THINKING SMART: INCORPORATING SMART BUILDINGS DESIGN

THEORY, BUILDING INFORMATION MODELING, AND INTEGRATED

PROJECT DELIVERY INTO ARCHITECTURE DESIGN SCHOOL

CURRICULUM

by

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Abstract

Building Information Modeling (BIM) and Integrated Project Delivery (IPD) methodologies are rapidly becoming fundamental core practices in the 21st-century architecture, engineering, and construction (AEC) industry. These two integrated industry design practices are the fundamental elements to the creation of Smart Buildings, the highest functioning efficient buildings in the world. The theory behind creation of these highly efficient structures is Smart Buildings design theory. Understanding the principles of Smart Buildings design theory assists architects in designing structures in a holistic way, beginning with the end in mind, establishing the role of responsible steward and practitioner towards a sustainable planet. In the United States, traditional buildings are responsible for 73% of electricity consumption and nearly 40% of total greenhouse gas emissions. Smart Buildings can help to conserve resources and protect the environment. Practicing architects and architectural students must be taught to think smart. One way to teach them is to evolve the architecture curriculum framework by inclusion of BIM and IPD, adapting modifications to an outdated approach to architecture education. This research project identified several key themes, both within and among the academy and the profession, relative to thinking smart and designing Smart Buildings. Technical software training courses are needed before such software finds its appropriate place in the architecture design studio. The AEC industry has an opportunity to transform its reputation as an industry of low technology and high inefficiency into one of high technology and extreme efficiency by shifting the existing paradigm and psychological mindset to BIM and IPD methodologies.

Dedication

I dedicate this dissertation to my mother and father, Betty and Alfred Gonzales, and to my wife, Magdalena, who have supported and inspired my dreams and aspirations with unwavering steadfastness.

Acknowledgments

Obtaining a doctoral degree is an academic ambition that should not be taken lightly. I could have never completed this journey without the guidance and support of many exceptional individuals, including my faculty mentor, committee members, numerous industry professionals, and colleagues in the architecture, engineering, and construction industry.

This project has allowed me to better understand the level of commitment required to fulfill a lifelong dream.

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CHAPTER 1. INTRODUCTION

Introduction to the Problem

Digital information technology continues to rapidly develop and to have a direct impact on every aspect of modern society. Robert A. M. Stern (as cited in Deamer & Bernstein, 2010), an iconic American architect and dean of the Yale School of Architecture, said, "In professional practice, coping with digitally enhanced technology in architecture has become a constant" (p. 15). As such, leaders of educational institutions are challenged to establish suitable ways to integrate these new technologies into the core curricula of traditional professions, including that of architect (Bruton, 2012). Building Information Modeling (BIM) and Integrated Project Delivery (IPD) are collaborative methodologies, each stemming from a technological foundation; together, BIM and IPD are the fundamental building blocks for the future of highly efficient buildings and facilities, also known as Smart Buildings. These collaborative methodological concepts provide architecture design students an innovative framework for a smarter, more efficient approach to the built environment, especially buildings and industrial facilities.

As noted by Yale University architecture professors Deamer and Bernstein (2011), "The architectural academy is only now beginning to critically examine what BIM might mean. . . . BIM pedagogy is in its infancy as various episodic experiences are conducted in design studios, digital fabrication labs, engineering curricula, and research projects" (Deamer & Bernstein, 2011, p. 1I). Thinking in a design computational context,

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BIM and IPD methodologies are common but hotly debated subjects among professional practitioners and the academy. Proponents of each approach have struggled to define the importance of technology in the traditional profession of architecture design (Erhan, Youssef, & Berry, 2012; Shelden, 2012).

Within the context of the architecture school curriculum as dictated by the National Architectural Accrediting Board (NAAB), Deamer and Bernstein (2011) pointed out there is an intellectual academic discussion between "teaching skills but not knowledge. This is where software instruction usually resides" (Deamer & Bernstein, 2011, p. 1). This academic ideology within the architectural design school curricula is where BIM technology currently resides as of 2014. Furthermore, most architects believe BIM is simply a three-dimensional computerized software program. The rationale behind this incorrect belief is simple: BIM technology is generally included as an elective or workshop course that offers zero degree-earning credit expressing the perception to those in architecture design schools of a non-essential professional career option (Deamer & Bernstein, 2011).

To address this shortcoming of awareness about the utility of BIM beyond the classroom, research was needed to explore how to incorporate BIM, IPD, and Smart Buildings Design Theory practices into the curriculum for NAAB schools of architecture in the United States. More critical is the need to find an effective delivery strategy to teach this technology once it has been introduced to the academic curriculum. Architecture design school curriculum experts posit that BIM can potentially be included in credit-earning courses such as structures technology, environmental courses, fabrication courses, or professional practice "not as a skill tool, but as an example of

methods that will be required of a graduate in most offices" (Deamer & Bernstein, 2011, p. 1). The challenge, then, is the decision of how to advance the historical and traditional role of the architecture profession in preparing to practice in the 21st century.

This study explored the architecture, engineering, and construction (AEC) industry trends as of 2014, as well as NAAB schools of architecture core curriculum requirements. In January 2013, the McGraw-Hill Construction SmartMarket Report indicated that an "industry-wide adoption of BIM surged from 28% in 2007 to 71% in 2012 . . . and they are forecasting even greater implementation over the next two years" (p. 4). Clearly, the AEC industry has embraced this technology. Additionally, the same report noted that a shortage of newly graduated architecture students who possess the BIM and IPD skills needed to fill the jobs in the 21st-century AEC industry. This critical educational gap can potentially affect the AEC industry for years to come. This study was conducted as a piece of original work (see Appendix A).

Background, Context, and Theoretical Framework

Seminal research suggests that the Smart Building is composed of advanced and integrated systems for "building automation, life safety, telecommunications, user systems and facility management systems" (Sinopoli, 2010, p. 3). When buildings and/or facilities are designed and constructed as a composite unit and in a physical and logical perspective, the results are high-functioning buildings with lower development and operational costs (Sinopoli, 2010). Although these truisms are widely recognized, there remains a general misunderstood perception in the AEC industry of how to efficiently achieve Smart Buildings design under the current architecture and engineering educational pedagogy and curriculum.

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Research has identified that students who are taught the function of collaborative thinking through computation digital design technology, the root of BIM, coupled with the concept of IPD (a collaborative contractual agreement) as the process rather than the means to an end, are more likely to fully realize the need for integrated practice later in their studies as well as in their professional practice (Monson, 2010). Structured pedagogies and instructional strategies of incorporating BIM and IPD into AEC curricula are well documented and recognized as a necessity for future architecture and engineering students (Barison & Santos, 2010; Joannides, Olbina, & Issa, 2012; Peterson, Hartmann, Fruchter, & Fischer, 2011; Sacks & Barak, 2010). The aim, then, is to raise awareness among NAAB architecture graduate-level program leaders of the need to change the characterizations of the architecture design school education.

BIM is the primary driving force of a paradigm shift in the AEC industry; this shift "will lead to changes in the performance of professionals in the Architecture, Engineering and Construction (AEC) sector" (Barison & Santos, 2010, p. 1). Research indicates that BIM reduces costs during the design, construction, and operational lifecycle of a building. Reducing cost in these critical building construction and operational elements is where the AEC industry can gain from integration of Smart Buildings Design Theory (Sinopoli, 2010). In addition to reducing costs, case studies have shown a major reduction in the overall time required to deliver a project (Bitterman, 2011). Time savings is especially evident during the construction phase of a project, when the project can be created 100% virtually before actual construction activities begin.

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Gallaher, O'Connor, Dettbarn, and Gilday (2004) supported the notion of virtual construction, revealing the inefficiencies in the AEC industry as noted in a report prepared by the U.S. Department of Commerce Technology Administration—National Institute of Standards and Technology (NIST). The AEC industry, which is generally acknowledged as advocating low technology and high fragmentation, has the potential to be revolutionized by including "3-D modeling technologies, a host of Internet- and standards-based design and project collaboration technologies" (Gallaher et al., 2004, p. ES-1). Additionally, this change in approach might boost innovation in a faltering industry that is also one of the largest revenue-generating industries, approximately $159T, in the world (U.S. Department of Commerce, 2012).

Architectural curricula in NAAB schools in the United States are grounded in either the *École de Beaux Arts* or Bauhaus pedagogical frameworks (Cheng, as cited in Deamer & Bernstein, 2011). Each of these frameworks are products of their time, although much of the pedagogical theories and reasoning remain influential in contemporary architecture design schools. In the 1920s, when the *Beaux Arts* movement was at its height, students focused on theories and the emphasis of instruction was on formal order, composition, and excessive and elaborate ornamentation. In the 21st century, architecture design students have focused more on how to reduce the carbon footprint of buildings and to develop creative and affordable housing solutions. Buildings, facilities, and construction projects in contemporary society vary vastly from those associated with royal commissions or summer palaces of a bygone era. Important tools of design students in the 21st century are personal computers and digital

computational software programs that did not exist in the days of *Beaux Arts* and Bauhaus.

Özener (2009) acknowledged that BIM and IPD should be included in the curriculum for graduate-level architecture students to enhance these students' overall preparedness to use current and future technology. Furthermore, Özener (2009) stated,

> One obvious potential continuation of this research is replication of the study in various M.Arch (Master's in Architecture) programs with different students groups, modified settings, and new tools. New experimental studies can serve as case studies for continuing research toward the creation of sound pedagogical strategies for BIM and IPD. (Özoner, 2009, p. 292)

Building on these findings establishes the foundation and hypothesis for this research project: BIM and IPD are necessary additions to NAAB architecture academic programs.

Statement of the Problem

Within the global AEC industry, newly graduated bachelor of architecture and masters of architecture students have experienced increasing difficulty in finding employment (Abdul-Alim, 2013). This difficulty is further exacerbated if architecture school graduates have not been exposed to, have not learned, or do not understand BIM and IPD processes for professional practice of architect. BIM and IPD are the foundational elements associated with Smart Buildings and building automated design theory. Smart Buildings Design Theory, BIM, and IPD methodologies represent current philosophies, workflows, and best practices among architects, engineers, construction managers, and building owners in the global AEC market (Eastman, Teicholz, Sacks, & Liston, 2011; Sinopoli, 2010).

Smart Buildings design theory is often referred to as Virtual Design and Construction (VDC). VDC postulates the advantage of being able to develop more

accurate design projects by enabling architects and engineers to examine multiple design options, produce engineering analysis, scrutinize cost effectiveness in constructability, and validate energy efficiency in buildings before physical construction is ever undertaken. These up-front activities contribute to the maximization of construction budgets and increased long-term revenue gains for building owners and operators, and therefore the built environment and society as a whole. The combination of these methodologies is the largest paradigm shift the AEC industry has ever witnessed and NAAB should consider including these key methodologies in the core curriculum for schools of architecture design in the United States.

Purpose of the Study

The purpose of conducting this qualitative study was to explore how advanced technology practices in the architectural design field are changing the overall AEC industry. Best practices for integration and implementation of these advanced practices and technology were researched to advance architecture design school curriculum. There was a need to investigate and evaluate the reasons why the majority of architecture design schools have not included BIM processes, technology software, or computational design methods training as part of their 21st-century curricula. Preliminary research indicates that schools of construction management (CM) and building trades have included components of smart buildings design theory and BIM into their curricula, so it was unclear why these professional practices had been excluded from curricula designed to train students preparing to become architects.

Historically, architects serve as primary conductors and primary points of contact on large-scale architecture and engineering design projects. Without architects'

knowledge of the concepts of Smart Buildings Design Theory, their role in large-scale building projects is diminished dramatically. The study was conducted to illustrate that Smart Buildings Design Theory and the principles and concepts of BIM and IPD should be a required curriculum components incorporated into all NAAB schools. By establishing these three components as core curriculum courses, enables newly graduated architecture students will have an advantage needed over graduates of CM programs and building trade schools. Equipped with the knowledge of Smart Buildings Design Theory, coupled with the traditional core theoretical and various schools of design knowledge, such as *Beaux Arts* and Bauhaus, advanced-degree graduate architects can remain an integral focal point of building construction projects.

Research Questions

The focus of this study was the extent to which architects understood, were exposed to, and used BIM and IPD in the AEC industry. Three research questions were developed and guided this study:

Research Question 1: How does the AEC industry perceive the incorporation of Smart Buildings Design Theory, BIM, and IPD processes into the curriculum of architecture design schools for maximum student and AEC industry benefits?

Research Question 2: What are the current ideologies in NAAB schools regarding the use of BIM technology and IPD methodologies in architecture design school curricula?

Research Question 3: How do BIM and IPD processes influence the 21st-century AEC industry and the practices of architecture professionals?

Subquestions designed to answer these three research questions were posed to two groups of professional licensed architects, university graduate school professors, and graduate-level architecture design school students. One group had been exposed to BIM and IPD, and the other group, which had not been exposed to BIM or IPD, served as the control group.

