

1. INTRODUCTION

The construction industry has both positive and negative social, environmental, and economic impacts on society. The industry provides buildings and facilities to satisfy human needs, and plays a vital role in urbanization (Zuo & Zhao, 2014). It contributes toward the national economy by creating direct and indirect employment opportunities. The United States (U.S.) construction sector contributed 4.2% to the gross domestic product (GDP) in 2016 (U.S. Bureau of Economic Analysis, 2017), and added 214,000 jobs in the same year (U.S. Bureau of Labor Statistics, 2017). The negative impacts of the construction industry are also well documented. In 2016, about 40% of total U.S. energy consumption was consumed by the residential and commercial buildings (U.S. Energy Information Administration [EIA], 2017). Besides that, buildings produce greenhouse gas (GHG) emissions which are responsible for global warming. Nearly 40% of GHG emissions are caused by design, construction, and operation of buildings (Whole Building Design Guide [WBDG], 2016). To mitigate negative impacts of building on the environment, green building standards, certifications, and rating systems have been developed in 1990s aimed at promoting sustainable design (WBDG, 2016).

While sustainability and green are often used interchangeably, both terms are about more than just reducing environmental impacts (Green Building and LEED Core Concepts Guide, 2011). Initially green buildings were intended to reduce the negative impacts on the environment caused by the building industry. Gradually the green building movement aspired to create more healthy places and support quality of life for all. At present, green building strives toward "net-zero" by consuming less resources than they can produce (Green Building and LEED Core Concepts Guide, 2011). There are several sustainable building rating systems to examine the performance of a building, such as, Leadership in Energy and Environmental Design (LEED).

Building Information Modeling (BIM) is being used to provide data for energy performance and sustainability assessment, and the leading design and construction organizations are adopting BIM to enable integrated design, construction and maintenance towards Net-Zero Energy buildings (Maltese, Tagliabue, Cecconi, Pasini, Manfren, & Ciribini, 2017). BIM identifies options to optimize building energy efficiency during the life cycle, hence can provide information to support the calculation of credit points related to rating systems (Maltese et al., 2017).

This paper aims to review the various aspects of green and net-zero buildings, and the role of BIM to highlight the state of art and future needs in this field. In addition to the review, this paper seeks to raise awareness and start a dialogue about inclusion of net-zero in curriculum to ensure graduates are prepared with the knowledge and skills necessary to perform the preconstruction and construction activities for net-zero projects. The paper also provides a useful reference for both industry practitioners and academics who are interested in the application of BIM in attaining the net-zero goals.

2. LITERATURE REVIEW

2.1 Green Building

The term green building is often used interchangeably with the term sustainable building or high-performance building. When defining "green building", the U.S. Environmental Protection Agency (EPA, 2016) emphasizes environmentally responsible and resource-efficient processes throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation and deconstruction, which complements economy, utility, durability, and comfort. Kibert (2016) defines resource efficiency in a design as it relates to the building's high level of energy and water efficiency; appropriate use of land and landscaping; the use of environmentally friendly materials; and minimizing the life-cycle effects of the building's operation. However, many of the green building elements are not new or unique. Historically, builders were familiar with the passive design principles, e.g., capturing sunlight for natural lighting, and wind for heating and cooling long before the initiation of "green building" (Green Building and LEED Core Concepts Guide, 2011).

There are several sustainability assessment methods for buildings. Among them, Building Research Establishment Environmental Assessment Method (BREEAM) is the first ever rating system, published in the United Kingdom (UK) in 1990 (WBDG, 2016). BREEAM covers most types of construction currently in use, and assesses energy, transport, water use, material, waste, land use and ecology, pollution and innovation, internal environment (i.e., health and wellbeing), and management processes of a building using weighted coefficients assigned respectively to each criteria (Chen, Yang, & Lu, 2015). In 2000, the U.S. Green Building Council (USGBC) developed green building criteria, LEED rating system, initially for new construction (WBDG, 2016). Soon it gained prominence and later included rating systems for existing buildings and entire neighborhoods. LEED is applicable for construction, operation, and maintenance work. It assesses the performance in integrative process, location and transportation, sustainable sites, water efficiency, energy and atmosphere, material and resources, indoor environmental quality, innovation in design, and regional priority through a set of prerequisites and credits (Chen et al., 2015).

Both BREEAM and LEED inspired the development of other rating systems which are tailored to their own context, and some of them expand their scope to address more recent developments in sustainability such as net-zero energy. The basic structures of these assessment tools are similar to a large extent in terms

of covering various aspects of sustainability, a number of credits allotted to each category, and different rating tools for different types of projects (Zuo & Zhao, 2014).

