IMPLEMENTATION OF BUILDING INFORMATION MODELING (BIM) INTO EXISTING ARCHITECTURE AND CONSTRUCTION EDUCATIONAL CURRICULUM

By

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A THESIS PRESENTED TO THE GRADUATE SCHOOL OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN BUILDING CONSTRUCTION

UNIVERSITY OF FLORIDA

2011
To Professor Kontaridis
να εύχεσαι νά ’ναι μακρύς ο δρόμος
ACKNOWLEDGMENTS

I would like to thank Dr. Svetlana Olbina and Dr. Raymond Issa. I can only think it rare that one finds such warmth and guidance under one roof. I also wish to thank Dr. Jimmie Hinze for his guidance throughout the research process.
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<td>ACCE</td>
<td>American Council for Construction Education</td>
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<tr>
<td>AEC</td>
<td>Architecture/ Engineering/ Construction</td>
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<tr>
<td>ASCA</td>
<td>Association of Collegiate Schools of Architecture</td>
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<td>BIM</td>
<td>Building information modeling</td>
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<td>CHEA</td>
<td>Council for Higher Education Accreditation</td>
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<td>FM</td>
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<td>Mechanical/ Electrical/ Plumbing</td>
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<td>National Building Information Modeling Standards</td>
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The benefits of building information modeling (BIM) to the construction industry are limitless when compared to the traditional approach to design and construction. The opportunities for advancement in BIM software are continuously expanding as new technologies are discovered. BIM skills are in high demand, and many construction and architecture schools are responding to this demand by restructuring existing educational curriculum to incorporate BIM technologies. To properly equip students with the skills demanded by the design and construction communities, many schools are introducing BIM within their coursework and new faculty selections are also being made in terms of their skills in BIM as a response to industry demands and future needs of the construction industry.

The objective of this research was to determine the degree of current implementation of BIM into existing architecture and construction educational curriculum. This research would provide a point of reference to the construction industry and educators to evaluate the current implementation of BIM and to identify trends in the teaching of BIM in construction education as well as in the related field of...
architecture. The research was undertaken to characterize the extent and nature of the use of BIM in university programs in the United States. Research included a literature review about BIM, outlining its history and benefits and identifying industry demand and challenges in adopting BIM.

A survey of the implementation of Building Information Modeling (BIM) into existing architecture and construction curriculum was developed and sent to construction and architecture schools in the United States. The survey collected data from schools across the country regarding the degree of integration of BIM into existing curriculum, including information about the size of the schools surveyed, the degree of focus on BIM, types and amount of BIM coursework offered, BIM estimating and scheduling software used, the number and background of faculty teaching BIM, and finally, the schools’ BIM teaching philosophy and expectations, including goals in regard to the students’ target level of BIM knowledge upon graduation.

This research indicated that both architecture and construction schools have an interest in or have already transitioned to implementing BIM within curriculum. This research also found that the majority of the schools expect students to have some knowledge of BIM upon graduation. The majority of the schools perceived BIM as important to industry demand and planned to fully integrate BIM into their curriculum. A comparison of architecture and construction schools also provided results gauging the level of interest and implementation in each field. The survey found that more architecture than construction schools had implemented BIM into curriculum, and, while more construction schools implemented BIM at the freshman level, more architecture schools implemented BIM at the graduate level. Construction schools were also more
likely to use 4D models in teaching construction scheduling and 5D models in teaching construction estimating when compared to architecture schools.
CHAPTER 1
INTRODUCTION

Introduction

Ten years ago, “BIM” was not a common utterance among those in the construction industry. Today, however, BIM, or building information modeling, is the modeling tool of choice in many leading design and construction companies. The technology behind BIM has rapidly advanced and has become more convenient and adaptable for companies to utilize. Five years ago, BIM was not as well-understood as a concept as it is today. This may partly be due to the fact that BIM is an ever-evolving concept, as the boundaries of BIM's capabilities continue to expand as technological advances are made.

The benefits that BIM brings to the construction industry are ever-evolving and improving. As integrated project delivery (the early collaboration of design, fabrication, and construction of a project) becomes more popular, the demand for building information modeling, or BIM, is steadily growing. BIM skills are in high demand, and many construction and architecture schools are responding to this demand by restructuring existing educational curriculum to incorporate BIM technologies. Many architecture and construction schools are beginning to integrate BIM into the existing framework of courses offered. To properly equip students with the skills demanded by the construction industry, many schools are introducing BIM within their coursework and making new faculty selections based on BIM skills as a response to industry demands and future needs of the construction industry.
Problem Statement
The extent that BIM has been incorporated in the curricula of university architecture and construction programs in the United States has not been fully determined to date. This information could be helpful to serve as a guide both to the industry and to schools as to the current state of BIM education.

Research Objectives
The objective of this research was to determine the degree of current implementation of BIM in architecture and construction education. This research would provide a point of reference to the construction industry to evaluate the current implementation of BIM and to identify trends in the teaching of BIM in construction education as well as in the related field of architecture. This research also sought to identify the architecture and construction schools that have successfully integrated classes on BIM technologies into their existing educational curriculum and how and in which courses each has transitioned to incorporate BIM technologies. This research also aimed to collect data regarding the size and type of each school, the degree of focus on BIM, types and amount of BIM coursework offered, BIM-specific and scheduling software used, number and background of faculty teaching BIM, and finally, the schools’ goals in regard to the students’ target level of BIM knowledge upon graduation. In summary, the research results were to characterize the extent and nature of the use of BIM in university programs in the United States.
CHAPTER 2
LITERATURE REVIEW

Overview
This literature review consists of four sections regarding the implementation of building information modeling (BIM) into existing architecture, engineering, and construction curriculum. The first section of this literature review attempts to define BIM and its applications, while the second section focuses on the history of BIM in the architecture, engineering, construction (AEC) industry. The third section presents the advantages of BIM to owners, architects, engineers, and contractors. The fourth section describes industry demand and the challenges associated with adopting BIM, while the fifth and final section describes BIM in education and notes several accrediting agencies.

What is BIM?

The National Building Information Model Standard (NBIMS) defines BIM as a shared informational resource which digitally represents the physical and functional characteristics of a building and allows for reliable decision-making throughout the building’s life cycle (NIBS 2007). BIM uses consistent and coordinated data for a project throughout its design and construction. Today, BIM has become common knowledge in the construction industry. One manufacturer of BIM software, ArchiCAD, describes BIM as a “single repository” of both graphical and non-graphical documents while another manufacturer, Bentley, describes BIM as modeling both graphical and non-graphical aspects of a building throughout its life with and with the use of a database (Eastman, 2009).
So, what exactly is BIM? Building information modeling is the creation and use of coordinated, consistent, computable information about a building project in design, information used for design decision making, production of high-quality construction documents, predicting building performance, cost estimating, construction planning, and, eventually, for managing and operating the facility (Krygiel and Nies, 2008). As BIM functions parametrically, objects within the model need to be defined only once (in other words, in only one view), as all views are extracted from a singular building model as described in the various manufacturers’ definitions of BIM. Each view is then consistent in size, specification, and location, reducing errors in the drawing and presentation process due simply to errors in drawings (Eastman 2009). To clarify, BIM allows for a project to embody all dimensions, such that any changes to the model will simultaneously affect all other views of the project. It is precisely this ability to function parametrically which distinguishes BIM from the commonly-known two and three-dimensional computer-aided design (CAD). CAD presents information about a project in strictly two and three-dimensions, i.e., plans, sections, elevations, details, and so on are presented independently of each other and are not linked to scheduling or estimating databases, necessitating corrections to each view (or drawing and information) each and every time a change is needed. This frequent and necessary process of consistently updating each view of the project increases the chance of error and is time-consuming. BIM, however, corrects this inefficiency through its parametric capabilities and facilitates design and schematics all the way down to project completion and continued operation, maintenance and facilities management throughout a building’s usable life (Thomson and Miner 2006).
Also, the parametric capability of BIM allows data to be stored and linked to objects within the model. Objects built into BIM carry a specified geometry, type, and other relationships or attributes. Objects built into BIM are unique in that the objects carry all necessary and related information, limited not merely to its physical shape but to its function and life cycle as well. Objects built into BIM are often called “smart objects” as they do not merely serve as physical placeholders; rather they are as if a set of information and instructions, attached to all necessary data such as supplier information and even maintenance procedures. BIM’s capability to embed various data within objects offers a dynamic platform on which “multiple groups in different locations” can work and collaborate on projects (Thomson and Miner 2006).

The Construction Management Association of America defines BIM as the coordinated use of digital information for a building project. The digital information may consist of costs, schedules and 3D models (Egan 2008). The coordinated use of such information has made BIM a valuable tool in both the commercial and government sectors. The United States General Service Administration (GSA) defines BIM as an object-based and data-rich parametric digital representation of a project. Users can then extract views which can provide feedback and can improve project design (OCA 2006). The GSA has been working with BIM manufacturers in an effort to ensure that the design and construction industry are prepared to comply with current GSA requirements, and describes such requirements for creating building information models with specific properties and object types (OCA 2007).

It is necessary to distinguish the difference between what is meant by two-dimensional (2D) modeling, three-dimensional (3D) modeling, and four-dimensional
(4D) modeling, or BIM. Two-dimensional modeling is based on the x and y axis, while three-dimensional modeling incorporates also the z axis, or depth. In this research, the term “two-dimensional” is meant to describe an approach to producing drawings which is without 3D modeling capabilities and also cannot carry with it information of, for example, time, structure, or materiality as does a building information model. BIM, however, carries with it these added informational dimensions. For example, the addition of time to the model creates a building information model, as the model not only serves as a spaceholder physically (in the x, y, and z axes), but also is attached to information regarding time, allowing instant simulation of the construction of a project, all while functioning parametrically and updating as changes are made (Eastman 2009).