<center>**Rationale, Relevance, and Significance**</center>

Rationale

The AEC industry is often acknowledged as being a low-technology, and inefficient industry (Smith & Tardif, 2009). This negative label is harmful because the construction industry is also one of the largest industries in the world in terms of revenues (U.S. Department of Commerce, 2012). As of early 2014, the United States' infrastructure on the brink of failure after a lengthy recession, and climate change (partially due to energy consumption inefficiencies of historical buildings) has been pegged as causing everything from unorthodox weather patterns to global economic shifts (Katz, 2012). Workflows in the contemporary AEC industry have each party (e.g., architects, engineers, contractors) serving in individualistic roles, referred to as the silo-ed approach. This approach suppresses and discourages the sharing of vital project information early and often, a practice that has proven over the past 50 years to be inefficient (Smith & Tardif, 2009).

BIM and IPD methodologies call for each team member of a proposed building project to work collaboratively from the start. This approach has not been followed in 21st-century AEC marketplaces. By introducing both the problem and the solution to future architects early in their careers—while still in school—these behaviors could be

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reversed, allowing for the design and construction of more buildings and facilities utilizing a more efficient process. Exploring emerging trends in the AEC profession, coupled with understanding the relevance to curriculum in higher education, is important for individuals considering entering the field of architecture. Determining the impact of exposure to BIM and IPD in architectural students' schooling might encourage more NAAB schools of architecture to incorporate these programs into their curricula and thereby establish a foundation of knowledge that will be used throughout the lifelong careers of these graduate architects.

Relevance

When preparing students for their role as professional practitioners in the field of architecture, three competencies must be addressed: technology, business, and organizational issues (Demkin, 2008). Implementation of BIM technologies in organizations can have profound impacts. Preparing students during their coursework (i.e., adding BIM and IPD methodologies to schools of architecture curricula) would establish a foundation and fundamental knowledge to support new architects, allowing them to be better equipped to master the challenges that lay ahead.

Higher education students are proficient and comfortable with embracing change, especially as it relates to technology and information management. These advanced technologies help to "produce future professionals . . . to execute designs faster and produce designs that have demonstrably higher performance" (Özener, 2009, p. iii). Ambrose (2012) stated this sentiment most effectively:

> BIM . . . provides potential critical analysis of how architectural design is taught. Academia must seek out new design methodologies for exploring architecture that reflect the representational shift of BIM by developing teaching methods that reprioritize ways of seeing, thinking and making. (Ambrose, 2012, p. 54)

There is a paradigm shift occurring in the global AEC industry towards a more effective way to design, construct, and operate buildings. This technological paradigm shift applies to buildings of all shapes, sizes, and uses including residential, commercial, educational, healthcare, and industrial facilities. This paradigm shift is based on the development and advancements in technology since the dawn of the 21st century in the AEC industry. The most critical advances are BIM and IPD. As stated by Luciani, Garagnani, & Mingucci (2012) contributors of *Practical BIM 2012: Management, Implementation, Coordination, and Evaluation* at of the University of Southern California sixth annual symposium on Building Information Modeling,

> BIM, new design paradigm in the AEC world, is a methodology supported by sophisticated computer tools. At the ending of the 80's in the last century, a family of software products has been developed in order to gradually cover many requirements proper of the BIM approach. Nevertheless some fundamental aspects, although managed by current tools, still show limitations if compared to an ideal perfect world. (p. 19)

Additionally, when BIM and IPD methodologies are coupled with the principles of sustainability (often referred to as green building), this collective of components create the foundational principles of the Smart Buildings Design Theory. Globalization of business structures and business models in the AEC industry has influenced the global construction economies. Firms that have incorporated Smart Buildings Design Theory into their standard workflows have created a monumental shift and advanced beyond the competition. Forward-thinking and forward acting-companies that have embraced the core concepts of Smart Buildings are expected to outpace those that have not yet adopted these practices (Eastman et al., 2011).

A potential problematic issue related to professional architectural service firms is how to meet the needs of clients, specifically facility owners who require Smart

Buildings as the final deliverable of a project. The profession of architecture has begun to struggle with the issue of how to acquire suitable personnel who are educated and trained on the use of appropriate tools (i.e., BIM computational design tools), are familiar with IPD methodology, and who are able to incorporate these practices in the most efficient manner (McGraw-Hill Construction, 2013). Furthermore, it has been "widely acknowledged and increasingly well understood" that the social benefits of adopting BIM and IPD includes all beneficiaries of a building project, including the architect, contractor, owner, facility operators, subcontractors, and manufacturers (Deutsch, 2011, p. 13).

A comparative case study research method was employed in conducting this study. By compiling the responses from a questionnaire, supplemented with AEC industry member interviews and conversations, a viable theoretical understanding and approach was developed to incorporate 21st-century technologies into the core curriculum of the 200-year-old *École des Beaux-Arts* pedagogy of contemporary NAAB schools of architecture.

Significance

This study was significant because it addressed the need to advance the curriculum for 21st-century architecture students to include current technological advancements. The study advanced prior research by filling a knowledge gap involving an understanding of the impact of exposure to BIM and IPD in schools of architecture. Not only will the findings of this study help to educate students on the latest technology influencing the AEC industry, but also it will help future architects in knowing how to create better and smarter building designs (Özener, 2009).

BIM and IPD, the AEC industry technology addressed in this study, have gone from being "buzzword(s) with a handful of early adopters to the centerpiece of AEC technology, which encompasses all aspects of the design, construction, and operation of a building" (Eastman et al., 2011, p. vii). Additionally, experts in the field agree that the old methodologies of drawing-based computer-aided design techniques have been cast aside by the majority of leading architectural and engineering firms. Embracing technology is not only occurring in larger firms, but also at most other AEC firms who have realized the benefit of transitioning and heading towards implementation of BIM and IPD practices (Eastman et al., 2011).

The most critical component of the BIM and IPD adoption and movement involves more than just a technological change. That component is a process change—in essence, a psychological change in the way the industry performs its business practices and the process by the way buildings are literally put together (Eastman et al., 2011). The process of discovering why these critical tools of the trade have been excluded from the for-credit curriculum of the majority of architecture schools in the United States is of grave concern for the profession as a whole.

Nature of the Study

This research study employed the qualitative research method to determine how students' exposure in architectural design school curriculum to Smart Buildings Design Theory, BIM, and IPD can be included in today's schools of architectural design curriculum. Qualitative methodology was the appropriate method because what was being evaluated was the human experience as it was associated with the synthesis of the arts and science (Merriam, 1998). The objective of understanding the impact of BIM and

IPD exposure to this information as part of the architectural design curricula, and how that exposure, if so could be improved. This was accomplished by conducting interviews with master's-level architecture students, professors in schools of architecture, and practicing architect professionals. The sampling of this research study is aimed to include a wide range of various opinions associated with a somewhat controversial topic in contemporary AEC industry. Open-ended conversational interviews were conducted with members of professional organizations such as the American Institute of Architects (AIA), the National Council of Architectural Registration Board (NCARB), and the National Architectural Accrediting Board (NAAB).

Following the qualitative method of research allowed for an in-depth look into the perceptions of appropriate subject matter included in the curriculum for contemporary architecture students. In essence, this study examined the potential of moving forward from the traditional practical design and case method problem-solving educational learning methods used in architecture schools to a more theoretical and virtual design method.

The study was conducted using the comparative case study methodology. Comparative research is the process of looking at two similar groups and comparing them, by examining something about one or all of the things being compared (Heidenheimer, Hugh, & Adams, 1983). Using comparative research in this study showed how effective a particular strategy (i.e., integration of BIM and IPD technology practices) as an education curriculum component has been. Strengths of the comparative method are that the results of the study can be used to support educational and administrative decisions. Performing the research study within the diverse academic and

professional atmosphere of the New York City region allowed for the integration and assumptions of social and cultural components related to comparative research. Additionally, access to the required participants was readily available in the New York City area.

Comparison in this study included interviewing individuals from two NAAB schools: one at which a BIM and/or IPD component has been incorporated into the curriculum (with two or more classes) and one school at which a BIM and/or IPD component has not been incorporated into the curriculum. The study included interviewing students from each of the NAAB schools that participated. The research also included interviewing professional practitioners, both those who have incorporated BIM and/or IPD into their current workflow and those who have not. The study consisted of semistructured interviews conducted primarily face-to-face, including some specific questions as well as open-ended conversational dialog. The interviews were conducted with local professional practitioners and within universities in the New York City area.

Access to seminal sources and experts in the field was readily available within this researcher's current professional associations and memberships. An initial document review was conducted with information from several NAAB schools in the United States. As of 2013, there were 154 NAAB-accredited professional programs in architecture housed in 123 institutions offering the following degrees: doctor of architecture (1), master of architecture (95), or bachelor of architecture (58; NAAB, n.d.). The only way to become a professionally licensed architect in the United States is to earn a degree from an NAAB school.

The logic of this comparative case study was established by clearly selecting the relevant groups. The unit of analysis was based on the small group category (Yin, 2009). Small groups consist of three to five participants. Data were collected from a sampling of three primary sectors: architects (current practitioners), university professors and/or administrators in NAAB schools of architecture, and currently enrolled architecture students in NAAB schools of architecture. Three participants from each of the three groups from the two separate settings were interviewed for a total of between 14 and 18 participants. The number of participants needed for this exploratory unit of analysis was based on the rationale of not including too many participants, not too many schools, or too many regions; preventing the danger of collecting an overwhelming amount of data and ensuring that the study remained reasonable in scope (Stake, 1995).

Mason (2010) stated that, "There is a point of diminishing return to a qualitative sample—as the study goes on more data does not necessarily lead to more information" (p. 2). Data collection from small-group category participants results in more concrete findings (Yin, 2009). Furthermore, each of these participant groups collaborates with one another in the field of architecture, which culminates in mutual overall benefit. Interviews continued until saturation was achieved. In other words, if the same results continued to be similar or exactly the same among the population, the interviews were discontinued. The researcher believed the sample size was large enough and diverse enough that the important perceptions were uncovered and that the data did not become repetitive or superfluous.

The interviews were conducted in the settings chosen as appropriate for each group. For the professional architects group, the interviews were conducted in their office

and/or the public location of their choice. Professors and/or administrators group members were interviewed at their university office and/or the public location of their choice. For the students group, the interviews were conducted at the university or a public location of their choice.

Definition of Terms

Building Information Model (BIM). A digital representation of the physical and functional characteristics of the facility [that] serves as a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its life cycle from inception onward (National Institute of Building Sciences [NIBS], 2007, p. 21).

Computer-aided design (CAD). Design based on computer technology, including software applications, processes, and output files, developed to improve efficiency and precision in the creation of technical drawings. CAD drawings may be two-dimensional (2-D) or three-dimensional (3-D), and are used to visualize building plans, elevations, interior spaces, subsystems, fixtures, and other elements used in a BIM model (Rouse, 2011).

Design. A general term used for the tasks performed by architects and engineers, specifically in the preparation of plans, specifications, and design analysis. Plans and specifications are required to be clearly identified in terms of the design phase they represent.

Integrated Project Delivery (IPD). A method of project delivery distinguished by a contractual arrangement among a minimum of owner, constructor, and design professional that aligns business interests of all parties. IPD motivates collaboration throughout the design and construction process, tying stakeholder success to project

success, and embodies contractual and behavioral principles. Contractual principles

include (a) key participants bound together as equals, (b) shared financial risk and reward

based on project outcome, (c) liability waivers between key participants, (d) fiscal

transparency between key participants, (e) early involvement of key participants, (f)

jointly developed project target criteria, and (g) collaborative decision making.

Behavioral principles include mutual respect and trust, willingness to collaborate, and

open communication (AIA, n.d., para. 1).

Parametric. A technological term used to identify interrelated 3-D geometry

shapes.

Smart Building. A product and a process of being a high-performance building,

an automated building, or an intelligent building. The goal of Smart Buildings is to

decrease first costs, decrease operating cost (including energy), decrease the

environmental impact and increase occupant comfort, convenience, and safety. Architects

and constructors achieve Smart Buildings by adjusting and modifying the traditional

design and construction process and using technology to better manage and maintain the

building. A Smart Building integrates building technology systems at a physical, logical,

and application level. These systems are integrated horizontally among all subsystems

and vertically to facility management and business systems. Systems may include

building automation, life safety and security, telecommunications and power, energy and

enterprise management systems, and information management software. The integration

design of a Smart Building should include structured cable, open network protocols and

standardized databases, and take advantage of existing and emerging technology (World

Architecture Community, n.d., para. 1).

Assumptions, Limitations, and Delimitations

Assumptions

The researcher who conducted this study has had more than 10 years of exposure to the concepts, methodologies, and issues discussed in this study. The researcher was an AEC industry expert in the AEC Smart Buildings industry and has provided consulting training and implementation principles to some of the leading architecture and engineering firms in the world. The researcher took pains to remain unbiased throughout the study, allowing for the collection and synthesis of the data to provide the most accurate understanding of Smart Buildings technology influence on the academy, primarily NAAB graduate schools of architecture.

Limitations

Weaknesses in this study involved members of the groups having strong biases on their level of involvement with the Smart Buildings movement. This bias also contributed to a weakness regarding disagreement over the importance of incorporating these technological methodologies into a graduate-level architecture program, or an undergraduate program, for that matter.