2.2 Net-Zero Energy Building

As previously mentioned, the building industry is a major energy consumer (40%) in the U.S. (EIA 2017). However, this energy consumption can be significantly reduced by incorporating energy-efficient approaches into the design, construction, and operation of buildings (WBDG 2016). Dependence on fossil fuel can also be reduced by introducing on-site and off-site renewable energy sources. Executive order 13514 (EO 13514) titled "Federal Leadership in Environmental, Energy, and Economic Performance" was issued in October 2009 and requires all new federal buildings from 2020 and thereafter be designed to achieve zero-net-energy by 2030. The goal was to establish a cohesive approach towards sustainability and to prioritize GHG emissions reduction for federal agencies (WBDG 2016). Zero Energy Building (ZEB) is defined as an energy-efficient building where the actual annual consumed energy is less than or equal to the on-site produced renewable energy, and which is typically grid-connected to transfer any surplus of on-site renewable energy to other users (U.S. Department of Energy [DOE] 2015). However, a new Executive Order (EO 13693) "Planning for Federal Sustainability in the Next Decade" was issued on 19 March 2015 which expanded the requirements established by EO 13514 (EPA 2017). It proposes to cut GHG emissions 40% over the next decade from 2008 levels and increase the share of electricity the federal government consumes from renewable sources to 30% (EPA 2017). Starting in 2020 Executive Order 13693 requires that all new construction of federal buildings greater than 5,000 gross square feet achieve energy net-zero and, and where feasible water or waste net-zero, by fiscal year 2030 (Implementing Instructions for Executive Order 13693 [IIEO] 2015). This requirement is similar to that of EO 13514. However, the 5,000 gross square feet limitation is new, as is the water or waste net-zero aspirational goal (IIEO 2015).

2.2.1 Approaches for net-zero energy building

According to IIEO (2015), strategies for the design, construction, and operation of net-zero buildings should take an integrative, whole building perspective to identify innovative approaches rather than a step-by-step traditional system, and these strategies should be initiated at the early stage of planning to maximize cost-efficiencies and chances for success. The net-zero building will ensure that the actual annual source energy consumption is balanced by on-site renewable energy (IIEO 2015). Following approaches for net-zero energy buildings have been outlined by IIEO (2015):

- A combination of minimizing energy use and implementing renewable energy strategies.
- Energy modeling and energy use targets during design process to stretch thinking.
- Not to oversize primary mechanical systems.
- Energy recovery and cogeneration (combined heat and power [CHP]) possibilities).
- Alternative strategies for building design such as solar (photovoltaic), wind, solar hot water, solar ventilation preheating, ground sources heat pump, biomass/waste to energy, and geothermal. The alternative energy only can be used when its fuel stock is renewable or it is a CHP facility that displaces conventional fuel.
- Pre-occupancy commissioning and monitoring the first 12 months of building operations.

2.2.2 Approaches for net-zero water building

The net-zero water building goal is to reduce total water consumption and return the equivalent amount of consumed water, including municipal supply, to the same watershed without compromising groundwater and surface water quantity or quality (IIEO 2015). IIEO (2015) outlined the following approaches for net-zero water buildings:

- Limit the consumption of freshwater resources.
- Return water to the same watershed by not depleting groundwater and surface water.

- Perform water balance assessments of building systems during design to identify unnecessary water uses.
- Implement water conserving approaches.
- Consider rainwater harvesting and alternative water sources (including recycling and reuse of water).
- Meet lower quality water needs with lower quality water supply (use lightly treated rainwater and tertiary treated wastewater for flushing toilets).

2.2.3 Approaches for net-zero waste building

The target for net-zero waste building is to "reduce, reuse, recycle, compost, or recover solid waste streams (except for hazardous and medical waste) thereby resulting in zero waste disposal" (IIEO 2015). According to IIEO (2015), some of the approaches for net-zero waste buildings are:
- Reduce the amount of solid waste generated, and reuse or re-purpose when possible.
- Maximize recycling opportunities.
- Use composting for organic materials.
- Design to provide water supply/drainage as necessary to maintain cleanliness in compostable holding container areas.
- Consider waste to energy to eliminate waste.

2.2.4 Criteria/Metrics for Net Zero Buildings

The certification process of a net-zero energy building (NZEB) can be done by using the structure of the Living Building Challenge, managed by International Living Future Institute (ILFI), which is a performance based standard and can be applied to any building type, includes landscape and infrastructure projects, partial renovations and complete building renewals, new building construction, neighborhood, campus and community design (WBDG, 2016). This certification requires 12 consecutive months of zero energy performance for a project, without the use of onsite combustion (International Living Future Institute [ILFI], 2017). The performance areas include site, water, energy, materials, health, equity, and beauty. The additional requirement for NZEB is that the project's energy needs must be fulfilled completely by on-site renewable energy on a net annual basis (WBDG, 2016). According to ILFI (2017), it formed a partnership with the New Buildings Institute (NBI) to streamline the certification process and database for NZEB. Within this partnership, ILFI will continue to administer the certification, while NBI will act as lead certification auditor as well as administer the database (ILFI, 2017). Table 1 provides a summary of the green building rating/certification systems discussed in this section.