BIM takes a multi-dimensional approach, allowing the building team to see how the pieces of their project fit together in real time (McFarlane 2008). A 3-D model is created in BIM and dimensions of scheduling and cost are embedded in each object in the model. Dimensions of cost and scheduling are able to be incorporated through the BIM’s capability to link several databases to a single model, allowing one model to carry with it all necessary information about the project, refining the design process and allowing users to catch errors early as the BIM model is in essence a virtual version of the entire actual project. The model can also easily create space calculations as well as analyze energy efficiency (Sabongi 2009). BIM offers a database which is “the truth” at any moment in time, is reliable, and encourages collaboration (McGraw-Hill 2008).

**BIM Software**

Some of the major manufacturers of BIM are Bentley, Graphisoft, VICO, VectorWorks, and Autodesk. Various BIM software available includes Bentley Architecture / Structural / Building Electrical / Building Mechanical Systems, Graphisoft
ArchiCAD, VectorWorks ARCHITECT, and Autodesk’s Navisworks and Revit Architecture / Structure / MEP. Modeling software can be divided into unidirectional vs. bidirectional editing, and also into single-file vs. multifile databases. When a model is created, views are then generated, or taken, directly from the model. These views are typically plans, sections, and elevations. When a change is made to the model, the views that were previously taken from the model also change to reflect the recent editing of the model (Goldberg 2005).

In a unidirectional approach, if changes are made to the views extracted from the model, the model is not changed. The unidirectional approach stores separate, electronic files, which, although linked, do not automatically change other views nor alter the model (Goldberg 2005).

In the bidirectional approach, however, the views extracted from the model are linked in real time, meaning that any changes made to the drawings automatically change the model and all other drawings. For example, ArchiCAD, VectorWorks ARCHITECT, Bentley Architecture, and Autodesk Revit are all examples of the bidirectional approach. The software uses either a single-file or multi-file database in order to manage coordinating drawings to the model. While the single-file database is efficient, the file size can become extremely large, whereas the multi-file database is a collection of smaller files, yet more cumbersome to manage (Goldberg 2005). ArchiCAD uses a bidirectional associative model in one 30 megabyte PLN file and uses geometric description language as its model creation language, which provides information as 2D symbols, 3D models, and text specifications (Goldberg 2005).
VectorWorks ARCHITECT is a cross-platform BIM program which provides drafting and detailing. Objects can be tagged with information about the material, manufacturer, and price, and can create linked schedules, tables, and reports. It also incorporates NURBS to create complex, organic shapes, and also produces high-quality renderings (Goldberg 2005).

Bentley Architecture is based on the MicroStation platform and is object-oriented. Its user interface includes rendering and animation, and its capabilities include reporting, cost analysis, scheduling, and bidirectional integration with engineering applications. The drawings are linked to the model, and the user can choose to work in 3D or in 2D and any changes made will apply to the entire model in either working plane (Goldberg 2005).

Finally, Autodesk Revit is bidirectional software which allows the user to change, at any point and in any view, an object or component, while instantly making the same change in the 3D model. The software can be linked to energy analysis and specification writing. Elements within the software are broken into categories, families, and types, and the user is able to edit and create additional elements (Goldberg 2005).

**Capabilities of BIM**

It is difficult to define BIM without explaining first its capabilities and goals. Building information modeling is, in one respect, exactly as it states. Building, information, and modeling are combined to form one carrier of information needed to execute a building. BIM could equally have been named AEC for architecture, engineering, and construction, as it is BIM’s inclusion of the vital aspects of each field that make it invaluable to each party involved.
The process of BIM begins with a 3-dimensional model which is input into BIM software. Design issues within the model are then resolved at an early stage of design. The model is loaded with information, as each component or modeled item carries with it specifications of size and material properties and cost. Because the BIM process begins with the goals and parameters of a project already defined, it is a useful tool in accurately estimating cost and energy performance. The mechanical and electrical systems are also modeled and merged with the structural model, highlighting through clash detection any areas in conflict, and providing a visual understanding of the larger sequence and order of the building process to all those involved. The model becomes the first pass at construction, as the many coordinating designs involved have been input into the same model, and any clashes have been carefully resolved. The ability to graphically understand such conflicts provides an incredible advantage to all involved. The builder also benefits tremendously as change orders due to design errors are virtually avoided and issues are resolved before breaking ground (Carmona 2007).

Another important aspect of BIM is not only the building process, but the entire lifecycle of the building after the building is constructed. BIM works hand-in-hand with facilities management operations, or FM. Companies with large FM organizations are adopting BIM, and to no surprise, as even a mere 1% savings in operating costs can result in a significant amount of savings for millions of square feet. Technology behind BIM allows for energy simulations in operations and can include results of changes such as refurbishment to an existing building by inputting the changes into the model. BIM can assist the owner in long-term operations through the as-built model. The capability of BIM to assist both in the design and building process and also to serve as a virtual
model of the building in real time brings benefits to the owner, architect, and builder, as changes and simulations can be virtually tested before being physically executed. The BIM model can remain an accurate representation of the building for future expansion or renovation if kept up-to-date. BIM serves as a database throughout the life of the building (Carmona 2007).

BIM requires that design and construction be a collaborative process. The adoption of BIM software in architecture and construction has proved beneficial through its ease of compatibility between design and construction phases (Carmona 2007).

A building information model can assist with visualization, fabrication and shop drawings, code reviews, forensic analysis, facilities management, cost estimating, construction sequencing, and the detection of conflicts and collisions (Eastman et. al 2008). BIM can also be used for simulations, energy analysis, structural design, and GIS integration. In terms of visualization, BIM can generate renderings as the project is built and easily produce images. Shop drawings are also easily produced when needed once the model is complete. As the model incorporates all dimensions of the project, officials may also use a building information model for the review of local building codes and fire-protection systems. Also, as the fourth dimension of BIM, a building information model can incorporate the scheduling of ordering equipment and facilities management. Leaks and failures can also be illustrated, as well as clash detection, in order to avoid real time conflicts during construction (Azhar 2008b).

History of BIM

The introduction of BIM into the construction industry has reduced the risk of errors due to miscommunication and has made more efficient the design and construction process within the AEC community. The beginnings of BIM were originally
developed in the early 1980s, as the AEC community adopted architectural drawing software packages, such as AutoCAD and Microstation, which improved 2D drawings through the support of digital generation of 2D construction documents (Eastman et al. 2008). Computer-aided drafting (CAD) evolved to BIM in the mid 90s, which has since become 4D and 5D modeling. In this research, the following “dimensions” of BIM were used as described:

- 3D: create models for 3D coordination
- 4D: implement scheduling into the models
- 5D: implement cost into models
- 6D: implement other information into models as in “operations and maintenance”

Although BIM did not develop overnight, the speed at which it has gained momentum in the past five years has been impressive. BIM software is taking the place of CAD due to the information embedded in the building information model. The digital information within the model acts as a digital representation of a physical building, allowing users to update and maintain the model for facilities management (Watson 2010).

**Beauty of BIM: Benefits**

The beauty of BIM is its dependence on collaboration. As various professionals are working together simultaneously on one model, the risk of errors and omissions is significantly reduced, in turn leading to more efficient cost estimating and scheduling. Planners can anticipate accurate schedules early in the design phase and estimators can easily monitor checks and balances. BIM considers the building’s entire lifecycle as
well as includes all information about the building and its lifecycle. BIM can define and simulate the life of a building, including its delivery and operation. Owners, architects and engineers, and contractors benefit from this collaborative and stream-lined process (Carmona 2007).

**Benefits of BIM for Owners**

Using BIM can increase the value of a building, shorten the project schedule, allow reliable cost estimates, produce market-ready facilities, and optimize facility management and maintenance (Eastman et al. 2008). In regard to facilities management, a BIM model offers an accurate and detailed record of the project. The owner need not depend on traditional 2D construction drawings which may have errors and are not accurate records of what was actually built, or true as-builts. Instead, the owner is given the building information model to which the owner may refer for any future renovations or energy analyses. Scheduling is made more efficient and, therefore, the owner can also expect a shorter project duration. Owners can expect to have more control and indirectly, more savings, through using BIM on a project design and construction (Eastman 2009).

Owners may find satisfaction with the ease of verifying requested programmatic requirements. The use of BIM may even encourage owners to become more involved during the conceptual and schematic design phases as ideally all parties can easily communicate and work together. Owner-directed change orders may be significantly reduced as owners can more easily communicate with architects and engineers to ensure all project components are in agreement between parties involved.
Benefits of BIM for Architects and Engineers

The introduction of BIM into the architecture and engineering field has expedited and made extremely efficient the design process. Architects have long-exchanged 2D drawings in order to communicate their design ideas. Though 3D models are modeled in architectural firms and may be graphically accurate in resemblance to the final product, the models produced function primarily as design tools. While design considerations such as light and shadow simulation studies are executed in such 3D modeling software, such as Rhinoceros and 3ds Max, specific information of the final product is not carried in the model. With BIM however, the 3D model serves to carry with it all the information acquired and specific to the project. One important benefit for architects is BIM's capability of serving as a rendering tool, a graphically-accurate model, and also as a set of final drawings. BIM allows for sections and elevations of a model to be instantly created as opposed to being drawn separately. The sections, plans, and elevations are taken directly from the 3D model, and are consistent with the information input into the original model (Eastman 2009). The 2D drawings which are generated from the 3D model are linked to the model and allow for any changes to the model to automatically be reflected in the 2D drawings as each is linked to the other. This linking of the 3D model to 2D drawings significantly reduces errors in the design stage. Typically, using the traditional 2D drawing exchange, the architect must reference simultaneously any plans, sections, or elevations. When a change is needed, the change must be made in each drawing. Though well-intended, often the process of independently updating each drawing or file is difficult to coordinate accurately. There is a high risk of error in using the traditional 2D approach due to the nature of the exchange of 2D drawings and often liability issues arise among architects. Through the
adoption of BIM, such errors of translation can be avoided, preventing costly delays due to inaccurate drawings. Another significant benefit to architects of BIM is the as-built, up-to-date model of a building that is available when the architect begins a renovation, addition, or alteration. Traditionally, the architect would attempt to track down the most recent as-built drawings available, which may be inaccurate as often the building is aged and drawings are either unavailable or dated. The architect must then re-draw the space, consuming time that could have been saved had an as-built BIM model been available (Carmona 2007).