Delimitations

The scope of these issues, BIM, IPD, and Smart Buildings design theory in academia was far too broad to cover in one study. This study contributed to the discovery of whether or not there is a true need to include these 21st-century industry practices in academic preparation for the profession. Speculation rests on whether BIM, IPD, and Smart Buildings design theories (as well as other associated industry technologies) are necessary subject matter that should be included in the future by NAAB schools of

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architecture. Incorporating Smart Buildings theory, BIM and the IPD methodologies have shown the potential to disrupt the current practices in typical A/E firms and to replace an outdated system with a far more efficient one (Deutsch, 2011).

In a competitive global engineering climate, far-sighted firms have sought ways to gain the advantage in all aspects of the design, bid, and construction processes. The financial bottom line is rapidly becoming a heavily weighted element along the critical path of large-scale engineering and real estate development projects. Firms seek qualified individuals to add to the assets of the company; they are finding the task of securing these individuals increasingly difficult. That search and that difficulty are the primary reasons these two critical and advanced technologies must become a core component of the architecture design school curriculum. The 20th-century curriculum being taught in most schools of architecture in the United States is outdated. Evidence of that truth is reflected in online forums where architects are questioning, why are NAAB architecture schools not teaching BIM? This study validated and produced a recommended process for advancing the architecture academic and practitioner roles.

Organization of the Remainder of the Study

The remainder of the study includes a review of literature, which is presented in Chapter 2, the details of the methodological approach presented in Chapter 3, the analysis of the data presented in Chapter 4, and the summary of findings and conclusion presented in Chapter 5.

CHAPTER 2. LITERATURE REVIEW

Introduction to the Literature Review

This review of the existing literature involved examination of research studies that reflect an emerging consensus as well as equally differing opinions that contribute to the complex environment of technological integration in the professional architect's practice. This environment is the realm in which the educational process of BIM and IPD methodologies occurs. The literature is focused on the following five topics: (a) history of the architecture profession, (b) formalizing education (examining emergence of architecture design school curriculum, (c) 19th- to 20th-century theory for educating architecture students, (d) entry of the architecture profession into the digital age, and (e) technology and efficiencies in Smart Buildings as a frequent topic of discussion in the AEC industry. The resources for the literature review were distilled from key industry journals in the fields of architecture, engineering, education, and digital computing. Pedagogical approaches in current schools of architecture were reviewed from books and reports, which included the Association of Collegiate Schools of Architecture (ACSA), AIA, NAAB, and the NIBS. Additionally, the literature review validated the choice of the case study qualitative research methodology used for this study.

Theoretical Framework

The educational theory of constructivism is a viable element for examining techniques for the strategic implementation of advanced 21st-century technology into a

profession that stems from ancient and classical approaches (Gül, Williams, & Gu, 2012).

Architecture can be traced to an identifiable activity that is several thousand years old.

However, in American history, the first formal education of an architect, Richard Morris

Hunt, occurred in the mid-19th century, when he attended the *École des Beaux-Arts*

(School of Fine Arts), which had been established in Paris, France, in 1621 (Yatt, 1999).

According to constructivism theory, students build upon prior knowledge; in the

case of architecture students, prior knowledge is accrued in years 1 and 2 of a bachelor of

architecture degree program. From this point, it is worthwhile for students to examine a

potential focus area that may include cutting-edge, technological, and forward-thinking

approaches to the profession of architecture. University-level educators must be prepared

to embrace technology when thinking about new ways to address traditional teaching

methods, by moving away from didactic instruction methods of standard lecture and

note-taking techniques to a more innovative student-centered approach. The teaching

practice must be self-reflecting on foundational pedagogical beliefs because the

introduction and implementation of BIM technology cannot stand on its own without

prior pedagogical evaluation.

There is a critical breakdown in this area. What seems to occur in American

schools of architecture is that the professor themselves have been sheltered and separated

from what occurs in real-world practices (Deamer & Bernstein, 2011). Many university

professors have not been exposed to and/or have become disconnected from the new

industry methodologies such as BIM and IPD (Tombesi & Deamer, 2011). This missing

connection relates to the concept of prescriptive theory, a theory that describes how

educators help students learn, an instructional method used to foster learning. Prescriptive

theory, as noted by Gagné and Briggs (1974), yields maximum the efficiency and capacity of human learning when educators seek to minimize the time required to transfer information into memory and maximize the efficiency of retrieving that information.

The Gagné-Briggs (1974) theory of instructional design is composed of nine procedures. The initial procedures are intended to gain the student's attention. As the procedures continue, the process culminates with the enhancement, retention, and the transfer of knowledge. Current understanding and speculation regarding the evolutionary function of the brain and the learning process should assist such prescriptive delivery learning theories in designing learning environments that provide for maximum learning efficiency (Blanchard & Thacker, 2007). Furthermore, prescriptive learning theory can only become relative if academic administrators and professors can also commit to fostering these advanced real-world industry practices.

Hamilton and Watkins (2009) discussed the educational practices in architecture schools in the 21st century; similar to other educators, they stated that despite the changing realities of the [architecture] practice, architectural education has not changed significantly (Ambrose, 2012; Barison & Santos, 2010; Deamer & Bernstein, 2011). The 2014 NAAB architecture school curriculum and educational model is based on the 19th-century *École des Beaux-Arts* and Bauhaus methodologies, both of which prepare students for an outdated and invalid form of practice in the 21st century (Cheng, as cited in Deamer & Bernstein, 2011). Arguments include the lack of education in the areas of technical competence, interdisciplinary teamwork skills, comprehensive knowledge of social and behavioral sciences, and lack of scientific perspective for evidence evaluation.

According to Hamilton and Watkins (2009), integrated teaching models posit the principles of preparing future architects for integrated collaborative practice (i.e., IPD methodology). Additionally, they proposed an evidence-based design approach to pair up the teaching of sustainability (Green Design), both important components of Smart Buildings design theory principles. Hamilton and Watkins further stressed that the changing directions of the profession compel educational institutions to engage in a thorough analysis of the state of architectural education with a long view of the future state of architectural practice. This effort should lead to well-reasoned suggestions for curriculum revisions and restructuring of the design studio model.

Review of the Research Literature and Methodological Literature

To understand the future of the architecture practice, it is necessary to examine the origin and development of the practice.

History of the Architecture Profession

The initial practice of architecture began in the ancient world during the great Egyptian and Greek Empires, with documentation dating the architect's presence in 3000 B.C. In terms of graphical accounts, research has estimated that the architect, as a planner, was evident as far back as 7000 B.C. (Kostof, 1977). In those times, the architect was simply a conceiver of a structure prior to it undergoing construction. As Kostof (1977) remarked, "This is what architects are, conceivers of buildings. What they do is to design, that is, supply concrete images for a new structure so that it can be put up" (Kostof, 1977, p. xvii). During antiquity, the architect was purely associated with the rich and powerful, which included aristocratic landowners, the state, and the Church. During

this time, the architect held no social hierarchy and was held only slightly above the laboring classes.

At the time of the Roman Empire (approximately during the 1st and 4th centuries), the architect began to earn a slow ascension in social status as an important and influential person. During this era, "a fully trained Roman architect was also expected to be expert in construction, hydraulic engineering, and surveying and planning" (MacDonald, as cited in Kristof, 1977, p. 28). Throughout the Roman Empire, architecture was closely aligned with the art world, in essence, making architecture the art of buildings. There were no formal educational processes for architects; they were still largely the product of craftsmen or artisans who worked with their hands.

The architecture profession entered the Western Middle Ages (13th–14th century) and began to formalize in terms of building commissions, building programs, aesthetics, symbolism, and formal methods of documentation (Kostof, 1977). The Middle Ages were an era of great structures: cathedrals, castles, and monasteries. The architect's education came by way of apprenticeship. The architect, often referred to as a master builder, generally rose through the ranks that evolved from an empirical craftsman's skill as the foundation. The architect's professional was also grounded in liberal arts; the architect was considered to be an expert in the knowledge of building technology (Kostof, 1977). Individuals were selected and sponsored primarily by the Church for their expertise in overseeing the construction of the great cathedrals.

The emergence of the Italian architect during the 15th century was the first recognition of the architect as a profession or specialization (Ettlinger, as cited in Kostof, 1977). During this period, the foundation for the profession as it came to be known was

established, although the architect was still considered among the ranks of artisans. There was no formal educational school devoted to individuals who wished to supervise or gain practical knowledge.

The Italian Renaissance (mid- to late-15th century through early 17th century) was a fascinating setting for the development of elaborate art, architecture, philosophy, and culture. During this period, the rise of the profession of architect was attributed to the expansion of new concepts, theories, and technologies in Western civilization, many which directly influenced the form of buildings (Burke, 1999). These environmental humanistic concepts and theories included order, arrangement, proportion, symmetry, décor, formalism, and distribution of objects in a way that affected the overall synthesis of urban surroundings. Buildings were analyzed, rationalized, and understood for their role in developing hubs of commerce (Lowry, 1965). The Italian architecture student was usually identified at a young age; however, he still apprenticed under the supervision of a painter or sculptor with no formal educational curriculum or pedagogy (Ackerman, 1954).

The initial formalization of the principles of the profession of architect occurred in England around the mid-16th century (Kostof, 1977). Changes in both the intellectual and social schools of thought were the catalysts that spurred society to recognize the architect as a professional. Additionally, the economic shift from an agrarian-based society to a capitalist-based society was a contributing factor. Shute's (as cited in Kostof, 1977) book, *The First and Chief Groundes of Architecture* (1563), was among the first to discuss theories in the context of architectural design. The architect's professional traits and personality were expanded to include characteristics, talents, and proficiencies in

literature, history, philosophy, astronomy, and medicine, not just drawing, surveying, or arithmetic. A notable practice was the highly collaborative process that carried over from Medieval times.

The *École Nationale et Speciale des Beaux-Arts* was established in Paris, France, in the mid-17th century. The *École*, as it was called, was noted as one of the leading academies of the world; it had a high set of standards in regards to painting, sculpture, and architecture. The *École* firmly established itself as the first formalized architecture educational program in the world. The Academy of Architecture within the *École* became the prototype for architecture education in the United States, focusing on a structured curriculum of rational design theory and governmental patronage (Draper, as cited in Kostof, 1977). The architecture student's curriculum focused on examining the classical ancient Greek and Roman buildings, on *atelier* (studio design courses), lectures, and competition programs; students were also required to demonstrate exceptional drawing skills (Kostof, 1977). In 1968, the *École des Beaux-Arts* ceased offering instruction or granting diplomas in architecture.

American students returning from studying abroad at the *École des Beaux-Arts*, namely Richard Morris Hunt and William Robert Ware, were instrumental in establishing schools of architecture in the United States. These schools of architecture emerged at the same time as the development of the U.S. democracy, and the Industrial Revolution—vital elements in the social paradigm shift. In the early to mid-19th century in the United States, the architect's practice had advanced from a craftsman (a construction craftsman builder or building mechanic) to a professional (Wood, 1999). As defined by Benjamin Henry Latrobe, the first professional architect and professional practitioner in the United

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States, was said to possess "combined theoretical knowledge with a practical understanding of building" (Wood, 1999, p. 9). This era also introduced the still-controversial issues of duties, authorities, and compensation. These same issues are attributed to the splintered building construction process of the 21st century—a noncollaborative, independently focused process: a non-IPD approach.

19th-Century Formalizing of the Architect Education

Formalization of architecture design and construction education in the United States in the mid-19th century came about from the British artisan and craft apprenticeship approach to learning. These individuals were known as building artisans. Through this method, the student received no wages, though he was supplied with food, clothing, and lodging. The apprenticeships generally lasted only a few years; although apprenticeships were meant to last seven years, this standard rarely adhered to (Wood, 1999). This apprenticeship-style methodology and specialized craft techniques such as carpentry and bricklaying set the foundation for the architectural education curriculum.

In 1857, the AIA was founded. The mission of the AIA is to "promote the scientific and practical perfection of its members" and "elevate the standing of the profession" (AIA, n.d., para. 1). A primary objective of the AIA founders group was to formalize architecture school education. The original concept for a formalized architecture education in the United States was to be based on the *École des Beaux-Arts* fundamentals. This concept called for formation of a grand-scaled central school, much like the *École des Beaux-Arts* in Paris, in which artisans, builders, engineers, and architects were all taught together, a foreshadowing of IPD methodology (Wood, 1999). However, the AIA failed to acquire the appropriate funding for the conceptual program,

and was forced to settle with implementing a less favorable curriculum program that was developed by Robert Ware of Massachusetts Institute of Technology (MIT, n.d.).

Prior to 1857, there were no formal schools of architecture in the United States and no formal licensing laws existed. Anyone (masons, carpenters, bricklayers) who wanted to identify himself or herself as an architect was allowed to do so. Forty years later, 1897, Illinois became the first state to develop and adopt professional licensing laws, which created a legal definition of an individual to call himself or herself an architect (AIA, n.d.). The founding of the AIA was the seminal moment that began the profound evolution of the profession of architect.