Building Rating/Certification System	Type of Standard/Certification	Issues/Areas of Focus
BREEAM (United Kingdom)	Certification system is a multi-tiered process with pre-assessment, third-party consultant guidance through an assessment organization for new construction, communities, in use buildings and EcoHomes.	Assessment uses recognized measures of performance, which are set against established benchmarks in energy and water use, internal environment (health and well-being), pollution, transport, materials, waste, ecology, and management processes.
Leadership in Energy and Environmental Design (LEED)	Green building rating and certification system through independent third-party verification for New Construction,	Performance in sustainable sites, water efficiency, energy & atmosphere, materials &

(United States)	Existing Buildings Operations & Maintenance, Commercial Interiors, Core & Shell, Schools, Retail, Healthcare, Homes, Neighborhood Development.	resources, indoor environmental quality, locations & linkages, awareness & education, innovation in design, regional priority through a set of prerequisites and credits.
NZEB	Certification program using the structure of the Living Building Challenge which can be applied to any building type.	One hundred percent of the project's energy needs must be supplied by on-site renewable energy on a net annual basis, without the use of on-site combustion.

Table 1: Summary of Assessment Tools (Portalatin et al., 2015; WBDG, 2016)

2.3 BIM for Net Zero

BIM digitally represents the physical and functional characteristics of a facility, acts as a shared knowledge resource, or process for sharing information, hence forms a reliable basis for decisions during the life-cycle of a facility (Suermann & Issa 2009). BIM began as an object-oriented building product model in the 1990s to compensate the weaknesses of computer-aided drafting (CAD) software by enabling the form, function, and behavior of building systems and components to be modeled (Sacks, Eastman, & Lee, 2004). BIM is now being used for many different purposes in construction projects, including visualization, fabrication/shop drawings, code reviews, energy simulations, design validation, option analysis, forensic analysis, facilities management, cost estimation, construction sequencing, and constructability reviews, conflict, interface, and collision detection (Ahn, Cho, & Lee, 2013).

Challenges and problems affecting all aspects of construction are being addressed by the adoption of many emerging and fast-growing innovations, chief among which is a variety of sustainability initiatives. As multi-disciplinary information can be integrated in one model through BIM, it creates an opportunity for sustainability measures to be incorporated (Azhar, Carlton, Olsen, & Ahmad, 2011). Generally, a construction project goes through three major phases within its lifecycle, e.g., design, construction, and maintenance and operation. At the initial stage of this lifecycle, authoring tools offer the opportunity to simulate the performance of a building before it is constructed by evaluating different types of materials that could be used in the project, and then choose the best one that meets the criteria (Msawealfi, 2010).

The advantage of BIM is that it links variables, dimensions, and materials to the virtual geometry of the building in a way that when an input or simulation value changes, the model automatically updates all life-cycle scenarios and components simultaneously (Spiegelhalter, 2012). According to Haynes (2009), if the parameters, e.g., variables, dimensions, and materials, are fully integrated within the design process in a BIM platform, most data needed to support design decisions and relevant performance analysis can be obtained automatically as the design proceeds. As a result, a multitude of 'what-if' scenarios and their sustainable alternatives can be evaluated at the early stage, when they are most beneficial in terms of sustainability and cost effectiveness (Haynes 2009).

Now, the major challenge for the construction professionals is to effectively use BIM parametric modeling in reaching the net-zero goals during the lifecycle, i.e., designing, constructing, operating, and monitoring of net-zero energy buildings (NZEB). According to Spiegelhalter (2012), integration of parametric model of NZEB with an integrated design-project delivery process should be done in a logical and systematic way, based on their very specific climate, economic and social-cultural indicators, so that the BIM model can keep track of the various parameters and life-cycle scenarios. Generally, achieving NZEB requires two major tasks to be done: 1) reduce energy demand by incorporating energy efficiency measures, and 2) generate electricity or other renewable energy to achieve the balance. Additionally, other building rating systems, indicators and performance-monitoring infrastructures, such as LEED or

BREAAM, can be incorporated to add qualified information on the overall sustainability performance of an NZEB (Spiegelhalter 2012).