The adoption of BIM also benefits civil engineers, who typically work with the architect on a project during the design phase. BIM principles apply to everything that is built, including roads and highways, allowing civil engineers to experience the same benefits as do architects (Strafaci 2008). Because BIM is an integrated approach and process, civil engineers also benefit from the ability to update all the related design elements automatically. Civil engineering's use of 2D drafting works much the same as an architect's, beginning with preliminary design, then detailed design, and finally construction documents. When a conflict arises and a change needs to be made in the initial design, time-consuming manual drafting updates must be made to the drawings, increasing the risk of error and costly setbacks. By using BIM, engineers can rely on one model to make changes. An intelligent 3-D model of a roadway can then provide a rich set of attributes associated with each structural element, and not merely a collection of points and surfaces (Strafaci 2008). Design and construction documentation are linked, allowing design changes to be made without timely alterations to construction documents. This facilitates faster construction and a more
predictable and realistic timetable estimate. Civil engineers can use BIM to design for constructability and road safety, and, in doing so, help to reduce mistakes in documentation. Because civil engineers often design first for code compliance, alternative designs are often not considered as viable options. BIM however allows the civil engineer to quickly analyze and test several alternatives (Strafaci 2008).

Integrated analysis tools such as geospatial and stormwater analysis also allow civil engineers to propose environmental solutions which may share the same cost with other designs which do not consider the environmental impact. With the push for sustainable design, BIM allows civil engineers to compete for projects that address environmental concerns. Without BIM, the initial design typically is not altered to find better solutions as the testing process is both time-consuming and costly. Building information modeling reduces risk and liability in projects in both infrastructure and transportation. Using model-based design tools, schedules are shortened and costs are lowered (Bennet 2010).

Geospatial capabilities of BIM allow the civil engineer to overlay the site design with a street centerline file of the immediate area surrounding the site. A geospatial buffer analysis can then locate the streets in a 1-mile radius and measure the length of road in the buffer area. The civil engineer can then compute the density and may be able to earn LEED (Leadership in Energy and Environmental Design) credits by locating the site in a high-density area. BIM also assists civil engineers in stormwater management. Again, as sustainable design becomes the standard, civil engineers aim to construct projects while minimizing erosion, recharging aquifers, and natural infiltration. The implementation of permeable pavements, rain gardens, bioswales, and
infiltration basins becomes a necessary aspect of design. BIM’s capability to integrate hydraulic and hydrologic analysis with civil engineering design models allows civil engineers to weigh options and choose the most sustainable solution. Also, civil engineers can use BIM for steep slope protection which protects existing habitats and minimizes erosion. Engineers are able to quickly check the surface data and learn which areas of the site are steep through a design model’s geospatial analysis and mapping capabilities. This information allows the engineer to instantly evaluate the degree of impact that any change would have on sensitive areas (Strafaci 2008).

BIM is also a beneficial to design and installation of mechanical, electrical, and plumbing systems. BIM is capable of capturing the functional relationships between the building and its components. Specific information about ducts, distribution panels, and pipes can be coordinated with the rest of the model. BIM creates a holistic approach to the design. The electrical engineer can be informed about the mechanical requirements in order to keep a record of the power requirements. BIM can then calculate the load needed and can alter the specifications of the mechanical equipment. The tools which BIM provides to the engineer also are of assistance in the mechanical, electrical, and plumbing (MEP) design process. Mechanical ductwork, piping, and plumbing are connected to both system sizing and layout tools. Users can perform engineering calculations directly in the model, including sizing mains, branches, or entire systems. Tools for system sizing are integrated with the layout tools and instantly update the size and design parameters of duct and pipe elements. BIM allows for the optimization and serviceability of HVAC systems (Holness 2006).
Benefits of BIM for Contractors

Building information modeling in construction is perhaps the most widely understood and valued in comparison to its use in architecture. This is not surprising, as the benefits BIM brings to the construction industry are ever-evolving and improving. BIM’s capability to resolve conflicts early on in the design stage through clash detection benefits the builder tremendously, as change orders are virtually avoided. Also, cost estimating is accurate as the BIM model is up-to-date and limits errors due to miscommunication between engineers or architects. The risk of error is extremely low in comparison to the traditional 2D approach, and the builder can proceed with the project having been modeled. Risks are reduced because conflicts have been resolved through real time with a system of checks and balances which the technology provides. Also, a schedule of construction activities using BIM can be accurately prepared. For example, construction phases can be simulated using Navisworks software, and each element or component can be linked to a database which provides information about each component. This enables any changes to automatically be updated in every step of the building process. Also, the ease and speed of producing material quantity takeoffs within a project at any moment give estimators an efficient method of checks and balances and often reduces bidding time (Holness 2006). Although, traditionally, quantity takeoffs and estimating typically occur late in the design stages, the use of BIM enables these estimates to occur early on and to be continuously updated as changes are made to the model (Ashcroft 2008).

BIM’s capability to resolve conflicts early on in the design stage through clash detection benefits the builder as change orders necessitated by conflicts are virtually avoided. Also, the accuracy of cost estimating is improved as the BIM model is up-to-
date, limiting errors due to miscommunication between engineers, contractors, and architects. The risk of error is low in comparison to the traditional 2D approach.

Industry and BIM

As legal issues continue to contribute to the growing cost of building, the construction industry will be forced to adopt an approach to construction that avoids unnecessary costs and aims to accomplish the owner's goals. Building Information Modeling brings a transparent and collaborative process to light, and encourages legitimate and straightforward design as well as equally legitimate and straightforward cost estimating. The benefits of BIM are limitless when compared to the traditional 2D approach and the opportunities for advancement in software are continuously expanding as new technologies are discovered. BIM's enhanced visualization, capability to perform conflict detection, data-rich database, and capability to perform simulations ensure that BIM will become the standard for construction (Ashcaft 2008). The future of renovations, additions, and alterations will change as as-built models will be readily available. Most importantly, BIM can bring transparency and trust to the construction industry.

Industry Demand for BIM

According to a survey conducted by Bentley Systems in 2007, the most important requirements AEC professionals would like BIM to address include: full support for producing construction documents, smart objects, object libraries, distributed work processes, multi-disciplinary capabilities, and integration with energy analysis, structural analysis and project management applications (Khelmani 2007). Steve Jones, the Senior Director of Business Development at McGraw-Hill Construction, referred to BIM as the gold standard by which firms do work, stating that BIM differentiates competitors,
saves time and money, and increases productivity and return on investment (McGraw-Hill 2008).

Upon graduation, students can expect to discover a high demand for BIM skills in the industry. BIM expertise leads to a greater understanding of the benefits and value of using BIM. The more experienced the user, the more valuable is the BIM process, as the company can efficiently utilize all of the benefits of BIM. Eighty-two percent of expert users say BIM has a positive impact on their companies’ productivity compared to 20% of beginner users (McGraw-Hill 2008).

Students graduating in the coming years can be expected to adopt new technologies such as BIM. The construction industry will need about 95,000 new craft workers each year for the next decade and will need to fill 12 million new jobs by 2012 (McGraw-Hill 2008).

BIM promotes a more collaborative environment. Seventy-two percent of users have had at least a moderate impact on their internal project processes, and two-thirds report that BIM has had at least a moderate impact on external project processes. Also, BIM is perceived by half of its users to have had a very positive impact on their companies (McGraw-Hill 2008).

**Challenges to Adopting BIM**

There are several challenges to companies adopting BIM; costs and training issues, as with any new technology, have proven to be the largest drawback to adopting BIM. The greatest challenge in adopting BIM is acquiring adequate training. It is particularly challenging because typically only a small number of employees has expertise in BIM. The challenge is in training others within the company. Training
should become less of a challenge as more expertise develops in the industry from schools, within firms, and from third parties (McGraw-Hill 2008).

It is no surprise that many companies are reluctant to switch to BIM as the software is new and the transition is often expensive. Because BIM software licenses can be expensive to obtain and companies must also consider training costs, the transition to BIM has been slow (McGraw-Hill 2008).

**Education and BIM**

The concept of BIM dates back to the early 70s with intelligent computer-aided design systems, and some BIM tools have been on the market for 20 years (Eastman 2009). Autodesk’s AutoCAD introduced designers to computer-assisted design and quickly became an international standard. Schools across the country recognized the need for AutoCAD and therefore began implementing AutoCAD drafting courses into curricula. While AutoCAD is certainly one of the primary drafting tools used by designers, its capabilities cannot compare to those encompassed in BIM. Schools across the country have recently begun implementing building information modeling into curriculum, and, as early as 2005, design schools across the globe began to investigate BIM and many decided to add this to their curriculum (Rundell 2005).

The Accreditation Board for Engineering and Technology (ABET) ensures that architectural engineering programs of study have a solid foundation in the fundamentals, and should include additional instruction in cutting-edge methodologies, such as design/build or sustainability (Vogt 2001). As BIM has gained popularity in recent years, its incorporation into programs of study such as architectural engineering and construction has been vital for the advancement and preparation of students. The Association of Collegiate Schools of Architecture (ASCA) is a nonprofit membership
association which was founded in 1912 to advance the quality of architectural education, with over 250 member schools. The ASCA encourages the transition to BIM through various means such as conferences regarding BIM and integrated studio projects, one of which took place at the University of Pennsylvania in 2008 and illustrated how BIM technologies can become a platform for collaboration between architects, engineers, and contractors (ASCA 2008). The American Council for Construction Education (ACCE) is recognized by the Council for Higher Education Accreditation (CHEA) as the accrediting agency for undergraduate programs in construction, construction science, construction management, and construction technology. One of the primary goals of the ACCE is to promote and improve construction education and research at the postsecondary level (ACCE 2011).
CHAPTER 3
RESEARCH METHODOLOGY

A survey of the implementation of building information modeling (BIM) into existing architecture and construction curriculum was developed and sent to construction and architecture schools in the United States. The survey collected data from schools in the United States regarding the degree of implementation of BIM into existing curriculum. The data included information about whether or not BIM was implemented into each school's educational curriculum and in which courses BIM was taught. The survey asked what the students' knowledge of BIM was to be expected to be upon graduation, as well as the school’s philosophy of BIM and in which areas of BIM the school especially concentrated such as in estimating and scheduling, among other inquiries and considerations. It was asked that one person was to complete the survey on behalf of each university.