The first university architecture programs launched in the United States were at MIT (Cambridge, MA), Cornell (Ithica, NY), and Columbia (New York, NY), all in the northeastern region of the country. These schools followed the English tradition of teaching a profession by providing a solid foundation in the liberal arts (e.g., history, mathematics, philosophy, literature, visual arts, music, and theology). The architecture curricula of these early university programs also included courses in drafting, design, materials, construction techniques, and professional practice, defining the architect as the building project orchestrator (Wood, 1999). Two additional schools, the University of Illinois (UI) and the Tuskegee Institute, followed next to serve architecture students in the midwestern and southern regions of the country. UI instituted a 2-year program geared specifically to builders and contractors, the forerunner of the modern CM degree programs, as well as a 2-year program in architectural engineering, neither of which had entered formal education (Wood, 1999).

In 1865, the first formalized school of architecture, the MIT School of

Architecture and Planning, was founded in Cambridge, Massachusetts, by William

Robert Ware (Wood, 1999). In developing the curriculum at MIT, Ware examined

curricula and professional practice from France, England, and Germany, attempting to

create a synthesis of what was best from each of these models (MIT, n.d.). The

curriculum offered structured, formal courses, which included classes in humanities, fine

arts, applied science, and the history of architecture. Ware's program, however, was still

peppered with influences of the *Beaux-Arts*, though with substantial differences. The

MIT School of Architecture and Planning became known as the leader in introducing the

modernism style to America.

Charles Babcock was another innovative architecture professor in the late 19th

century; he was a follower of Ware's approach towards the synthesis of best practices

from architecture education and practices from around the world. Babcock served as the

first architecture professor, dean, and director at Cornell University from 1871 to 1896.

Additionally, Babcock was one of the founding members of the AIA. Babcock's

approach towards an architectural curriculum included an emphasis on the physical

sciences, building materials, building technology, construction techniques, and historical

examination of Medieval architecture. Babcock also proclaimed that "before an architect

can become a true artist, he must be a master of the art of building and a man of science"

(Cornell University, n.d.,). Upon Babcock's retirement from Cornell University in 1897,

a formed *École* student, Alexander Trowbridge, took over and transformed the

architecture school curriculum to return to École standards. Cornell School of

Architecture was re-focused on learning about classical order, architectural drawing, design competitions, and the design studio agenda (Wood, 1999).

Although architecture curriculum and education was still not wholly defined, the *Beaux-Arts* curriculum became the preference of 19th century time period, primarily because this education style developed extraordinary draftsmen. Skilled draftsmen were needed to assist master architects who were designing large-scale commissions in New York. Furthermore, many individuals were still learning the craft through apprenticeship, informal drawing schools, sketch clubs, and correspondence schools. During the 19th century, initial formalization of architecture education meant university architecture programs had minimal influence on the profession.

20th-Century Theory for Educating Architecture Students

At the start of the 20th century, additional formalized schools of architecture continued to develop at Harvard, Yale, and the University of Pennsylvania. The curriculum at these architecture design schools followed the favored *Beaux-Arts* pedagogy of the time, a pedagogy that reflected architecture as a fine art. These were the programs that produced talented draftsman and shaped the structure for the modern American architect's professional office. The 20th-century architect's office evolved from a one- or two-man operation into large-scale corporate design factories (Wood, 1999). This business model further influenced the methodologies and direction for formal architecture design education.

However, around 1919, a new school of thought for theories in design and construction began to emerge and replace the *École des Beaux-Arts* pedagogy. The Bauhaus school of thought was defined and developed by influential German architect

and educator Walter Gropius. The Bauhaus was an international style in modern architecture with a curriculum consisting of experimental principles of functionalism, truth in materials, and practical training in workshops. The workshops were laboratories for developing models ripe for mass production, implements typical of the present day: a union of art and technology. This curriculum was intended to give artistic direction to industrial projects (Samson, 2005).

The Bauhaus style infusion from Europe in 1919 reflected a time of "technological leaps in engineering, building materials, and construction technology" (Cheng, as cited in Deamer & Bernstein, 2011, p. 14). Many of the immigrants seeking refuge from the wartime instability of Germany found themselves educators in American schools of architecture. The fundamentals of the Bauhaus style were focused on developing "a relationship between artistic culture and industrial civilization" (Ockman & Williamson, 2012, p. 117). The striking difference in the Bauhaus style, as it was delivered as an educational method in the United States as compared to the European approach, was in a much more pragmatic approach as opposed to the avant-garde attitudes of the time.

The Digital Age and the Architecture Profession

The onset of World War II sparked a global technological revolution, a *zeitgeist* of the Digital Information Age. This technological revolution was similar in scale to extraordinary global changes brought on by the Industrial Revolution. These tremendous innovative changes were experienced in the automotive, aerospace, manufacturing, and shipbuilding industries, all of which influenced the architectural design process. Furthermore, these advancements in technology changed the architectural practice in

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ways few individuals could have predicted. A paradigm shift radically changed how buildings were going to be conceived, designed, and produced. The Digital Age began shaping a different style of architecture, but even more, it changed the role of the architect and architecture education. What began to occur was a change in methodology of not only how architects designed buildings, but also how the components of buildings were manufactured and constructed (Kolarevic & Malkawi, 2005). The advent of the Digital Revolution brought on computational transformations of geometric space and contributed to architects' realization of the differences between what can be designed and what can be built.

In the early 1960s, the engineering world witnessed the development of the first interactive graphics and drafting tool—"Sketchpad"—developed by Ivan Sutherland and recorded in his Ph.D. thesis at MIT (Duan, 2004). Two newly developed technologies were being infused into the engineering world around the mid-1900s: one was a new interactive graphics technology dubbed computer-aided design (CAD) and the other was a technological methodology called numeric control machining, which was later renamed computer-aided manufacturing (CAM). Since then, the terms CAD, CAM, and/or CAD/CAM became industry buzzwords for what would take place in transforming the architecture profession.

In the 1960s, CAD programs were being developed mostly to assist aeronautic and aerospace engineers, but around the early 1980s, an open-source software program that could run on Microsoft Windows operating system was released. It was named AutoCAD. The first release of AutoCAD Version 1.0 was revealed at the COMDEX show in Las Vegas, Nevada, in November 1982; in 2014, it remains the most widely used

CAD program in the world. The AEC industry would never be the same. The small personal computer-driven CAD software revolutionized the integration of a technological approach to architecture. The question remained, would there be a need to teach architecture students this new technology?

Smart Buildings Become Subject Matter in AEC industry.

The release of AutoCAD in the early 1980s sparked the advent of digital computing entering the architecture and engineering design fields. Furthermore, this approach to designing buildings forever changed the AEC industry. The early release of AutoCAD and the infiltration to the industry provided the end user (the architect or engineer) with a low-cost and precisely accurate, fast, and efficient CAD authoring tool. These digital design tools helped designers to also think differently about the way various components of a facility related to each other.

The most widely accepted, fundamental acknowledgement and definition of Smart Buildings was credited to James Sinopoli (2010), which stated,

> Smart Buildings use building technology systems to enable services and the operation of a building for the betterment of its occupants and management. The drivers for Smart Buildings are the positive financial effects of integrated systems, energy conservation, greater systems functionality, and the continuing evolution of technology. The headwind to Smart Buildings is the inertia of people to move beyond the legacies of building design, construction and operation. Such processes as Building Information Modeling as well as the movement to energy-efficiency and sustainable buildings are beginning to change that, forever. (Sinopoli, 2010, p. xiii)

One of the first mentions of the concept of Smart Buildings was in an article published in the *New York Times* in 1984, which noted "a new generation of buildings that almost think for themselves . . . called intelligent buildings. An intelligent building has a computer for a brain and a fiber-optic cable nerve system" (Prial, 1984, p. L16). At that

time, the Smart Buildings concept was born and several technological trends began to take shape. Many of these new technological advancement were also attributed to the rapidly emerging and evolving personal computer. As of 2014, many of the concepts of Smart Buildings technology remain misunderstood by residential, commercial, and industrial building owners who do not recognize the economic value inherent in the efficiencies of Smart Buildings design.

When discussing the approach to Smart Buildings design theory, many individual components interrelate to make up the complete system. These components include heating, ventilation, and air conditioning (HVAC) systems; sustainability (green) energy and water efficiencies and conservation; lighting and electrical control systems; security; and data networks. The macro-elemental and primary processes for integrating each of these microcomposite components into Smart Buildings come via the BIM and IPD methodologies (Sinopoli, 2010).

What is BIM?

The underlying concept of the BIM process is described by Eastman et al. (2011) as the methodology "to develop an electronic representation of a building, in a form capable of supporting all major activities throughout the building lifecycle" (p. 72). The BIM concept was further refined as a "modeling technology and associated set of processes to produce, communicate and analyze building models" (Eastman et al., 2011, p. 16). Since its introduction, the BIM process has been a 21st-century emerging practice in the AEC industry.

Smith and Tardif (2009) further qualified the differences between the process and informational data warehousing or extraction. Their definition explained that the goal of

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BIM is not simply to create a single 3-D building model but, "instead, the goal is compiling a comprehensive, reliable, accessible, and easily exchangeable building information for anyone who needs it throughout the life cycle of a building" (Smith & Tardif, 2009, p. xix). The real business process in the AEC operations (AECO) industry must be aligned to substantiate bilateral communication and exchange of information among stakeholders to maximize value, and, as of 2014, this requirement has not been met (Eastman et al., 2011; Sinopoli, 2010; Smith & Tardif, 2009).

The NIBS, through the Whole Building Design Guide's National BIM Standard (NBIMS) document, provided a combined vision and definition for BIM technology. That vision/definition stated,

> BIM is an improved planning, design, construction, operations, and maintenance processing using a standardized machine-readable information model for each facility, new or old, which contains all appropriate information created or gathered about that facility in a format usable by all throughout its lifecycle. (NIBS, 2007, p 6)

The one core concept of BIM is that "nothing more—and nothing less—than a systems approach to the design, construction, ownership, management, operation, maintenance, use, and demolition or reuse of buildings" (Smith & Tardif, 2009, p. xxi).

These concepts described the distinction of BIM from the technologies typically used in contemporary architectural practice: non-intelligent CAD programs. BIM furthered the information about a building or facility and its relationships in an intelligent, data-rich fashion, enabling the lifecycle processes of the building. In essence, the BIM concept prescribed a philosophy that incorporated all essential informational characteristics of 3-D modeling, object-oriented representation, project database, interoperability, and simulation.

BIM models are composed of 3-D solid and surface shapes, which are used to represent the building components of the facility or structure. These components, often referred to as families, are composed of numerous combinations of geometric shapes, including rectangles, volumes, triangles, circles, b-splines, and Booleans loaded with metadata that describe what each component consists of. Additionally, each of these geometric shapes can be combined to create true-to-life virtual representations of any component associated within a building structure. Furthermore, these combined components create systems that can then be viewed in countless ways.

It must be understood that buildings and/or facilities are generally composed of seven primary cumulative components: (a) architecture (e.g., walls, doors, windows, stairs, escalators, elevators, roofs); (b) structural (e.g., concrete foundations, slabs, steel columns, beams, joists); (c) mechanical HVAC; (d) mechanical plumbing (hot and cold water, sanitary ventilation); (e) fire protection; (f) electrical (e.g., power, lighting, and special systems); and (g) information technology (e.g., building automation systems, building management systems, computerized maintenance management systems). Following are several examples of how a combined 3-D BIM model can be viewed.

Architectural example: Building core and shell. An architectural BIM is composed of the facility wall types, window types, floor types, roof types, and finishes.

Architectural example: Real-life visual rendering. As the architecture BIM progresses throughout the phases of design from schematic design to design development and construction documents, the BIM can be used to provide powerful graphic representation of the project.

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Architectural interiors. Architectural BIMs can also be used to provide clients with photo-realistic visualization renderings to provide information about furniture, fixtures, and equipment (FFE), space layout, and accessibility requirements.

Structural engineering example: Structural analysis components. BIM combines physical representation and digital analytical representation for structural engineering analysis, project coordination, and drawing production.

Mechanical engineering example: Mechanical ductwork systems. BIM mechanical ductwork systems physically and analytically describe the engineering design integrity of the system for the ventilation and air conditioning systems for the building.

Mechanical plumbing (hot and cold water, sanitary ventilation). BIM plumbing systems physically and analytically describe the water distribution, plumbing fixtures and sanitary venting systems of the building.

Fire protection example: Fire safety sprinkler system. BIM fire protection systems physical and analytically describe the fire protection distribution piping, sprinklers and shutoff valves.

Electrical power, lighting, and special systems example. BIM electrical systems physically and analytically describe the lighting, power, and special systems including the light fixtures, power distribution panels, circuiting and switching systems.

BIM has many various codified acronyms, and the researcher of the present study assumed that the definition of BIM included the following variables: virtual and digital modeling, VDC, parametric modeling, performance simulation analysis and assessment, building product models, database management, networking, interoperability and digital

communication in the context of design, construction, and operation stages. According to

Kymell (2008), the primary BIM processes fall into the following four major groups:

- processes that enable all members of a design project to develop an accurate understanding of a project;
- processes for the design, development, and analysis of the project with virtual models and simulations;
- processes for the management of procurement and construction of the project; and
- processes related to operations management during the actual use.

Kymell's definition of the process provided the alliance and structure of the BIM concept

for the remainder of this study.