2.4 Net-Zero, BIM, and Construction Education

As a result of net-zero and other sustainability initiatives gaining importance in the construction industry, sustainability is increasingly being emphasized in construction education. In architecture, engineering and construction (AEC) education, great effort has been made toward incorporating sustainability into existing or new courses (Becerik-Gerber et al. 2011). However, the cross-disciplinary nature of energy-efficient building design has created many challenges. One of the challenges is making students quantitatively understand how different building designs affect a building's energy performance, as concept-based instructional methods fall short in evaluating the impact of different design choices on a buildings' energy consumption (Shen, Jensen, Wentz, & Fischer, 2012). According to Shen et al. (2012), BIM with energy performance software provides a feasible tool to evaluate building design parameters by combining 3D visualization of the structure with energy performance analysis without requiring detailed mathematical calculations.

To prepare students for a future career in net-zero construction industry, an interdisciplinary approach is needed throughout the AEC higher education disciplines (Novak & Monson, 2013). Project-based learning has been proposed to supplement concept-based learning methods by many engineering educators and practitioners (Lima, Carvalho, Assunção Flores, & Van Hattum-Janssen, 2007), where actual projects are given to students with realistic imprecise problems similar to what they will encounter in real-world situations (Jonassen 1997). Students usually learn about mechanical systems and their performance characteristics in dedicated mechanical, electrical, and plumbing (MEP) lecture courses. These MEP courses include basic scientific concepts that aids in designing mechanical systems, like, climate, solar heating, thermal resistance, energy transfer, etc. (Novak & Monson, 2013). Besides that, some construction programs include specific coursework in environmental science. BIM is increasingly being incorporated in these MEP and stand-alone sustainability courses.

In a 2011 survey of AEC educational programs, the highest level of adoption of BIM and sustainability courses was identified within architecture, with lesser adoption levels in engineering and construction (Becerik-Gerber, et al., 2011). It was also found that, inclusion of energy modeling in architecture programs is 30-50%, 20-30% in the construction management programs, and less than 10% in the engineering education (Novak & Monson, 2013). Thus, the architectural programs are more advanced in incorporating the energy modeling tools in their curriculum than construction or engineering education. According to Novak and Monson (2013), "having the skills to use and understand energy analysis software as it relates to schematic BIM models could be incorporated into coursework issues of constructability, jobsite management, monitoring and control methodologies, as well as building commissioning and operations". Since the value creation in these activities all intersect with those of building design, the interdisciplinary thinking must be learned in order to engage them (Novak & Monson, 2013).

3. DISCUSSION AND CONCLUSION

While the practice of creating green buildings is not new, net-zero projects are yet a fraction of total new construction, but their numbers are increasing. A recent net-zero report revealed the existence of 332 verified or anticipated net-zero buildings in the United States and Canada at the end of 2016 (Hill, 2017). In this context, incorporating the concepts of net-zero in construction education is becoming a necessity to increase the students' knowledge that is required to make them more competent professionals in this area. One initiative is to integrate sustainable design analysis (SDA) parameters with BIM, so that BIM can be used as a tool to attain the sustainable built environment (Ceranic, Latham, & Dean, 2015). In recent times, BIM has become an important tool within the construction industry as the stakeholders are now more aware of the impact BIM can make in increasing the level of integration and collaboration across the various disciplines (BIM Essential Guide, 2013). However, academic research is lagging behind industry as far as

generating new knowledge for BIM-driven integrated practices (Forgues & Becerik-Gerber, 2013). To satisfy the industry demand for professionals with BIM knowledge, some universities have started to integrate BIM into AEC programs (Becerik-Gerber, Gerber, & Ku, 2011).

Most universities have struggled with BIM integration to find a common understanding of what knowledge and skills are needed in the industry (Sacks & Pikas, 2013). In 2017, the Academic Interoperability Coalition (AiC) published the BIM Body of Knowledge (Wu, Mayo, McCuen, Issa, & Smith, 2017) based on the findings from a Delphi Study in which an international group of panelists from the Architecture/Engineering/Construction/Owner/Operator (AECOO) industry participated. Panelists were professionals representing a variety of industry roles, including engineer, project manager, architect, and facility manager. Findings from the study are reported by:

- Level of implementation (i.e. plan it, coordinate it, manage it, do it)
- Role of user (i.e. designer, contractor, facility manager/operator, and consultant/specialist)
- Level of performance for organization and project (i.e. entry, middle, full)
- Type of knowledge (i.e. life cycle assessment, standards compliance checking, estimating, etc.)

As the demand for more BIM-competent workforce continues to grow, the BIM Body of Knowledge (BOK) (2017) provides educators with the big picture of BIM competency as defined by the construction industry. The BIM BOK recommends educators using a backward design model for BIM curriculum development and the utilization of findings in the BIM BOK to align student learning outcomes with career-specific BIM competencies desired by industry partners. The BIM BOK provides a valuable reference for pedagogy design to integrate BIM for net-zero building analysis and construction based on empirical evidence. Learning the knowledge and skills necessary to use BIM for net-zero building will prove valuable for both the student and the construction education community.

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