The colleges and universities which are members of the Association of Collegiate Schools of Architecture (ACSA) were surveyed for this study as representative of architecture programs across the nation. The schools which are members of the ACSA fall into several membership categories in both the United States and in Canada. These include full membership for all accredited programs in the United States, candidate membership for schools seeking accreditation, and affiliate membership for schools for two-year and international programs. For this study, the type of membership held by ACSA schools was not considered. The survey was sent to ACSA schools located in the United States. At the time of the survey, there were 119 institutions located in the United States listed on the ACSA website. A link to the survey was emailed on three occasions to each institution within a two-month period, between the months of
September and November. Responses were received from 43 institutions, yielding a response rate of 36%.

The colleges and universities which are members of the American Council for Construction Education (ACCE) were surveyed in this study as representative of construction programs in the United States. The ACCE is the accrediting agency for both four-year baccalaureate and two-year associate-degree programs in construction, construction science, construction management, and construction technology. The type of membership in regard to four-year or two-year accreditation held by the schools listed was not considered for this study. A link to the survey was emailed to all of the accredited programs of construction, construction science, construction management, and construction technology listed on the ACCE website. At the time of the survey, there were 70 accredited institutions on the ACCE website. A link to the survey was emailed on three occasions to each institution within a two-month period, between the months of September and November. Responses were received from 38 institutions, yielding a response rate of 54%.

**Survey Instrument**

The survey questionnaire that was developed for this study requested quantitative and qualitative information from the respective respondents. The survey was developed using the online survey tool, Zoomerang. There were a total of 27 questions in the survey. The first page of the survey stated that the survey link should be forwarded to a faculty member who would be best able to answer questions about the current use of building information modeling (BIM) in the curriculum, in case the initial recipient of the survey did not have the knowledge to answer the questions.
Demographics

The first section of the survey asked for demographic information about the institution including the discipline represented by the school, the name and location of the school, the number of both tenure and non-tenure track faculty within the school, and the student population of the school. Note that respondents were asked to check all disciplines that applied, allowing a school to complete only one survey on behalf of both architecture and construction programs within the university.

BIM-specific Demographics

The second section of the survey asked about BIM-specific demographic information. The survey asked if building information modeling (BIM) was implemented into the school’s curriculum and if a dedicated BIM course was offered. This section also asked how many classes implemented BIM and in which class levels BIM was implemented.

Faculty Background

The third section of the survey asked about the type (tenure and non-tenure track) and academic background of the faculty teaching BIM.

BIM Software

The fourth section of the survey asked which BIM software as well as which scheduling and estimating software were used in the curriculum.

BIM Coursework

The fifth section of the survey asked about the curriculum and coursework. The survey asked about the classes, both undergraduate and graduate, where BIM was implemented into coursework and if models were used to teach the coordination process, construction scheduling (4D BIM), and construction estimating (5D BIM). One
question asked respondents to categorize courses into the following fields: civil, design, electrical, estimating, mechanical, project management, scheduling, structural, technology, or other. It was expected that those completing the survey on behalf of the school would best categorize the courses offered in the categories provided in the survey.

**Expectations and Philosophy**

The sixth section of the survey asked about the level of knowledge each school expected its students to have upon graduation as well as each school’s philosophy of teaching BIM. This section of the survey also asked if research in BIM was conducted at the school and, if so, what type of the research was conducted. The complete survey is located in Appendix A.
CHAPTER 4
RESULTS

Descriptive Statistics

This section contains descriptive results including information about demographics and BIM-specific demographics, information about the level and type of BIM courses offered, faculty background, and BIM software, as well as the expectation of students’ knowledge, BIM teaching philosophy, and BIM research conducted at each school.

Section 1: Demographics

Respondents were asked about the discipline represented by the school, the number of both tenure and non-tenure track faculty within the school, and the student population of the school. Respondents were asked to select the discipline which their department represents (Figure 4-1). There were 45 responses (55%) for architecture, 37 responses (46%) for construction, and 9 responses (12%) for both engineering and engineering technology combined. There were six responses (8%) for other disciplines, such as interior design, urban design, and art, and 3 responses (4%) for facility management. Note that respondents were asked to select “all that apply” when answering this question.

Respondents were asked about the number of departmental tenure track faculty and non-tenure track faculty (Figure 4-2). When asked about the number of tenure track faculty, 20% of the schools responded as having less than 30% tenure track faculty, 29% as between 31% and 60%, and 51% as between 61% and 100%. When asked about the number of non-tenure track faculty, 39% of schools responded as having less than 30% of tenure track faculty, 31% as between 31% and 60%, and 30% as between 61% and 100%. Respondents most commonly stated that their school had
between 71% and 80% tenure track faculty and between 21% and 30% non-tenure track faculty.

![Figure 4-1. Discipline Represented by School (N = 81)](image1)

Figure 4-1. Discipline Represented by School (N = 81)

![Figure 4-2. Number of Tenure and Non-Tenure Track Faculty within School](image2)

Figure 4-2. Number of Tenure and Non-Tenure Track Faculty within School
When asked about the departmental student population, 6% of the schools responded as having less than or equal to 100 students within the department, 25% as between 101 and 200, 21% as between 201 and 300, 18% as between 301 and 400, 11% as between 401 and 500, 8% as between 501 and 600, 6% as between 601 and 700, and 5% as greater than 700 (Figure 4-3). Overall, over half (64%) of the schools responded as having a departmental student population between 101 and 400.

Figure 4-3. Departmental Student Population

Section 2: BIM-specific Demographics

The survey asked about BIM-specific demographic information. Respondents were asked if BIM was implemented into the school’s curriculum and if a dedicated BIM course was offered, as well as about the number of classes and the level in which BIM was implemented. When asked if BIM was implemented into curriculum, 78% of the schools responded as having implemented BIM into the curriculum and 60% of the schools responded as having a BIM-dedicated course as part of the existing curriculum.
When asked about how many classes implemented BIM within the curriculum, 19 schools (26%) responded as having one class implementing BIM, while 17 schools (23%) responded as having two classes, 13 as three classes, five as four classes, four as five classes, two as six classes, and three as seven classes (Figure 4-4). Three schools responded as having more than eight classes implementing BIM, while 8 schools responded as not having implemented BIM in any classes. Almost half (49%) of the schools responded as having either one or two classes implementing BIM.

![Figure 4-4. Number of Classes Implementing BIM (N = 81)](image)

When asked about the class level at which BIM is implemented within the curriculum, eight schools responded as having implemented BIM at the freshman level, 22 at the sophomore level, 26 at the junior level, 27 at the senior level, and 21 at the graduate level (Figure 4-5). Most respondents stated that BIM had been implemented in classes above the freshman level. Note that respondents were asked to select “all that apply” when answering this question.
Section 3: Faculty Background

The survey asked about the position and background of the faculty teaching BIM. When asked about the position of faculty teaching BIM, 22% of the schools responded as having BIM faculty in a “Lecturer” position, 37% as in an “Adjunct Faculty” position, and 41% as in a “Tenure Track Faculty” position (Figure 4-6). Most respondents stated that they had BIM faculty in the “Tenure Track” position. Note that respondents were asked to select “all that apply” when answering this question.

When asked about the background of faculty teaching BIM, 49 schools (73%) responded as having BIM faculty with a background in architecture, 23 (34%) with a background in construction and 15 (22%) with a background in engineering (Figure 4-7). Three schools responded as having BIM faculty with a background in facilities management and another three schools responded as having BIM faculty with a background in other fields such as urban, interior, and industrial design. One school
responded as having BIM faculty with a background in engineering technology. Note that respondents were asked to select “all that apply” when answering this question.

Figure 4-6. Position of Faculty Teaching BIM (N = 54)

Figure 4-7. Background of Faculty Teaching BIM (N = 67)
Section 4: BIM Software

The survey asked which 3D BIM software, scheduling software, and estimating software were used. Sixty-seven schools (96%) used Autodesk Revit, while ten schools (14%) used Graphisoft (ArchiCAD), seven Bentley, three VICO, two Nemetschek Vectorworks, and one Onuma Planning System (Figure 4-8). One respondent answered that other BIM software such as Digital Project and Tekla was taught. Note that respondents were asked to select “all that apply” when answering this question.

Figure 4-8. BIM Software Taught (N = 70)

Primavera / Suretrack were the scheduling software taught by 42 schools, while Microsoft Project was taught by 27 (Figure 4-9). Four schools responded as teaching other scheduling software such as Entourage and DProfiler, and 24 schools responded as not using any scheduling software.
Figure 4-9. Scheduling Software Taught (N = 73)

The most commonly taught estimating software were Excel-based and Timberline Precision Estimating, each taught by 16 of the schools (Figure 4-10). Onscreen Takeoff was taught by 11 of the schools, CostWorks and Winest by four of the schools, and Innovaya by two of the schools. Eighteen of the schools did not teach any estimating software, and nine of the schools responded as teaching “other” software such as Autodesk Quantity Takeoff, MC², HCSS-HeavyBid, BSD Building Systems Design, and Quick Bid software. None of the schools responded as teaching estimating using D4Cost or HardDollar software. Note that respondents were asked to select “all that apply” when answering this question.
Section 5: BIM Coursework

The survey asked about the curriculum and coursework at each institution. Respondents were asked at what level and in which classes, both undergraduate and graduate, BIM was implemented into coursework and if BIM models were used to teach the coordination process, construction scheduling (4D BIM) and construction estimating (5D BIM). Respondents were asked to state the level (basic, intermediate, or advanced) of BIM implementation in undergraduate classes (Figure 4-11). Seventy-one percent of the schools responded as having a basic BIM level in civil classes, while 29% responded as having intermediate level classes. Fifty-eight percent of the schools responded as having a basic BIM level, 39% an intermediate level, and 3% an
advanced level in design classes. Three-fourths of the schools responded as having a basic BIM level and the remaining 25% an intermediate level in electrical classes. Eighty-two percent of the schools responded as having a basic BIM level, 9% an intermediate level, and 9% an advanced level in estimating classes. Eighty percent of the schools responded as having a basic BIM level and 20% an intermediate level in mechanical classes. Three-fourths of the schools responded as having a basic BIM level and the other 25% an intermediate level in project management classes. Seventy-eight percent of the schools responded as having a basic BIM level and 22% an intermediate level in scheduling classes. Eighty percent of the schools responded as having a basic BIM level and 20% an intermediate level in structural classes. Sixty-two percent of the schools responded as having a basic BIM level and 38% an intermediate level in technology classes. All of the schools responded as having a majority of a basic BIM level in each individual BIM class type.