Additional Factors of the BIM Process

In the market of the 21st century, architects and engineers deliver three main

components of a project: drawings, specifications, and estimates. Additional elements

that considered as being part of the project deliverable are the incorporation of 4-D, 5-D,

and 6-D BIM. Further, with the introduction of new technology into an established

industry, computer software programs are expected to make a great contribution.

Extensive industry research contributes that "architectural firms of all sizes from around

the world are adopting BIM as both a technology and a process… allows for new

leadership roles to develop within innovative architectural design firms" (Skripac, as

cited in Kensek, 2012, p 29). Adaptation of the process of BIM in an organization is the

crux of the arguments: It disputes the status quo within the current state of the industry.

4-D BIM (Scheduling). The time required for a facility or building to become

available for use, known as its time to market, is heavily dependent on schedule

management. Supported within the BIM process is 4-D BIM, which combines 3-D

parametric geometry with project scheduling. 4-D BIM is the concept of construction

scheduling, a dynamic technique that can be used to examine or evaluate the status of a project before it is constructed, during various construction phases, at project completion, or at any specified date during the project (Kymmell, 2008). The primary and essential benefit of 4-D BIM is that this tool allows for the project design team (the architect, structural engineer, HVAC engineer, and electrical engineer), the contractor, and the owner to interactively simulate and evaluate the impact of planned construction sequences (Eastman et al., 2011). 4-D BIM is a relatively new innovation incorporated into the BIM process that uses technological software advancements to produce model-based animated timeline visualizations of the project delivery.

4-D BIM connects or links the 3-D BIM parametric geometry of the project with the project schedule. A project schedule is usually created in a software program such as Microsoft Office Project, or Oracle Primavera Project Management. Each component of the BIM project has a unique ID code; uniqueness allows for this code to be linked to a construction activity in the schedule. The dynamic process capability of 4-D BIM allows for project team to plan, evaluate, and predict the pre-construction approach, the status during construction, and future outcomes. Furthermore, 4-D BIM has been added to the traditional document deliverables. The final deliverable of a 4-D BIM is a documented project approach that can be used to track and provide start and end dates or any unforeseen time factors to quickly inform the project stakeholders whether the project is on track, ahead of, or behind schedule (Eastman et al., 2011).

The introduction of this design and construction technical concept should be presented to undergraduate and graduate students in NAAB schools of architecture. Doing so would allow for students to understand the impact of construction scheduling

and sequencing on construction logistics, construction crew scheduling, as well as other building component procurement activities on the life of a project. The overarching technical aspects of this subject are beyond the scope of this study, but are included to provide the reader with a fundamental conceptual understanding of this technology as it currently exists in the AEC industry (Messner, Holland, Poerschke, Parfitt & Madis, as cited in Deamer & Bernstein, 2011.)

 5-D BIM (Quantification). One of the most critical elements associated with the proposal of designing and constructing any new building or facility is the aspect of financial cost. As a project develops throughout the design phase using the BIM process and with further technologic advancements, it has become possible to perform electronic quantity takeoffs and cost estimating functions, known as 5-D BIM. 5-D BIM allows for rapid interim cost estimates to be performed that help to identify potential financial impacts early in the project development cycle so that alternatives can be considered. Using the 5-D BIM quantification process allows for the design team and owner to make more informed decisions (Eastman et al., 2011).

 Owners of large-scale buildings and facilities, such as the U.S. General Services Administration, college and university campuses worldwide, business corporation campuses (Google, Microsoft), state and federal facilities, and commercial and residential landlords are constantly challenged to improve operational efficiencies, generally by reducing cost. For architects, project managers, planners, and quantity surveyors, integrated 5-D BIM enables exploration of several different design scenarios. This capability is accomplished by illustrating the impact of any multitude of design changes on the facility and, most importantly, the budget.

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5-D BIM cost estimates and/or quantity takeoffs can be linked to the BIM model so that a change in the design is immediately reflected in the budget and program. As part of the BIM process and IPD methodology, using the 5-D BIM component makes it possible to work within a live interactive model. When the geometry of a facility is made (e.g., a longer wall, higher roof, wider windows or doors), the 3-D parametric geometry model will change the calculations for the program and cost. 5-D BIM provides the project teams with resource-loaded quantities, accurate cash flow forecasts, and even resource forecasts for major subcontractors (Muzvimwe, 2011).

It appears credible to provide the introduction of the 5-D BIM quantification design and construction technical concept to undergraduate and graduate students within NAAB schools of architecture. This addition to the curriculum would allow for architecture students to understand the impact of construction scheduling and sequencing of construction logistics and construction crew scheduling on the life of a project. The overarching technical aspects of this subject matter are beyond the scope of this study, but are included to provide the reader with a fundamental conceptual understanding of this technology as it currently exists in the AEC industry.

6-D BIM (Facilities management and operations maintenance). Recognized as the latest component of the intelligent BIM process, 6-D BIM has been defined as "optimize facility management and maintenance by exporting relevant as-built building and equipment information to start the systems that will be used over the lifecycle of the facility" (Eastman et al., 2011, p. 152). At the completion of a project, the BIM has been developed and populated with data-rich information to reflect as-built conditions.

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Additional information has also been included on most major assets of the building, such as the commissioning actions and the preventive maintenance protocols.

In a study conducted by the NIST, it was estimated that facilities operations inefficiencies in the United States cost $15.8B per year (Gallaher et al., 2004). Most of this financial waste can be attributed to a drop in the level of attention regarding critical building documentation as the project nears completion. Owners often receive disconnected or outdated construction documents, specifications, and critical equipment manuals. The focus becomes closing out the facility and receiving certificates of occupancy and owner handover.

6-D BIM methods have been developed to account for properly verified and processed documentation, all of which is then intelligently linked through parameters into the BIM model. Using 6-D BIM tools allows for facilities managers to quickly navigate through a 3-D model of the entire facility and to identify the buildings systems and components. The 6-D BIM software solutions can also alert and notify building engineers when issues arise or preventive maintenance is required on critical assets.

Although these scientific approaches are beyond the requirements of NAAB schools of architecture students, industry professionals have agree that it is credible to provide the introduction of the 6-D BIM technical concepts to graduate architecture students (Emig & Holley, as cited Deamer & Bernstein, 2011). This introduction would allow for architecture students to understand the impact that the contributions they make to the built environment have far-reaching consequences and should be considered during the design and construction processes. The overarching technical aspects of this subject are beyond the scope of this study, but are included to provide the reader with a

fundamental conceptual understanding of this technology as it currently exists in the AEC industry.

BIM software market summary. Within the context of the discussion of technology in 21st-century architecture design school curriculum, computerized software authoring tools warrant discussion. These BIM authoring tools allows for architects and engineers to create model 3-D ("families") that are flexible (parametric) and adaptable to satisfy countless numbers of architectural or engineering design intents. Much of the technology behind the capabilities of BIM authoring software is beyond the scope of this study. The reader should be aware that, as of 2014, there are a multiple software authoring tools capable of creating conceptual design that are beyond most architects' or engineers' creative imaginations.

As more members of the AECO industry join the discussion regarding the BIM process, additional attention must be focused on concepts that directly relate to the use of existing IT and information management resources in these already established AECO tasks and processes. IT is the physical backbone that allows for the BIM applications to work cohesively. At the time of authorship of this paper, there are several BIM authoring tools and software solutions available for both general and specific needs of the AECO industry.

Computer software vendors have different strategies, perspectives, and approaches for the development of BIM technology and for specific software design such as usability, design analysis, and documentation. As of 2014, the predominant BIM authoring tool is Revit, developed by Autodesk. Additional BIM authoring tools include ArchiCAD and Constructor developed by Graphisoft, AECOsim Building Designer

developed by Bentley Systems, Nemetschek VectorWorks Architect, and Tekla

Structures developed by Trimble. In addition to the 3-D BIM authoring tools, there are

various 4-D BIM (construction scheduling) tools such as NavisWorks and Innovaya. 5-D

BIM (quantification) software tools include Autodesk Quantity Takeoff (QTO), and Vico

Office developed by Trimble. The 6-D BIM (facilities management and operations)

software market is in its infancy; however, one 6-D BIM software integration tool is

EcoDomus. EcoDomus has been implemented at several government agencies, university

campuses, and corporate campuses in the United States. Worth mentioning are the

additional software solutions used for sustainability-related analytics. These include

Autodesk Green Building Studio and Ecotect.

What is IPD?

One cannot address the influence of Smart Buildings and BIM in the AEC

industry without the mention of IPD methodology. IPD has been defined as the "method

of project delivery distinguished by a contractual arrangement among a minimum of

owner, constructor and design professional that aligns business interests of all parties"

(AIA, 2013, para. 1). The IPD methodological process integrates "people, systems,

business structures and practices into a process that collaboratively harnesses the talents

and insights of all participants to optimize results, increase value to the owner, reduce

waste, and maximize efficiency through all phases of design, fabrication and

construction" (AIA, 2007, n.p.). The IPD concept arises from the well-documented

production inefficiencies that have plagued the AEC industry over the last century.

Teicholz (as cited in McGraw Hill, 2009) noted that "construction labor

productivity declined by nearly 20% between 1964 and 2003, while other non-farm

industries improved by more than 200%" (p. 12). Gallagher et al.'s (2004) study reported

construction industry inefficiencies rose to 30% waste, contributing to an estimated

$15.8B losses. The U.S. Bureau of Labor reported that all other non-farm industries

increased productivity to over 200%. The construction industry was the only industry that

became more inefficient over the past century (Teicholz, 2013).

Unfavorable statistical research results have caused many facilities owners to

examine the traditional project delivery methodology. The traditional project delivery

methodology consists of

- a fragmented approach to construction by fabricating and assembling on a "just-as-needed" or "minimum necessary" basis;
- a linear, distinct, segregated knowledge-gathering technique, hoarding information within the silos of knowledge and expertise;
- an individually pursued approach of minimum effort for maximum results;
- a paper-based, 2-D approach to documentation, analogical; and
- a unilateral effort to allocate transfer and risk by not sharing information (AIA, 2007).

It has also been well documented that consumers of building industry services

will benefit significantly from BIM and IPD, realizing that there is a better way to design,

produce, and deliver building construction projects. As noted by Salmon (2010),

Sophisticated consumers of building industry services see increased efficiency and productivity in almost every other sector of the economy. They are stunned and dismayed when the construction industry insists on delivering services in accordance with project delivery methods and business processes that date to post World War II era. (Salmon, 2010, para. 22)

Furthermore, IPD contractual agreements are evaluated on the ability of all

project team members to collaborate transparently and equitably by tying each

stakeholder's success and failure to conform to an IPD methodology (AIA, 2007). Much

of these IPD contractual agreements, however, depend on the ability of stakeholders to

understand—in essence, to be educated about—the structure of the process. The seven

elementary contractual principles of an IPD project are

- key participants bound together as equals;
- shared financial risk and reward based on project outcomes;
- liability waivers between key participants;
- fiscal transparency between key participants;
- jointly developed project target criteria; and
- collaborative decision making.

These core contractual principles are supplemented with three behavioral principles for

stakeholders, which include

- mutual respect and trust;
- willingness to collaborate; and
- open communication (AIA, 2011).

These principles can be enacted on public, private, or public-private/partnership

projects. However, each participant associated with a project, regardless of the role of the

individual or organization for whom he or she works (e.g., owner, constructor/sub, trade

constructor, design professional, and so on), must abide by these contractual and

behavioral principles to ensure successful outcomes.

With the advancements of the technical revolution, facility owners have

demanded that their projects be delivered more effectively, be designed better, be built

better, and be done with lower costs. Imagine, within the concept of the IPD

methodology, a facility manager, the end users (e.g., teachers, researchers, and office

personnel), contractors, and suppliers are all involved from the beginning of the design

process. Imagine the sole contributing factor for the outcome of the project is not based

purely on cost (change orders during construction are the common cause of cost

increases). Imagine the vast array of professional architect and multiple engineering

disciplines who are responsible for the design fully understanding the ramifications of their design decisions at the time the decisions are made. Envision the risks and rewards being structured based on value and appropriately balanced among all team members throughout the lifecycle of a facility. Finally, examine the overall sustainable aspects of a higher quality built facility within the ever-expanding global building warehouse (AIA, 2007). These imaginings are fundamental core contributions of knowledge that is required to improve the overall efficiencies in the AEC industry.

Many of these IPD success elements hinge on how the project data are housed, how they are shared, and how accessible these data are to project team members. These factors contribute to realizing the reliability and consistency for efficiencies in designing Smart Buildings (Gallaher et al., 2004). When project team members have access to real-time information about the project, relationships are established that yield reduced amounts of rework, less miscommunication, and overall time savings during the design and construction phases. Furthermore the evolution of the cloud allows for design professionals to collaborate virtually instantaneously, no matter where they may be located.

Shared risk correlated to the creation of reward for architects is a key strategy when evaluating the compensation of architects. Focus must be shifted from a tactical protectionist practitioner towards the goals of architectural design performance. Architect Phil Bernstein (as cited in Dispenza, 2013,) stated, "we (architects) need to harness the ability of information technology to create a degree of transparency, and use technology to make qualitative assertions" (para. 8). As of 2014, technology exists that allows for extensive collaborative examination and analysis of the design and construction risks that

should be harnessed. However, it is a matter of educating the project stakeholders to recognize the value proposition and harness the beneficial outcomes, which, in essence, create greater efficiencies.

Review of Methodological Issues

Qualitative case study methodology is the logical choice to employ to understanding the state of NAAB schools of architecture in 2014 because what is being examined is the human factor. Scholars and practitioners agree that the main cause for the slow recognition and adoption rate of BIM, IPD, and Smart Buildings design theory has not been not technology, but the lack of understanding, education, and reluctance of the status quo to think differently (Duetsch, 2011). The human factor, as it relates to aligning the social benefits of BIM and IPD to the academy and the profession, include the social benefits of "sociological, behavioral, collaborative, psychological, and motivational benefits of adopting BIM" (Deutsch, 2011, p. 14)

Additionally, the qualitative case study methodology lends itself to this study because the topic correlates to the three advantages of case study research: "the research questions, the control the investigator has over the actual behavioral events, and the focus on contemporary as opposed to historical phenomena" (Yin, 2009, p. xix). In this study, the research questions called for an interview style for the collection of data. Also, because the study was conducted in the New York City area, the investigator had access to resources in both the academic and professional arenas. Lastly, the focus of the study was on the effects of 21st-century technology on a traditional profession, which has real-life context.

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Purposive Case Study

Conducting research in the qualitative research framework generally allows for much smaller samples. However, qualitative research can also be labor-intensive. Conducting purposive case study research is unique in that it is "not sampling research" because "we do not study a case primarily to understand other cases" (Stake, 1995, p. 4). Furthermore, Yin (2009) stated, "if a sampling logic had to be applied to all types of research, many important topics could not be empirically investigated" (p. 56). In this case study research, the cases (those that were using technology in architecture curriculum and those that were not) were purposefully chosen to highlight or illustrate aspects of the phenomenon in question (Creswell, 2009). As a result, there was no sampling framework or listings necessary from which to select a sample.

Saturation

In the present study, the primary objective was to compile an adequate amount of qualitative data that would assist in understanding that "Putting BIM in the early, core studios where it can be tackled head on, early on, and by everyone, then makes sense" (Deamer & Bernstein, 2011, p.1). Therefore, several questions had to be answered when determining the potential make-up of a group of research participants. How many participants are needed? When will participants be chosen? What is the basis for participant selection? To support these issues and to ensure that the quantity of representative data were collected, the method of saturation was applied as the guiding principle. Saturation has been described as the point where it becomes "counterproductive" and that "the new [that] is discovered does not necessarily add anything to the overall story, model, theory or framework" (Strauss & Corbin, 1998, p.

136.) Although the number of speculated participants was evaluated, saturation was the ultimate driver in determining the study size.

Synthesis of Research Findings

If BIM and IPD methodologies are to be taken seriously in academia as well as at the practitioner level, both the academy and profession must be willing to explore the unknown and embrace the risk of the marketplace in elevating the efficiency of the AEC industry. Furthermore, as stated by Deamer and Bernstein (2011), Yale School of Architecture professors, "BIM is an opportunity for architecture to recapture its rightful place in the building industry, some of us also think that academia should seize it as an opportunity to reimagine the education of a designer/architect" (p. 3).

This review of literature defined the need for an extended look into the 21st-century schools of architecture pedagogy and curriculum methodologies. The pedagogical methodologies of the *Beaux-Arts* and Bauhaus schools are antiquated. The techniques used to graphically represent conceptual designs 200 years ago remain valid; the only difference is that they are not being generated on ink and canvas, but on high-powered computer processors and software programs. The message is the same, the message conveyance is different.

Examination of the top NAAB schools of architecture in the United States reflected that although technology was one part of a master's in architecture (M.Arch) degree program, BIM or IPD methodologies were nowhere mentioned, specifically by name. The top architecture schools were retrieved from an online list (Rosenfield, 2012). Curricula for the top five, Harvard University, Columbia University, Yale University,

Massachusetts Institute of Technology, and Cornell University, revealed any courses specifically related to BIM technology content.

Critique of Previous Research

The general consensus among academic peer-reviewed scholarly articles was agreement that BIM and IPD technology has rapidly advanced and become the primary design methodology used in contemporary architecture design firm. However, as Joannides et al. (2012) remarked,

> The extent of BIM implementation in accredited programs in architecture and construction education at universities in the U.S. has not yet been fully determined. Information about the current state of BIM education would be helpful to both industry and to academia. (Joannides et al., 2012, p. 84)

Joannides et al. (2012) conducted an extensive research study focusing on BIM and IPD in education. Their study involved a quantitative survey of the Association of Collegiate Schools of Architecture (ASCA) curricula. Although the report was helpful, the ASCA does not govern the academic curriculum for U.S. schools of architecture: the NAAB is the only accrediting board that can approve or deny architecture school academic curricula. Therefore, this study focused only on NAAB schools of architecture for data compilation.

Georgia Institute of Technology initiated a BIM-centric program, which revealed the capabilities of BIM and IPD methodological approaches in specific building technology courses. These courses are offered as part of the Master of Science degree with a major in architecture and a concentration in digital design and fabrication (Georgia Tech, 2013a). A seminal proponent of BIM in academia, Charles Eastman, leads the Georgia Tech degree program. The program includes a definitive BIM courses, such as: ARCH 6501 Analogue Digital Design Computation, ARCH 6503 BIM Applications, and

ARCH 6507 Parametric Design (Georgia Tech, 2013b). Inclusion of this program

validated the importance of sharing data across the design intent using parametric objects.

Much of the previous research has examined micro-level details of the BIM

software and processes and has not addressed the root of the issue: where do future

architects learn the basis of Smart Buildings design theory concepts and

integrated/collaborative project development methodologies? From an architecture

practitioner's point of view, Krygiel and Nies (2008) provided a comprehensive

framework for BIM adoption to support green building design addressing BIM

technology, process, and organizational change in architectural design practice.

Combining current global issues with Smart Buildings technology theories further

justifies the need for inclusion in of this course of study in education.

Furthermore, the architectural design firm Kieran and Timberlake (2004)

produced strong viewpoints regarding contemporary architectural construction processes

by comparing them to emerging manufacturing methods used in the aerospace and

automotive industries. To produce a manifest for architecture practice in the 21st century,

Kieran and Timberlake addressed the changing relationships between the major aspects

of architecture such as aesthetics, art, form, production, and commodity. They proposed a

vision for the future—that the new architecture will not be about style, but will urge

integrated and collaborative methods and processes that underlie successful deliverables:

buildings.

According to Kieran and Timberlake (2008), the segregated and silo

specialization model of the 20th century is no longer sustainable and should not be

accepted. The production of a building design becomes a part of the process by working

with assemblers from the outset; this approach makes more sense, especially in regards to design errors and omissions. In the BIM and IPD methodologies, the designers function not only as the form creator, but also as the conduit of information to the producer, who determines how things are made and provides the sequence of assemblies and joining systems.

Architects Kieran and Timberlake (2008) set out to prove and stress their point on the importance of parametric modeling and BIM for the whole design and construction process of in a project called the Loblolly House. The process narrative manifested this new paradigm of design as simulation not representation (Kieran & Timberlake, 2008). The process in developing the Loblolly House was based on a kit of parts, a prefabricated approach through the utilization of intensive use of parametric BIM models. Additionally, the BIM process was used to simulate construction process and optimize the supply chain. Design and detail documentation were made with iterative stages of parametric modeling. Kieran and Timberlake (2008) merged all system layers of the building, used parametric components provided by suppliers, and created specific reports and documentation extracted from the integrated building model. Sunlight studies and environmental analyses were also performed using the model (Kieran & Timberlake, 2008).

Chapter 2 Summary

Technology is rapidly advancing. Much attention has been focused on incorporating technological tools into the curriculum of many academic fields. The incorporation of these tools, such as the personal computer, the Internet, and software applications, has been evaluated at all levels of the educational spectrum, from preschool

education to advanced university-level degrees (Picciano, 2001). Emphasis on technology in the classroom has also become a priority for administrators who need to incorporate these contemporary instructional tools into their schools. Two previous dissertations focused on incorporating technology into an academic curriculum. These studies used the qualitative research method.

The common understanding of BIM implies two of its major components as the process and the information, which are facilitated by the adequate technology. This facilitation involves the generation and utilization of coordinated, consistent, and computable information in all stages of the building lifecycle (Clayton et al., 2009).

Existing literature includes well-reasoned arguments and studies demonstrating the effective use of advanced IT to support building design. According to industry books, recent articles and research papers, BIM has received intense attention in the AEC/FM (Facilities Management) industry (Teicholz, 2013; Azhar, 2011, Becerik-Gerber & Jazizadeh, 2012; Sabol, 2008). This attention has been partly driven by software vendors' marketing efforts as well as by growing recognition of the theory of information integration and the resulting process efficiencies described in industrial papers and reports.

As noted in the Mc-Graw Hill SmartMarket Report (2009), the business value of BIM includes:

- improved jobsite efficiency through more effective interfacing of people, processes, materials, equipment and information;
- greater use of prefabrication, preassembly, modularization, and offsite fabrication techniques and processes;
- innovative and widespread use of demonstration installations; and
- effective performance measurement to drive efficiency and support innovation.

As noted by the U.K. Office of Government Commerce (2007), IPD results in greater efficiencies. The U.K. Office of Government Commerce estimated that savings of up to 30% in the cost of construction can be achieved when integrated teams promote continuous improvement over a series of construction projects. The U.K. Office of Government Commerce further estimated that single projects employing integrated supply teams can achieve savings of 2-10% in the cost of construction.

The practice of architecture continues to change at a rapid pace, primarily due to advancements in technology and global organizational business structures. Forward-thinking academics as well as practitioners imagine an education in architecture "where students fluidly exploit the latest technology to develop their studio designs, instantly tapping 3-D information and testing and improving their projects after using sophisticated analytical tools" (Cheng, as cited in Deamer & Bernstein, 2011, p. 12). Academic accounts such as these should spur NAAB schools of architecture curriculum committees to examine their approach to integrating BIM and IPD into schools or architecture.

This review of literature identified gaps in the literature and established a foundation for identifying the need for industry corroboration and a proposed theoretical model for BIM adoption into schools of architecture curriculum. Regardless of the thousands of academic peer-reviewed scholarly articles and dozens of books written on the importance of advancing the AECO industry, the one critical issue has yet to be addressed: the people problem (Deutsch, 2011). The review of literature identified the need of begin to condition the mindset of future architects by introducing the principles of BIM technology early on in students' academic programs.

Building projects have become more competitive, with owners demanding greater efficiencies, fewer project change orders, and shorter construction schedules. Owners expect faster tracks to tenant occupancy. These factors are the main drivers for implementing a technological and collaborative methodology in the design and construction industry.

CHAPTER 3. METHODOLOGY

Introduction to Chapter 3

The qualitative research method was selected for this educational curriculum study. The qualitative method provided the appropriate narrative and descriptive approach based on an empirical process to derive and produce a descriptive portrait of the findings. Qualitative research, as noted by Gay, Mills, and Airasian (2006), "is the collection, analysis, and interpretation of comprehensive narrative and visual data in order to gain insights into a particular phenomenon of interest" (p. 399).

Purpose of the Study

The purpose of this qualitative study was to explore how potential changes and enhancements to the core curriculum and how this will affect NAAB schools of architecture and graduate architecture students throughout the United States. This study was conducted to better understand if Smart Buildings design theory and the concepts of BIM and IPD could assist the NAAB to make better decisions about incorporating current technology trends into the M.Arch curriculum. As noted in the McGraw-Hill Engineering News Record (Sacolick, 2012), the premier AEC trade journal, the flow of young practitioners acquiring skills in BIM has shrunk, which may affect the industry for years to come. The data collected from the present study was intended to help to explain the appropriate techniques, styles, and methods needed to incorporate these advanced design methodologies firmly into the base curriculum in schools of architecture. This

change is critical to ensure the advancement and future esteem of the profession of architect.

Research Questions and Hypotheses

A comparative case study was conducted and consisted of two specific groups: those who used BIM and IPD technology in their current professional practice or academic coursework and/or pedagogy, and those who were not. The following research questions were posed to each participant of each group:

Research Question 1: How does the AEC industry perceive the incorporation of Smart Buildings design theory, BIM, and IPD processes into the curriculum of architecture design schools for maximum student and AEC industry benefit?

Research Question 2: What are the current ideologies in NAAB schools regarding the use of BIM technology, and IPD methodologies in architecture design school curricula?

Research Question 3: How do the BIM and IPD processes influence the 21st-century AEC industry and the practices of architecture professionals?

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Research Design

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The qualitative research method allowed for an in-depth look into the perceptions regarding appropriate subject matter included in the curriculum for 21st-century architecture students, as required by the NAAB (see Appendix B for NAAB guidelines). In essence, the study sought to understand whether there was believed to be a need for moving forward from the traditional practical design and case method problem-solving educational learning methods used in most architecture design schools as of 2014.