Respondents were asked to state the class format (lab, lecture, or both) of courses implementing BIM in the undergraduate curriculum (Figure 4-12). Forty percent of the schools responded as having a lab class format in civil classes, while 60% responded as having both a lab and lecture format. Thirty-two percent of the schools responded as having a lab class format in design classes, while 68% responded as having both a lab and lecture format. A fourth of the schools responded as having a lab class format, 13% as having a lecture format, and 62% as having both a lab and lecture format in electrical classes. Eighteen percent of the schools responded as having a lab format, 9% as having a lecture format, and 73% as having both a lab and lecture class format in estimating classes. Ten percent of the schools responded as having a lab format, 30%
as having a lecture format, and 60% as having both a lab and lecture class format in mechanical classes. Half of the schools responded as having a lab format in project management classes, while the other half responded as having a lecture format. Eleven percent of the schools responded as having a lab format, 11% as having a lecture format, and 78% as having both a lab and lecture class format in scheduling classes. Ten percent of the schools responded as having a lab format, 40% as having a lecture format, and 50% as both a lab and lecture class format in structural classes. Fifteen percent of the schools responded as having a lab format, 15% as having a lecture format, and 70% as having both a lab and lecture class format in technology classes. Having both a lab and lecture class format was the most common response from the respondents.

Figure 4-11. Level of BIM Implementation in Undergraduate Courses
Respondents were asked to state the level (basic, intermediate, or advanced) of BIM implementation in graduate classes (Figure 4-13). No schools responded as having implemented BIM into civil classes. Thirty-eight percent of the schools responded as having a basic BIM level in design classes, and 62% an intermediate level. All of the schools responded as having an intermediate BIM level in electrical, estimating, and project management classes. Half of the schools responded as having a basic BIM level in mechanical classes, and the other half an intermediate level. Half of the schools responded as having an intermediate BIM level in scheduling classes, and the other half an advanced level. All of the schools responded as having a basic BIM level in structural classes. Seventeen percent of schools responded as having a basic BIM level in technology classes, 50% an intermediate level, and 33% a basic level. Most of the schools responded as having an intermediate level of BIM implementation for all class types.
Respondents were asked to state the class format (lab, lecture, or both) of courses implementing BIM in the graduate curriculum (Figure 4-14). None of the schools responded as having implemented BIM into civil classes. Fifty eight percent of the schools responded as having a lab class format in design classes, while 42% responded as having both a lab and lecture format. All of the schools responded as having both a lab and lecture class format in electrical, project management, and structural classes. Half of the schools responded as having a lab format in estimating, mechanical, and scheduling classes, while the other half responded as having both a lab and lecture class format. Seventeen percent of the schools responded as having a lab format, 17% as having a lecture format, and two-thirds as having both a lab and lecture class format in technology classes. Having both a lab and lecture class format as well as having lecture class format were the most common responses from
respondents for all class types, although a lab class format was the most common response for design classes.

![Bar chart showing class format of graduate courses implementing BIM.](chart)

**Figure 4-14. Class Format of Graduate Courses Implementing BIM**

Respondents were asked to characterize BIM implementation within their programs into the following categories: create models for 3D coordination (3D), implement scheduling into the models (4D), implement cost into models (5D), implement other information into models as in “operations and maintenance” (6D), “none”, or “other”, including energy analysis and modeling as well as architectural design possibilities (Figure 4-15). Regarding the undergraduate curriculum, 42 of the schools characterized BIM implementation as 3D modeling, 16 of the schools as 4D modeling, 15 of the schools as 5D modeling, five of the schools as 6D modeling, eight of the schools as “none”, and eight of the schools as “other”, which included responses such as visualization, simulation, clash detection, value and life cycle issues, and exploration of architectural design possibilities. Regarding the graduate curriculum, 23
of the schools characterized BIM implementation as 3D modeling, nine of the schools as 4D modeling, 11 of the schools as 5D modeling, five of the schools as 6D modeling, 15 of the schools as “none”, and 2 of the schools as “other”, which included responses such as energy modeling and analysis. The majority of the respondents on behalf of undergraduate curriculum characterized BIM implementation first as 3D modeling, followed by 4D modeling, 5D modeling, “other”, “none”, and, finally, 6D modeling. The majority of the respondents on behalf of graduate curriculum characterized BIM implementation first as 3D modeling, followed by “none”, 5D modeling, 4D modeling, “other”, and 6D modeling. Note that respondents were asked to select “all that apply” when answering this question.

Figure 4-15. BIM Implementation in Curriculum at Undergraduate and Graduate Level
Twenty-eight percent of the respondents stated that they use BIM models to teach the coordination process, 22% of the respondents stated that they use 4D models to teach construction scheduling, and 15% of the respondents stated that they use 5D models to teach construction estimating.

**Section 6: Expectations and Philosophy**

The survey asked about the level of knowledge each school expected its students to have upon graduation as well as each school’s philosophy of teaching BIM. Respondents were also asked to describe any research in BIM that was conducted in the school.

Respondents were asked to characterize the philosophy of implementing BIM within the curriculum. As the question was open-ended, responses were grouped into the following categories: “BIM is not important”, “unsure of the importance of BIM”, “plan to implement BIM”, “introduce/become familiar with BIM”, “BIM as a management tool”, and “fully integrate BIM”. Two-thirds of the respondents described their philosophy as fully-integrating BIM (Figure 4-16). Six percent of the respondents stated that their philosophy was to introduce/become familiar with BIM and another 6% saw BIM as a management tool. Four percent of the respondents planed to implement BIM in the future, while 11% of the respondents were unsure of implementing BIM in the future. Six percent of the respondents stated that they did not feel that BIM was important to implement into the curriculum.

Respondents were asked to state the level of BIM knowledge expected from students upon graduation. Almost half (49%) of the schools responded that a basic level of BIM knowledge was expected upon graduation, and 40% responded that an intermediate level of knowledge was expected (Figure 4-17). Four percent of the
respondents expected an advanced level, and 2\% expected an expert level. Five percent of the respondents chose “other” as the expected level of BIM knowledge upon graduation, specifying that no BIM knowledge was expected.

Figure 4-16. Philosophy of BIM Implementation

Respondents were asked to list any other skill sets related to BIM use and collaboration which are expected of graduates. Responses included BIM presentation and visualization skills, using BIM as an analysis tool, energy modeling, collaboration and problem-solving, knowledge of the Autodesk Navisworks software, an understanding of the interoperation and simulation capabilities of BIM, BIM in project management, and design communication through BIM.
Respondents were asked to categorize their perception of how industry views the importance of BIM. Forty-four percent of the respondents felt that BIM was very important to industry, while 37% felt that BIM was important (Figure 4-18). Seventeen percent of the schools felt that BIM was somewhat important to industry, while 2% listed “other”, specifying that knowledge of BIM was important within firms and very important to vendors. None of the respondents felt that BIM was not important to industry or that they did not know. Overall, both architecture schools and construction schools felt that industry viewed BIM as very important or important.

When asked if research on BIM was conducted, one-third of the respondents stated that research on BIM was conducted within their program. Respondents were also asked to list the BIM areas in which the research was conducted as well as the
funding sources and the grant amounts. Responses listing the areas of BIM research included: BIM estimating, BIM implementation by construction companies, BIM integration into architectural engineering curricula, implementing BIM into mechanical and electrical coursework, BIM and LEED rating, BIM visualization, BIM and energy modeling, BIM accessibility to architects, benefits of BIM for architects, pedagogy of BIM, BIM applications, BIM for electrical contractors, BIM simulation, BIM implementation by owners for operations and maintenance, locating RFID tags in a BIM model, BIM to collaborative viewing, and energy modeling simulation of affordable housing. Funding sources listed included construction companies, internal grants, university research funds, the Department of Energy (DOE) Building America study, the National Electrical Contractors Association, and the Boston Society of Architects. The amount of the grants ranged from $15,000 to $110,000.

Figure 4-18. Perception of Importance of BIM to Industry
Stratified Sampling

Results of the survey were stratified to compare the responses from architecture and construction schools. The results compare BIM-specific demographics of both architecture and construction schools, the level and type of BIM courses offered, faculty background, and BIM software, as well as the expectation of students' knowledge, BIM teaching philosophy, and BIM research conducted.

Section 1: BIM-specific Demographics

When asked if BIM had been implemented into the curriculum, 78% of the respondents representing both architecture and construction schools responded as having implemented BIM into the curriculum. Sixty seven percent of the respondents representing architecture schools responded as having a BIM-dedicated course as part of the existing curriculum, compared to 53% of the construction schools.

When asked how many classes implemented BIM within their curriculum, 31% of the architecture schools and 20% of the construction schools responded as having one class implementing BIM (Figure 4-19). Twenty one percent of the architecture schools and 26% of the construction schools responded as having two classes, 23% of the architecture schools and 11% of the construction schools had three classes, 8% of the architecture schools and 6% of the construction schools had four classes, and 2% of the architecture schools and 9% of the construction schools had five classes. There were no respondents representing architecture schools which responded as having six classes, though 5.5% of the construction schools did. Two percent of architecture and 5.5% of construction schools responded as having implemented BIM into seven classes. There were no respondents representing construction schools which responded as having more than or equal to eight classes implementing BIM, though 8%
of the architecture schools did. Five percent of the architecture schools and 17% of the construction schools responded as not having implemented BIM in any classes.