The study was conducted using the comparative case study methodology. Comparative research method is the process of looking at two similar groups and comparing them by examining something about one or all of the things being compared (Heidenheimer et al., 1983). Conducting comparative research in this study facilitated the researcher to obtain insight into how well a particular strategy (integration of BIM and IPD technology practices) incorporated or not incorporated as an education curriculum component has worked, as perceived by architect students and practicing professional architects. Strengths of the comparative method are that the results of the study can be used to support educational and administrative decisions. Performing the research study within the diverse academic and professional atmosphere of New York City allowed for the integration and assumptions of social and cultural components related to comparative research. Additionally, access to the required participants was readily available in the New York City area.

The comparison included interviewing four NAAB schools, two of which have incorporated a BIM and/or IPD component into their curriculum (with two or more classes) and two schools have not included a BIM and/or IPD component. The study included interviewing students from each of these four NAAB schools. The research also included interviewing professional practitioners who have incorporated BIM and/or IPD into their current workflow, and those who have not.

The study consisted of semistructured interviews conducted primarily face-to-face, including some specific questions as well as open-ended conversational dialog. The interviews were conducted with local professional practitioners and within universities in the New York City and surrounding area. Access to seminal sources and experts in the

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field of architecture were readily available within the researcher's professional associations and memberships.

Target Population, Sampling Method, and Related Procedures

In alignment with the strategies for qualitative case study methodology, listed below will describe the specific characterization of the target population, the sampling methods, and additional related procedures that were followed to conduct the research problem.

Target Population

An initial document review was collected from several NAAB schools in the United States, and was then narrowed in focus to only those in the northeast region of the country. As of 2014, there were 154 NAAB accredited professional programs in architecture housed in 123 institutions offering the following degrees: doctor of architecture (1), master of architecture (95), or bachelor of architecture (58; NAAB, n.d.). The only way to become a professionally licensed architect in the United States is to earn a degree from an NAAB school.

Participants were chosen based on their involvement with the field of architecture, either as practicing professionals, professors, or as students. They either had or had not been exposed to BIM and/or IPD in school, and either were or were not using the technologies in their professional practice or instruction curriculum. Industry participants (professional practicing architects) were selected based on their previous experience with BIM methods and their technological capabilities, and each of the participants in this group represented firms that had accomplished comprehensive projects using BIM methods and technology and those firms that had not made the transition. Faculty

participants were selected according to their expertise and experience with studio

teaching and integration of digital methods in architectural education, and those faculty

members who had no exposure at all to these technologies. Student participants were

those who had been exposed to BIM and IPD in course study and those who ha no such

exposure at all.

The design of the case study groups was established to facilitate collection of

comprehensive information from each of the different audiences. A multiple category

design was used with different audiences of industry representatives, faculty, and

students. The participants represented a broad audience including large and mid-sized

architectural design firms. The faculty audience represented schools that offered diverse

expertise in architectural education, teaching of technology, and digital design principles.

Students were selected from NAAB M.Arch program, with the additional requirement

that they had taken at least two BIM and/or IPD courses (if they were assigned to the

"have" group). A summary of the number of members in each participant group, as

proposed and actual, is presented in Table 1.

Table 1. *Expected and Actual Numbers of Interviewed Participants, by Category*

Expected participants (*n*)	Participant category	Actual participants (*n*)
2–4	Professional with BIM practice	3
2–4	Professional with NO BIM practice	2

Table 1. *Expected and Actual Numbers of Interviewed Participants, by Category*
(continued)

Expected participants (*n*)	Participant category	Actual participants (*n*)
2–4	Faculty with BIM curriculum	3
2–4	Faculty with NO BIM curriculum	2
2–4	Students with BIM curriculum	2
2–4	Students with NO BIM curriculum	2

Establishing the logic of this comparative case study was based on selecting participants for the relevant groups. The unit of analysis was based on the small group category (Yin, 2009). Small groups consist of three to five members. Data were collected from a sampling of three primary sectors: architects (current practitioners), university professors and/or administrators in NAAB schools of architecture, and currently enrolled graduate architecture students in NAAB schools of architecture. Participants from each of these three categories were organized into groups according to whether they had or had not been exposed to BIM and IPD. There were a total of 14 participants.

The number of participants needed for this exploratory unit of analysis is based on the rationale of not including too many participants, not too many schools, or too many regions, thereby preventing the danger of collecting an overwhelming amount of data and ensuring that the study remained reasonable in scope (Stake, 1995). As Mason (2010) stated, "There is a point of diminishing return to a qualitative sample—as the study goes on more data does not necessarily lead to more information" (p. 2). Data collection from small group category participants results in more concrete findings (Yin, 2009).

Furthermore, each of these participant groups have collaborated with one another in the field of architecture, which culminates in mutual overall benefit.

Interviews continued up to saturation, which means if the same results continued to be similar or exactly the same among the population, the interviews were discontinued. The researcher believed the sample size was large enough and diverse enough that the important perceptions were uncovered and that the data did not become repetitive or superfluous.

The interviews were conducted in the following settings: for the professional architects group, the interviews were conducted in their office and/or the public location of their choice. Interviews with the professors and/or administrators group were conducted at their university office and/or the public location of their choice. Interviews with members of the students group were conducted at the university or a public location of their choice. All of the interviews were audio-recorded, transcribed, and coded for conceptual content and analysis. All of the participant questions were developed based on the preliminary research questions and research objectives.

Sampling Method

The sample was derived using purposive sampling design. The population for this research study included architects (members of the AIA, the NIBS, and those publicly listed on the New York State professional licensing website (NYSED, 2014), NAAB university professors and/or administrators, and architecture students who were attending a M.Arch program at the time of the study. The researcher's intent was to interview between 14 and 18 participants; 14 individuals were interviewed. As shown in Table 1, participants included five architects (current professional practitioners with 5 or

more years of experience), five university professors and/or administrators (with 5 or more years of experience at their university), and four students who were enrolled in a master's-level architecture degree program in an NAAB school at the tie of the study.

According to Yin (2009), the number of participants used in a case study should be determined by "(a) the type of research questions (b) the control an investigator has over actual behavioral events (c) the focus on contemporary as opposed to historical phenomena" (p. 1). For this study, the researcher fully comprehended the research questions as they applied to all three groups of participants, and could also qualify the need not to collect an unnecessary amount of data. The researcher interviewed until saturation was achieved. Further, the researcher had reasonable investigative control and access to participants because the researcher resided in all three spheres of the study: he was an adjunct academic professor, professional practitioner, and graduate student. Finally, the focus of research was the integration of new technologies into the 21st-century AEC industry. The integration of BIM and IPD methodologies into American schools of architecture curriculum required an examination of contemporary technological practices to verify if there was a need to reduce the use of outdated practices in the industry.

The researcher selected professionally licensed architects in the New York City region from the list of architects publicly named on the AIA website (AIA, 2014). Two NAAB schools in the New York City region were identified from the list of schools supplied on the NAAB website (NAAB, n.d.). A course catalog was requested from the schools selected. By reviewing the course catalog, the researcher was able to verify whether or not the selected school was or was not offering two or more courses related to

BIM and/or IPD. Student participants were selected and contacted with support of the university administrator. Each participant selected was provided with the Capella University's department of Institutional Review Board (IRB) approved permission letter. The researcher worked closely with the university administrator to ensure little to no disruption to the activities of the students and professors who participated in the study. Each group of participants was open to men and women, ages 20 to 60, and of any ethnicity or race.

Setting

Interviews were scheduled to take place at the time and location agreed upon by both researcher and participant. Data collection occurred via face-to-face conversations in semistructured interview sessions. Any follow-up interviews or need for clarification of the collected data was conducted primarily by face-to-face conversations. In cases where scheduling face-to-face meetings proved difficult for both parties, follow-up was conducted by telephone or e-mail correspondence.

Following are examples of the questions posed to participants:

1. What is your current understanding and/or definition of BIM and IPD methodologies?

2. How do you perceive the integration of BIM and IPD methodologies in contemporary architecture design schools?

3. How do you perceive the quality of these courses offered in your university?

4. How would you describe the characteristics of the faculty teaching these courses?

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5. How do you perceive the influence of these processes on the AEC industry and the professional practice of architecture today and in the future?

Qualitative research conducted using face-to-face interview technique allowed for the researcher to acquire in-depth knowledge and perceptions of the participants through their responses. It also allowed for interpretation, from the participants' responses to develop stable and conclusive narrative reporting.

Interview questions were derived using the literature review, specifically from a quantitative study performed by Joannides et al. (2012). Joannides et al.'s study examined the implementation of BIM into ACSE and American Council for Construction Education schools. This study produced raw qualitative data on the subject matter as it related to NAAB architecture design schools.

Instrumentation

Based on Yin's (2009) approach, the goal was for the researcher is to collect, present, and analyze the data fairly, and bring the case study to closure by presenting the findings in this doctoral dissertation. For this research study, the researcher had general face-to-face contact with the participants for the purpose of conducting interviews. The participants in this study included university-level students, professors, and architecture professionals, all over the age of 18. The researcher conducted the interviews, collected the data, and compiled the data from a home office or library.

The researcher acted in the role of an emic—an individual who has information as an insider (Punch, 1998). The researcher was a professional architect, licensed general contractor, and real estate broker working at the time of the study in New York City. New York is one of the most active and dynamic architecture, construction, and real estate

capitals in the world. The researcher had a solid grasp and understanding of the underpinnings of the state of the AEC industry at the time of the study. Additionally, by selecting groups in the New York City geographical area, the researcher had established sufficient access to participants to allow for collection of data and review of additional documentation.

The researcher understood the importance of setting aside bias from influencing the study and remained neutral during the data discovery and analysis timeframes. The researcher did not disclose his own personal familiarity with BIM and IPD methodologies to the participants. The researcher understood that analysis and reporting of the data received from participants drove the results of the study. Additionally, the researcher kept a research journal to capture and explicate personal findings, reactions, and reflections throughout the project.

Data Collection

Initial contact was made via e-mail with each member of the three groups to introduce the purpose of the study, including an attached letter of informed consent to participate. An initial sample discussion question was e-mailed describing the context of the interview questions. The IRB permission letter and letter of informed consent was sent to each participant who has freely agreed to participate in this study. Included in the e-mailed correspondence were a preliminary requests for a time and place to meet, based on the participant's convenience. Each participant was given five business days to return the request for a time and place to meet. The researcher received responses from all participants within the five day period alleviating the need to follow up.

Before the interview process began, the participant was requested to sign the informed consent form in the presence of the researcher. A copy of the signed and countersigned form was provided to the participant, and the original signed and countersigned form was filed and stored in a safe location in the home office of the researcher. The researcher will audio-recorded the session to assist in the transcription of the data. Participants were informed of the recording process and agreed to being recorded.

Field Test

The researcher presented the research study to three industry professionals as well as to a recent master's degree recipient in architecture. It was determined that a preliminary field test was unnecessary.

Data Analysis Procedures

The blueprint for this research project was multiple data sources including current documentation, archival records, interviews, physical artifacts, direct observations, narratives, and participant observation. Additionally, the investigator collected and integrated a nominal amount of quantitative survey data, which assisted in reaching a holistic understanding of the phenomenon being studied: the integration of BIM and IPD methodologies in NAAB schools of architecture. The data from each of these multiple sources were consolidated in the analytical process (Baxter & Jack, 2008). Data collection and analysis occurred concurrently to allow for checking of themes, pattern matching, and comparing to real-life scenarios related to the AEC industry.

The researcher remained true to the original case and incorporated the sharing of data among the participants, encouraging the member-checking methodology (Stake,

1995). As the data were collected and analyzed, the researcher integrated the process of member-checking. Member-checking is a processing in which the researcher's interpretations of the data were shared with the participants, most of whom took the opportunity to discuss and clarify the interpretation, and, if necessary, contribute new or additional perspectives on the issue. The researcher then transcribed the interview data collected.

A computerized database, QSR International NVivo Version 10.0.2 was used to assist the researcher in organizing and analyzing the content from the interviews and the open-ended questionnaires. The researcher was cautious to not collect an overwhelming amount of data that would require extensive management. The data collected were arranged into four distinct categories: sources, themes, analysis, and findings.

The researcher documented the participants' responses and added opinions, and also coded demographics, age, and gender. These descriptive data were reviewed to determine if age, race, or level of education (e.g., bachelor's or master's degree), had anything to do with the results. Triangulating the data helped identify pertinent themes emerging from having used the qualitative research method. Triangulation of data in research is the "use of more than one approach to the investigation of a research question in order to enhance confidence in the ensuing findings" (Bryman, n.d., p. 1)

The data were further used to answer the research questions. The resulting data were then presented in a narrative format that was supported by any necessary tables, graphs, or images necessary to describe the questionnaire, the population, the sample size or technical definitions.

Limitations of the Research Design

Through literature review, professional training, and 25 years of experience in the AEC industry, the researcher had a clear purpose for undertaking this study and the need to understand the implementation of BIM technology into NAAB schools of architecture. Additionally, the researcher had, at the time of the study, 10 years of real-world experience using BIM and IPD methodologies. The researcher made distinct and definitive efforts to practice the principle of epoche as the method in truth finding. In essence, the researcher suspended his own beliefs regarding the subject matter while the interviews and data analysis were conducted.