![Bar chart showing number of classes implementing BIM by architecture and construction schools.](image)

**Figure 4-19. Number of Classes Implementing BIM: Comparison of Architecture and Construction Schools**

When asked at which class level BIM is implemented within their curriculum, one architecture school and seven of the construction schools responded as having implemented BIM at the freshman level (Figure 4-20). Eight of the architecture schools and 14 of the construction schools responded as having implemented BIM at the sophomore level, 13 of the architecture schools and 13 of the construction schools implemented BIM at the junior level and senior level. The largest difference was found in the responses for BIM implementation at the graduate level, with 16 of the architecture schools in comparison to five of the construction schools having implemented BIM at the graduate level. Note that respondents were asked to select “all that apply” when answering this question.
Section 2: Faculty Background

When asked about the background of the faculty teaching BIM, all (37) of the architecture schools and 12 of the construction schools had BIM faculty with a background in architecture, while three of the architecture schools and 20 of the construction schools had faculty with a background in construction (Figure 4-21). Three of the architecture schools and 12 of the construction schools had faculty with a background in engineering. Three of the construction schools had faculty with a background in facilities management while the architecture schools had none. Three of the architecture schools had faculty teaching BIM with backgrounds in other fields such as urban, interior, and industrial design. One construction school responded as having faculty teaching BIM with a background in engineering technology. Note that respondents were asked to select “all that apply” when answering this question.
Figure 4-21. Background of Faculty Teaching BIM: Comparison of Architecture and Construction Schools

Section 3: BIM Software

Autodesk Revit was the BIM software used by all (37) of the architecture schools and by 30 of the construction schools, while Graphisoft (ArchiCAD) was used by five of the architecture schools and five of the construction schools (Figure 4-22). Three of the architecture schools and four of the construction schools taught Bentley. None of the architecture schools responded as teaching VICO, compared to three of the construction schools. One architecture school and one construction school taught Nemetschek VectorWorks, and one architecture school taught Onuma. One architecture school and two of the construction schools taught either no software or
other BIM software, such as Digital Project and Tekla. Note that respondents were asked to select “all that apply” when answering this question.

Figure 4-22. BIM Software Taught: Comparison of Architecture and Construction Schools

Section 4: BIM Coursework

Twenty-three percent of the architecture schools and 29% of the construction schools stated that they use BIM models to teach the coordination process. Seven percent of the architecture schools and 35% of the construction schools stated that they use 4D models to teach construction scheduling. Ten percent of the architecture schools and 19% of the construction schools stated that they use 5D models to teach construction estimating.
Section 5: Expectations and Philosophy

Respondents were asked to characterize the philosophy of implementing BIM within the curriculum. As the question was open-ended, responses were grouped into the following categories: “BIM is not important”, “unsure of the importance of BIM”, “plan to implement BIM”, “introduce/become familiar with BIM”, “BIM as a management tool”, and “fully integrate BIM”.

Seventy three percent of the architecture schools and 64% of the construction schools stated that their philosophy was to fully-integrate BIM into their curriculum (Figure 4-23). Eight percent of the construction schools stated that their philosophy was to introduce/become familiar with BIM and another 8% plan to implement BIM in the future. Twelve percent of the construction schools saw BIM as a management tool. None of the architecture schools saw BIM as a management tool or stated that their philosophy was to introduce/become familiar with or to implement BIM in the future. Eighteen percent of the respondents representing architecture schools and 4% representing construction schools were unsure of implementing BIM in the future, while 9% of the architecture schools and 4% of the construction schools stated that they did not feel that BIM was important to implement into curriculum.

Respondents were asked to state the level of BIM knowledge expected from students upon graduation. Forty nine percent of the architecture schools and 48% of the construction schools responded that a basic level of BIM knowledge was expected upon graduation, while 39% of the architecture schools and 41% of the construction schools responded that an intermediate level of knowledge was expected (Figure 4-24). Four percent of both the architecture and construction schools expect an advanced level, and 4% of the architecture schools expect an expert level. Four percent of the
architecture schools and 7% of the construction schools chose “other” as the expected level of BIM knowledge upon graduation, specifying that no BIM knowledge was expected. Overall, a basic or intermediate level of BIM knowledge was most commonly expected from students upon graduation by both the architecture and construction schools.

Figure 4-23. Philosophy of BIM Implementation: Comparison of Architecture and Construction Schools

Respondents were asked to categorize their perception of how industry views the importance of BIM. Sixty one percent of the architecture schools felt that BIM was very important to industry in comparison to 29% of the construction schools, while 32% of the architecture schools felt that BIM was important to industry in comparison to 42% of the construction schools (Figure 4-25). Another 7% of the architecture schools and 26% of
the construction schools felt that BIM was somewhat important to industry, while 3% of the construction schools listed “other”, specifying that knowledge of BIM was important within firms and very important to vendors. None of the respondents felt that BIM was not important to industry or that they did not know. Overall, both the architecture and construction schools felt that industry viewed BIM as being very important or important.

![Figure 4-24. Expected Level of Students’ BIM Knowledge upon Graduation: Comparison of Architecture and Construction Schools](image)

When asked if research on BIM was conducted, greater portion of construction schools (46%) than architecture schools (21%) stated that research on BIM was conducted within their program. Respondents were also asked to list the BIM areas in which the research was conducted as well as the funding sources and the grant amounts. There were no common research topics from architecture and construction schools. Responses from construction schools listing the areas of BIM research
included: BIM estimating, BIM implementation by construction companies, BIM integration into architectural engineering curricula, implementing BIM into mechanical and electrical coursework, BIM and LEED rating, pedagogy of BIM, BIM applications, BIM for electrical contractors, BIM implementation by owners for operations and maintenance, and locating RFID tags in a BIM model. Responses from architecture schools stating the areas of BIM research included: BIM visualization, BIM and energy modeling, BIM accessibility to architects, benefits of BIM for architects, BIM simulation, BIM to collaborative viewing, and energy modeling simulation of affordable housing.

Figure 4-25. Perception of Importance of BIM to Industry: Comparison of Architecture and Construction Schools

Stratified results from both architecture and construction schools serve to illuminate trends in the implementation of BIM as to the type of school surveyed for this research. The summary of the stratified results is shown in Table 4-1. Results listed
under “Total” reflect the total descriptive statistics obtained from the survey, while results listed under “Architecture” and “Construction” reflect only the results which apply to each type of school respectively. The percentages which are listed have been calculated as a percentage of the total amount of respondents for each question, while the numbers which are listed represent the actual number of the schools that responded to each question. The number of the schools listed under “Architecture” and “Construction” equal the number of the schools under “Total” for each question.

Table 4-1. Comparison of Responses from Architecture and Construction Schools

<table>
<thead>
<tr>
<th>Survey Question</th>
<th>Architecture</th>
<th>Construction</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implemented into Curriculum</td>
<td>32 (78%)</td>
<td>29 (78%)</td>
<td>61 (78%)</td>
</tr>
<tr>
<td>BIM-dedicated Course</td>
<td>29 (67%)</td>
<td>20 (53%)</td>
<td>49 (60%)</td>
</tr>
<tr>
<td>Number of BIM Classes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zero</td>
<td>2 (5%)</td>
<td>6 (17%)</td>
<td>8 (11%)</td>
</tr>
<tr>
<td>One</td>
<td>12 (31%)</td>
<td>7 (20%)</td>
<td>19 (26%)</td>
</tr>
<tr>
<td>Two</td>
<td>8 (21%)</td>
<td>9 (26%)</td>
<td>17 (23%)</td>
</tr>
<tr>
<td>Three</td>
<td>9 (23%)</td>
<td>4 (11%)</td>
<td>13 (18%)</td>
</tr>
<tr>
<td>Four</td>
<td>3 (8%)</td>
<td>2 (6%)</td>
<td>5 (7%)</td>
</tr>
<tr>
<td>Five</td>
<td>1 (2%)</td>
<td>3 (9%)</td>
<td>4 (5%)</td>
</tr>
<tr>
<td>Six</td>
<td>0 (0%)</td>
<td>2 (5.5%)</td>
<td>2 (3%)</td>
</tr>
<tr>
<td>Seven</td>
<td>1 (2%)</td>
<td>2 (5.5%)</td>
<td>3 (3.5%)</td>
</tr>
<tr>
<td>Eight or more</td>
<td>3 (8%)</td>
<td>0 (0%)</td>
<td>3 (3.5%)</td>
</tr>
<tr>
<td>Level of Implementation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Implementation</td>
<td>1 (4%)</td>
<td>7 (28%)</td>
<td>8 (16%)</td>
</tr>
<tr>
<td></td>
<td>Sophomore</td>
<td>Junior</td>
<td>Senior</td>
</tr>
<tr>
<td>--------------------------</td>
<td>-----------</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td></td>
<td>8 (31%)</td>
<td>14 (56%)</td>
<td>22 (43%)</td>
</tr>
<tr>
<td></td>
<td>13 (50%)</td>
<td>13 (52%)</td>
<td>26 (51%)</td>
</tr>
<tr>
<td></td>
<td>13 (50%)</td>
<td>14 (56%)</td>
<td>27 (53%)</td>
</tr>
<tr>
<td></td>
<td>16 (62%)</td>
<td>5 (20%)</td>
<td>21 (41%)</td>
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### Background of Faculty Teaching

#### BIM

<table>
<thead>
<tr>
<th></th>
<th>37 (100%)</th>
<th>12 (40%)</th>
<th>49 (73%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architecture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td>3 (8%)</td>
<td>20 (67%)</td>
<td>23 (34%)</td>
</tr>
<tr>
<td>Engineering</td>
<td>3 (8%)</td>
<td>12 (40%)</td>
<td>15 (22%)</td>
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<td>Engineering Tech</td>
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<td>0 (0%)</td>
<td>1 (1%)</td>
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<tr>
<td>Facilities Mgmt</td>
<td>0 (0%)</td>
<td>3 (10%)</td>
<td>3 (4%)</td>
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<tr>
<td>Other Areas</td>
<td>3 (5%)</td>
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<td>3 (4%)</td>
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</table>

#### BIM Software Taught

<table>
<thead>
<tr>
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<th>3 (8%)</th>
<th>4 (13%)</th>
<th>7 (10%)</th>
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</thead>
<tbody>
<tr>
<td>Bentley</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Revit</td>
<td>37 (97%)</td>
<td>30 (94%)</td>
<td>67 (96%)</td>
</tr>
<tr>
<td>VICO</td>
<td>0 (0%)</td>
<td>3 (9%)</td>
<td>3 (4%)</td>
</tr>
<tr>
<td>Archicad</td>
<td>5 (13%)</td>
<td>5 (16%)</td>
<td>10 (14%)</td>
</tr>
<tr>
<td>Onuma</td>
<td>1 (3%)</td>
<td>0 (0%)</td>
<td>1 (1.5%)</td>
</tr>
<tr>
<td>VectorWorks</td>
<td>1 (3%)</td>
<td>1 (3%)</td>
<td>2 (3%)</td>
</tr>
<tr>
<td>Other</td>
<td>1 (3%)</td>
<td>2 (6%)</td>
<td>3 (4%)</td>
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#### Type of BIM Models Used

<table>
<thead>
<tr>
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<th>7 (23%)</th>
<th>9 (29%)</th>
<th>16 (28%)</th>
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<tbody>
<tr>
<td>3D for Coordination</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>4D for Scheduling</td>
<td>2 (7%)</td>
<td>11 (35%)</td>
<td>13 (22%)</td>
</tr>
<tr>
<td>Philosophy of BIM</td>
<td>5D for Estimating</td>
<td>Fully-integrate</td>
<td>Integrate</td>
</tr>
<tr>
<td>------------------</td>
<td>------------------</td>
<td>-----------------</td>
<td>-----------</td>
</tr>
<tr>
<td>Implementation</td>
<td>3 (10%)</td>
<td>2 (9%)</td>
<td>4 (18%)</td>
</tr>
<tr>
<td>BIM as Management</td>
<td></td>
<td>1 (4%)</td>
<td>1 (4%)</td>
</tr>
<tr>
<td>Tool</td>
<td>6 (19%)</td>
<td>3 (6%)</td>
<td>5 (11%)</td>
</tr>
<tr>
<td>Introduce/Become</td>
<td></td>
<td>1 (4%)</td>
<td>3 (6%)</td>
</tr>
<tr>
<td>Familiar</td>
<td>9 (15%)</td>
<td>2 (4%)</td>
<td></td>
</tr>
<tr>
<td>Plan to Implement</td>
<td>16 (73%)</td>
<td>16 (64%)</td>
<td>32 (67%)</td>
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</table>

<table>
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<tr>
<th>Expected Level of Students' BIM Knowledge upon Graduation</th>
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</thead>
<tbody>
<tr>
<td>Basic</td>
</tr>
<tr>
<td>Intermediate</td>
</tr>
<tr>
<td>Advanced</td>
</tr>
<tr>
<td>Expert</td>
</tr>
<tr>
<td>Other</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Perception of Importance of BIM to Industry</th>
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</thead>
<tbody>
<tr>
<td>Very Important</td>
</tr>
<tr>
<td>Important</td>
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69
<table>
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<tr>
<th>Category</th>
<th>Count (Percent)</th>
<th>Count (Percent)</th>
<th>Count (Percent)</th>
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</thead>
<tbody>
<tr>
<td>Somewhat Important</td>
<td>2 (7%)</td>
<td>8 (26%)</td>
<td>10 (17%)</td>
</tr>
<tr>
<td>Not Important</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Do Not Know</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Other</td>
<td>0 (0%)</td>
<td>1 (3%)</td>
<td>1 (2%)</td>
</tr>
<tr>
<td>Research Conducted on BIM</td>
<td>6 (21%)</td>
<td>13 (46%)</td>
<td>19 (33%)</td>
</tr>
</tbody>
</table>
CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

Summary and Conclusions

It is first important to note that the response rates for this study were encouraging; the survey yielded a 35% response rate for architecture schools which are ACSA members and a 53% response rate for construction schools which are ACCE members. This is encouraging both to educators and industry professionals supporting the transition to BIM. As interest in the implementation of BIM into educational curriculum grows, schools across the United States are restructuring curriculum and hiring faculty to better equip students for the growing demand of BIM knowledge in the industry. The survey results showed that:

- While there was a wide range in the size of the schools, most respondents stated that they had less than or equal to 15 tenure as well as non-tenure track faculty, and that that their departmental student population was between 101 and 400. Responses from schools of such varying sizes indicate an interest in BIM which is not limited to large schools.

- In terms of implementing BIM within the curriculum, about 80% of the respondents stated that they had implemented BIM into curriculum, and more than half of the respondents stated that they had a BIM-dedicated course as part of existing curriculum.

- The majority (96%) of the respondents stated that they teach Autodesk Revit, followed by 14% of respondents who teach ArchiCAD. Primavera and Microsoft Project were the most commonly taught scheduling software, and Excel-based and Timberline Precision Estimating were the most commonly taught estimating software. Though the majority of respondents have implemented BIM into their curriculum (about 80%), a third of respondents, primarily from architecture schools, do not yet teach estimating or scheduling software.

- All schools which have implemented BIM stated that BIM had been implemented at a “basic” level in undergraduate classes. A majority of the schools stated that BIM had been implemented at an “intermediate” level in graduate classes. The majority of the respondents on behalf of undergraduate curriculum characterized BIM implementation first as 3D implementation. When asked specifically if BIM models are used in teaching, the majority of respondents stated that they use BIM
models in teaching the coordination process, followed by 4D models in simulating
construction scheduling, and 5D models in teaching construction estimating.

- The majority of the respondents described their philosophy in implementing BIM
  as fully-integrating while a very small percentage of respondents stated that they
did not feel that BIM was important to implement into curriculum.

- In terms of the schools’ expectations of their students' knowledge upon
  graduation, the majority of the respondents stated that either a basic or
intermediate level of BIM knowledge was expected upon graduation, while a small
percentage stated that an advanced or expert level of BIM knowledge was
expected.

- The majority of the respondents stated that knowledge of BIM was either very
  important or important in satisfying industry demand. None of the respondents
stated that knowledge of BIM in regard to industry demand was not important or
that they did not know.

Over a third of the respondents stated that research in BIM was being conducted within
their respective academic unit.

A similar number of respondents representing architecture (43) and construction
schools (38) were surveyed for this research. Comparison of the responses from
architecture and construction schools showed that:

- While a comparable percentage of architecture and construction schools
  responded as having implemented BIM into curriculum, a slightly greater
percentage of architecture schools than construction schools responded as having
a BIM-dedicated course as part of existing curriculum. Also, 5% of the
architecture schools compared to 17% of the construction schools responded as
not having implemented BIM in any classes.

- A greater percentage of construction schools than architecture schools
implemented BIM at the freshman level. However, the largest difference was found
in the responses for BIM implementation at the graduate level, with a greater
percentage of architecture schools than construction schools implementing BIM at
the graduate level.

- VICO and Onuma BIM software were only taught by construction schools.

- When asked specifically if BIM models were used in teaching, a comparable
percentage of architecture and construction schools stated that they used BIM
models in teaching the coordination process, though a greater percentage of
construction schools used 4D models in simulating construction scheduling, and a
small percentage more construction than architecture schools used 5D models in teaching construction estimating.

The survey yielded encouraging response rates which suggest that schools are taking an interest in teaching BIM. A large majority of the schools surveyed had implemented BIM into the curriculum and had at least one BIM-dedicated course. Autodesk Revit was the most commonly taught BIM software, Primavera and Microsoft Project the most commonly taught scheduling software, and Excel-based and Timberline the most commonly taught estimating software. It can be concluded that BIM is studied at a greater depth in graduate studies; the survey results show that BIM is currently being implemented primarily at a basic level into undergraduate curriculum and at an intermediate level into graduate curriculum. BIM is first implemented as a 3D tool, followed by the addition of scheduling (4D), and lastly with the addition of estimating (5D). The majority of schools were interested in fully-integrating BIM, and very few schools felt that BIM implementation was not important.

Construction and architecture schools are implementing BIM as a response to the industry’s demands; the majority of schools surveyed expected students to have a basic or intermediate level of BIM knowledge upon graduation and felt that knowledge of BIM was important in satisfying industry demand. Research in BIM technologies is also being conducted; about a third of respondents stated that research on BIM was being conducted within their schools.

A greater percentage of architecture schools than construction schools implemented BIM into curriculum and had at least one BIM-dedicated course, as well as implemented BIM at the graduate level. This may be attributed to the fact that architecture schools often have graduate programs of study as opposed to many
construction schools, of which a greater percentage implemented BIM at the freshman level.

It is apparent that construction schools are embracing the teaching of construction estimating and scheduling to a greater degree than architecture schools. None of the architecture schools surveyed taught Vico or Onuma software. A greater percentage of construction schools than architecture schools used 4D models in simulating construction scheduling and 5D models in teaching construction estimating.

Schools in the United States are taking an interest in implementing BIM into existing curriculum as a means of adequately preparing students for the industry. Construction schools are embracing BIM’s scheduling and estimating capabilities while architecture schools focus on the parametric capabilities of BIM.

Recommendations for Improvements to the Survey

The following improvements could be made to the survey in order to clarify the questions for respondents and to better provide for accurate results:

- In regard to demographics, respondents were asked to select the discipline which their department represents. It was stated in the question that respondents were to “select all that apply” when answering this question. As many of the respondents represent schools which offer both architecture and construction programs, it was not clear in several cases whether or not the respondent, whether a department chair or college dean, meant to represent the architecture or construction department. This observation did not affect the overall results; however, it may have had some minimal effect on the stratified sampling results comparing architecture and construction schools. It is recommended for the future survey that the option to “select all that apply” be omitted from this question.

- In the “BIM Coursework” section of the results, 28% of the respondents stated that they use BIM models to teach the coordination process. It may not have been clear that the intent of the question was to ask if BIM models were used in teaching the coordination process, meaning 3D BIM. As a large percentage (78%) of the respondents stated that BIM had been implemented into the curriculum (in response to an earlier question in the “BIM-specific Demographics” section of the results), it is surprising that only 28% of the respondents stated that they use BIM to teach the coordination process. It is recommended in the future that the
question be reworded to clarify the meaning of the coordination process to mean 3D BIM.

- In the “Faculty Background” section of the results, respondents were asked to select the position of BIM faculty within their department. As teaching assistants can have sole control of classes, it is recommended to add the position of “Teaching Assistant” to the survey as an option for respondents. It is also recommended that the survey ask about the level of education of the BIM faculty.

- It is recommended that the survey include questions addressing the highest degree of study in each school surveyed and the level (freshman, junior, etc.) at which students are admitted to the respective program.

- The survey could be also be sent to schools which are members of the Associated Schools of Construction (ASC) provided that a question asking if the school is accredited is added to the survey. Schools which are accredited by the Accreditation Board for Engineering Technology (ABET) could also be surveyed for this research as representative of engineering schools.

- The results could also benefit from an analysis of the location of the schools surveyed and a comparison of schools in urban areas to those in rural areas.

- It is recommended that the future survey is sent directly to a specific individual at each school as opposed to either the dean or the director of the school. In many cases the dean or director was not able to answer the survey questions, leading to confusion of responsibility for responding to the survey when passed on to another faculty member.

Recommendations for Future Research

As industry demand for knowledge of BIM grows, schools are changing long-ingrained curriculum to accommodate new classes and technologies, and oftentimes, faculty selection is made with this transition in mind. It may also be beneficial to ask schools about the challenges in transitioning to BIM and what has been done to overcome such challenges in an effort to provide a guide to schools which are considering but have not yet attempted implementing BIM. Comparisons of educational curriculum within schools to that of education within the industry would also likely yield valuable results.
Please take this survey. If you do not have the knowledge to answer our questions, please forward the link to this survey to a faculty member who would be better able to answer questions about the current use of Building Information Modeling (BIM) in your curriculum.

1. What discipline does your school/department represent? (Please select all that apply)

- [ ] A. Architecture
- [ ] B. Engineering
- [ ] C. Construction
- [ ] D. Engineering Technology
- [ ] E. Facility Management
- [ ] F. Other (Please specify)

2. What is the number of tenure track faculty in your school/department?

Enter Value: _________

3. What is the number of non-tenure track faculty in your school/department?

Enter Value: _________

4. What is the student population in your school/department for each of the classifications listed?

- [ ] FR _________
- [ ] SO _________
5. Which academic institution do you work for?


6. Where are you located? (City, State, Country)

City
State
Country:

7. Has your department implemented BIM into your curriculum?

☐ Yes
☐ No

8. Do you offer a dedicated BIM course in your curriculum?

_____Yes  _____No

9. What BIM software is utilized in your curriculum? (Please mark all that apply)

☐ A. Bentley
☐ B. Autodesk
☐ C. VICO
☐ D. Graphisoft (Archicad)
☐ E. Onuma Planning System
10. What scheduling software does your school/department use in your curriculum? (Please list those you use if they are not listed)

- A. Primavera
- B. SureTrack
- C. Microsoft Project
- D. None
- E. Other (Please specify)

11. Who is teaching the BIM curriculum? (Please check all that apply)

- A. Lecturer (Full Time Staff)  
  How many: ________
- B. Faculty Associate (Industry Professional teaching 1 class)  
  How many: ________
- C. Tenure Track Faculty (Full Time Faculty)  
  How many: ________
- D. Guest Lecturer (Industry Professional presenting in a single class period)  
  How many: ________

12. What category best describes the background of those who are currently teaching BIM? (Please check all that apply)

- A. Architecture
- B. Construction
- C. Engineering
D. Engineering Technology

E. Facilities Management

F. Other (please specify)

13. How many classes offered in your school/department implement BIM as part of the curriculum?

14. What undergraduate class(es) currently implement BIM in the curriculum? (Please mark all that apply)

☐ A. Civil
Class Hours: ________ BIM Level: Basic Intermediate Advanced Class Format: Lab Lecture Both

☐ B. Design
Class Hours: ________ BIM Level: Basic Intermediate Advanced Class Format: Lab Lecture Both

☐ C. Electrical
Class Hours: ________ BIM Level: Basic Intermediate Advanced Class Format: Lab Lecture Both

☐ D. Estimating
Class Hours: ________ BIM Level: Basic Intermediate Advanced Class Format: Lab Lecture Both

☐ E. Mechanical
Class Hours: ________ BIM Level: Basic Intermediate Advanced Class Format: Lab Lecture Both

☐ F. Project Management
Class Hours: ________ BIM Level: Basic Intermediate Advanced Class Format: Lab Lecture Both

☐ G. Scheduling
Class Hours: ________ BIM Level: Basic Intermediate Advanced Class Format: Lab Lecture Both
H. Structural
Class Hours: ________ BIM Level: Basic Intermediate Advanced Class Format: Lab Lecture Both

I. Technology
Class Hours: ________ BIM Level: Basic Intermediate Advanced Class Format: Lab Lecture Both

J. Other
Class Hours: ________ BIM Level: Basic Intermediate Advanced Class Format: Lab Lecture Both
Please briefly explain how BIM is implemented into each of the courses

E. Other (Please specify)

15. What graduate class(es) currently implement BIM in the curriculum? (Please mark all that apply)

A. Civil
Class Hours: ________ BIM Level: Basic Intermediate Advanced Class Format: Lab Lecture Both

B. Design
Class Hours: ________ BIM Level: Basic Intermediate Advanced Class Format: Lab Lecture Both

C. Electrical
Class Hours: ________ BIM Level: Basic Intermediate Advanced Class Format: Lab Lecture Both

D. Estimating
Class Hours: ________ BIM Level: Basic Intermediate Advanced Class Format: Lab Lecture Both

E. Mechanical
Class Hours: ________ BIM Level: Basic Intermediate Advanced Class Format: Lab Lecture Both

F. Project Management
Class Hours: ________ BIM Level: Basic Intermediate Advanced Class Format: Lab Lecture
Please briefly explain how BIM is implemented into each of the courses selected.

16. What is the philosophy for implementing BIM in your school/department?

17. What would best characterize how you currently implement BIM into your undergraduate curriculum? (Please select all that apply)

A. Create models for 3D coordination
B. Implement scheduling into the models (4D)
C. Implement cost into the models (5D)
D. Implement other information into models (6D Operations & Maintenance)
E. None of the above
F. Other (Please specify)
18. What would best characterize how you currently implement BIM into your graduate curriculum? (Please select all that apply)

- A. Create models for 3D coordination
- B. Implement scheduling into the models (4D)
- C. Implement cost into the models (5D)
- D. Implement other information into models (6D Operations & Maintenance)
- E. None of the above
- F. Other (Please specify)

19. Do you currently teach construction scheduling simulations using 4D models?

- A. Yes
- B. No

20. What estimating software do you currently utilize? (Please list those you use if they are not listed)

- A. CostWorks
- B. D4Cost
- C. Excel Based
- D. Hard Dollar
- E. Innovaya
- F. On Screen Take Off
21. Do you currently teach construction estimating using 5D models?

☐ A. Yes
☐ B. No

22. Do you currently teach the Coordination Process using BIM models?

☐ A. Yes
☐ B. No

23. At what level is BIM implemented in your curriculum? (Please select all that Apply)

☐ A. Freshman
☐ B. Sophomore
☐ C. Junior
☐ D. Senior
☐ E. Graduate

24. What level of BIM knowledge do you expect students to have upon graduation?

☐ A. Basic Understanding
B. Intermediate Understanding
C. Advanced Understanding
D. Expert Understanding

25. If there are other skill sets (related to BIM Use and Collaboration) that are not listed that you feel a graduate of your school/department should have please list.

26. How do you feel that industry currently views the importance of BIM?

A. Very Important
B. Important
C. Somewhat Important
E. Not Important
F. Do Not Know

27. Are you or anybody in your academic unit conducting research on BIM?
Yes
No
If Yes, please list the BIM areas that research is being conducted in, the funding source and the grant amount. If the research is not funded, please leave the agency and amount blank.

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LIST OF REFERENCES


Goldberg, Edward. (2005). “Software strategy: BIM comparison: how does BIM software stack up with the 3D model concept?” http://findarticles.com/p/articles/mi_m0BLL/is_1_22/ai_n11836215/


BIOGRAPHICAL SKETCH

Maya M. Joannides began her education at the University of Florida in the fall of 2004. After receiving a Bachelor of Design in Architecture in May of 2008, she went on to earn a Master of Architecture from the School of Architecture in 2010 as well as a Master of Science in Building Construction from the M.E. Rinker, Sr. School of Building Construction in 2011 at the University of Florida. While a graduate student at the University of Florida, she worked for the M.E. Rinker, Sr. School of Building Construction as a graduate teaching assistant for the BCN 3255 Graphic Communications course, of which print reading and Autodesk Revit were the focus. A graduate teaching assistant for nearly three years, she gained extensive experience both in the use of and in teaching digital technologies.

During the consecutive summers of 2007 and 2008, she worked as an intern for an architecture firm in north Florida, exposing her to the processes involved from initial design to construction and allowing her to explore the capabilities of computer-aided design at an early stage.

Maya’s interests are nestled in the merging of the design and construction fields. She hopes to further the transition to BIM within the design and construction industry through teaching and implementing the skills she has acquired at the University of Florida.