Case studies in qualitative research promote credibility or truth value through triangulation of data sources and data types (Baxter & Jack, 2008). To establish credibility, the researcher included the use of reflection, care, maintenance of field notes, and peer examination of the data. Credibility was reinforced through member-checking practices. During the analysis stage, the researcher promoted dependability by meeting with other researchers examining similar technology issues affecting the architecture design industry. This technique assisted in establishing consensus and in the examination of any emerging issues or themes (Baxter & Jack, 2008).

BIM and IPD are two of the most important paradigm-shifting methodologies to affect the AEC industry in over 25 years and will be a subject of discussion for several years to come (Eastman et al., 2011). Transferability to additional situations and populations within the architecture design school curriculum holds sufficient descriptive potential. The researcher addressed transferability by "sample selection of informants

representative of the phenomenon under study . . . the informants to the demographic information available on that group being studied" (Krefting, 1991, p. 220).

Each interview was transcribed, summarized, and used for member-checking. A summary was sent to most interviewees for review to ensure the credibility of their data provided (some e-mailed interviews went unanswered). The data were not included in the reporting process until the member checking process was completed by each participant. Systematic guides for the interview were developed to align with the research questions.

As technology continues to expand and the needs of enhancing 21st century architecture school curriculum are identified, this study will serve as a foundation for evaluating and verifying future implementations of BIM and IPD into NAAB schools of architecture in the United States. Ensuring transferability and expansion of the study was paramount to the researcher.

Chapter 3 Summary

The comparative case study methodology was a credible approach to understanding the issues, concerns, attitudes, and policies surrounding the inclusion of advanced technological applied sciences in 21st-century schools of architecture in the United States. One unexpected aspect of designed research methodology was the lack of positive response and interest from schools willing to participate in the study. The lack of response and the unexpected surprise of disinterest of the subject matter was carried on further into the study as the overarching themes were developed.

CHAPTER 4. DATA ANALYSIS AND RESULTS

Introduction

BIM and IPD methodologies were introduced to the AEC industry in the early 21st century. Therefore, at the time this study was conducted (in 2014), there were two definitive schools of thought: those organizations and academies that had embraced the BIM/IPD impact on the industry (the "have" group) and those organizations and academies that had not embraced the technology (the "have not" group). This distinction was the rationale considered and the reason the researcher took the approach of using the comparative case study methodology in exploring the issue. Using the comparative case study methodology allows for replication of the design, therefore making the study more meaningful (Yin, 2009). The participants' feedback provided fundamental insight regarding the potential of revising the NAAB process according to which 21st-century technology in the field of architecture is delivered to M.Arch design school students.

When exploring 21st-century technologies and how they apply to the traditional artistic professional practice of architecture, the researcher must gather information from all phases of the developmental process. These phases were represented by active university students, active academic faculty, and active professional practitioners. This chapter presents the sample, themes, and results extracted from the numerous interviews taken from the participants. The participants were categorized and defined in two groups: the "BIM/IPD haves" and "BIM/IPD have nots".

This chapter begins with a description of the sample participants' characteristics. It identifies and introduces the ideologies, attitudes, and mindsets of the "BIM/IPD haves" group, followed by the contrasting outlook of the "BIM/IPD have nots." Next, the research methodology is reviewed and the analysis techniques that were used to identify themes and trends are described. Finally, the research question results are reviewed and answered in the summary of findings.

Description of the Sample

The researcher conducted 14 narrative-style interviews within three categories of participants: (a) five university professors from NAAB schools of architecture, (b) four graduate school level architecture students obtaining M.Arch degrees, and (c) five active licensed registered architects engaged as professional practitioners. The participants were categorized as members of either the "BIM/IPD haves" group or the "BIM/IPD have nots" group. Each interview lasted 30–60 minutes. The interviews were audio-recorded and field notes were taken to support impressions of each interview.

The researcher contacted the administrative staff and, in some cases, higher level tenured faculty, from several of the top 10 graduate schools of architecture, as published on the *Architectural Record Journal* website (Stevens, 2014). A primary focus was placed on those universities located in the northeastern region of the United States, in keeping with the researcher's physical locale. Additionally, each school contacted was required to be listed on the NAAB website (NAAB, n.d.) to ensure credibility to the study. In a natural flow of the process, it was logical to request permission from the dean and the faculty at these universities, allowing access to interview current M.Arch students. This sample of participants fell under the category of current graduate-level

architecture faculty and students (both the BIM/IPD haves and the BIM/IPD have nots) who wished to participate, discuss, and give an opinion the matter of BIM and IPD in their academic learning environments. Each academic institution requested to remain anonymous due to the sensitivity of the subject and potential exposure, either positive or negative, identifying the institution might have caused.

The researcher has worked professionally in the architecture design industry for more than 25 years. This connection to the industry facilitated recruitment of licensed registered architect participants (both the BIM/IPD haves and the BIM/IPD have nots). The researcher was able to obtain interview permission from personal professional connections and through networking. Furthermore, the researcher verified that each professional practitioner was either listed on the AIA, and/or on their respective state professional licensee lookup table provided on public domain websites, as an active licensee in good standing. This process was conducted done to ensure credibility to the study (NYSED, 2014).

University Participation Sample—Faculty and Students

The researcher received only one response from a graduate school of architecture referenced on the top 20 schools list (Rosenfield, 2012). To maintain its anonymity, this university was referred to in the present study as University A. Contact with University A was made via a personal connection to one professor at the university (also a registered architect). At the time of the interview, the participant was traveling on business to the participant's office in New York City. Therefore the interview was conducted at the researcher's professional office in New York City, as agreed upon through e-mail

correspondence. No additional faculty or students were interviewed from University A. Characteristics of University 1 placed it in the BIM/IPD haves category.

University B was a leading public research institution serving the global as well as the local community. University B was well known for its strong presence in architecture and engineering education, particularly along the lines of a technology integrated curriculum. Characteristics of University B placed it in the BIM/IPD haves category. The researcher spoke with two faculty members and two graduate architecture design students. The interviews were conducted at the university in the design studio/classroom environment. Two students from University B participated in the study. Several more University B students wanted to participate, but time limitations precluded their involvement. Each interview was audio-recorded to allow for transcription to facilitate the data analysis.

University C was located in the heart of New York City. University C had a well-known reputation for developing students' understanding of culture and environmental issues related to preserving the traditions of architecture in the world of contemporary practice. The researcher spoke with the acting dean of the school of architecture. No additional professors or students opted to participate in the study. The interview took place at the campus in the design studio environment. The participant from University C was categorized as a BIM/IPD have not. The interview was audio-recorded for subsequent transcription and member checking.

University D was located in New Jersey and had a well-known reputation for developing students who intend to practice architecture professionally. It qualified and prepared M.Arch students to take the state professional licensing examination. The

researcher spoke with the one professor and two undergraduate students. The interviews took place on campus in the design studio environment. Participants from University D were categorized as BIM/IPD have nots. As was the case for all other participants, each interview was voice-recorded for subsequent transcription and member checking.

Professional Practitioners

Because of the purposeful nature of the study, the researcher faced no issues in gathering willing participants from BIM/IPD professional practitioners who were members of the BIM/IPD have group. Representation came from two medium-sized firms (50–100 employees) located in Manhattan. The third participant was a well-known BIM/IPD industry consultant in the New York City region, as well as a fellow of the AIA. Each interview took place in participants' respective professional offices and was audio-recorded for subsequent transcription and member checking.

Using the researcher's local contacts, the researcher was able to find three professional practicing architects that were willing to be interviewed and whose characteristics placed them in the BIM/IPD have nots category. These individuals were associated with small architecture firms, with between 10 and 50 employees.

Each interview was transcribed from the audio recordings for the second phase of the data collection process. Themes and subthemes were extracted from listening, reading, and reviewing the transcriptions a minimum of three times. Keywords were highlighted that supported the development of the primary, macro-level themes, and also the micro-level subthemes, which would underlay and contribute to the concepts of the study. The researcher used psychometric analysis, putting himself in the interviewee's mind, to understand the complexities and the simplicities of their responses. The

researcher reflected deeply on each interviewee's responses, which guided the evolution

of the themes. Each theme was given a color code and a name, a system the researcher

used for retention and recall of each theme.

For example, the theme of ability to accurately define/understand the concepts

was color-coded red. Each subtheme was color-coded with a red asterisk. This

organizational procedure assisted the researcher in quickly relating and recalling common

subject matter. Once the themes were fully developed, a precise definition (explanation)

was generated; often the definition was a direct quote from a participant. Each theme

directly supported the research questions. A summary of the data extracted from the

transcriptions describing each theme, subtheme, and definition for each theme is

presented in Table 2.

Table 2. *Themes and Subthemes*

Theme 1: Define/understand the concepts	
Definition: BIM/IDP is a project design, construction, and delivery process	
Subtheme	**Definition**
BIM does not infer teaching software	3-D modeling software is only one aspect
Academic course name	None specifically named BIM or IPD

Theme 2: Enthusiasm or confusion	
Definition: If familiar with the concepts, participants were enthusiastic; if unfamiliar with the concepts, participants expressed confusion almost to a point of defensiveness.	
Subtheme	**Definition**
The "have" participants were enthusiastic	Willingness to share their knowledge
The "have not" participants	Expressed confusion almost defensively

Theme 3: Acceptance or resistance	
Definition: Two solid camps (groups) and opinions	
Subtheme	**Definition**
Acceptance	Fully engaged and committed to moving technology forward
Resistance	Status quo, "we've always done it this way and will continue to teach/work this way"

Theme 4: Generational	
Definition: Two solid camps (groups) and opinions	
Subtheme	**Definition**
Pedagogy	Changing towards more collaborative work, less singular work. Adapting to a fluid integration of digital methodologies
Faculty	Faculty and professors disconnected with industry technologies

Research Methodology and Analysis

Each participant was provided with a copy of the Capella University Institutional

Review Board-approved consent form and a sample of the interview instrument

(questions) at least one week prior to our meeting. The interview instrument was

provided to the participants to allow them time to review and reflect on their perceptions

regarding the subject matter. The following questions and prompts were presented to the

university faculty member participants:

1. How long have you been in your present position? And at this institution?
2. What is your current understanding and/or definition of BIM and IPD methodologies?
3. How do you perceive the integration of BIM and IPD methodologies in today's architecture design schools?
4. Briefly describe your role as it relates to student learning.
5. What motivates you to use (or not to use) innovative industry technology in your teaching?
6. What is the strategy at this institution for improving learning as it relates to using technology in the field of architecture?
7. What resources are available to faculty for improving teaching techniques? Continuing education, industry conferences, and so on?
8. Have you or your colleagues encountered resistance to these reforms in your department? . . . on campus?
9. What are some of the major challenges your department faces in attempting to change teaching, learning, and assessment practices? What are the major opportunities?
10. Are there any particular characteristics that you associate with faculty who are interested in innovative teaching/learning initiatives?

The following questions were presented to the university graduate students and

the professional practitioner groups:

1. What is your current understanding and/or definition of BIM and IPD methodologies?
2. How do you perceive the integration of BIM, and IPD methodologies in today's architecture design schools?
3. How do you perceive the quality of these courses offered in your university? (Students-only question).
4. How would you describe the characteristics of the faculty teaching these courses? (Students-only question).

5. How do you perceive the influence of these processes on the AEC industry and the professional practice of architecture today and in the future?

The variations in each question supported the research questions. Not every question was asked to each participant. Much of the discussion depended on the participant's level of comfort with the subject matter, his or her overall experience and exposure to the AEC industry as a whole, as well as his or her demographics.

The data received from each of these multiple data sources were consolidated in the analytical process (Baxter & Jack, 2008). Data collection and analysis occurred concurrently to allow for checking of themes, pattern matching, and comparing to real-life scenarios related to the impact of BIM and IPD on the AEC industry. The researcher used QSR International NVivo, Version 10.0.2 a qualitative analysis software program, for assistance in coding and organizing the data to identify themes and context.

Data Analysis

Examination of the comparative case studies from the BIM/IPD haves and the BIM/IPD have nots, and compilation of the in-depth interviews revealed a direct contrast between BIM/IPD adoption and no adoption. The direct contrast provided a clear and established relationship based primarily on pedagogical ideology of the academy and the economic challenges between professional practices. The overall size of university as well as the overall size of the architecture firm was concerns identified early on as having an impact on the decision of whether BIM/IPD was relevant. This contributing factor was vaguely referred to in the literature review in terms of antiquated differences between population (size) of both architecture design schools and professional architecture firms (Deamer & Bernstein, 2011; Eastman et al, 2011; McGraw-Hill, 2013; Smith & Tardif, 2009).

Category 1: Themes 1 and 2

Research Question 1 was, How does the AEC industry perceive the incorporation of Smart Buildings design theory, BIM, and IPD processes into the curriculum of architecture design schools for maximum student and AEC industry benefit?

A well-defined theme was extracted from the interviews that expressed whether or not the participant possessed the basic ability to define and/or understand the BIM/IPD acronyms that were being presented for the study. This understanding laid foundational framework for contributing factors of whether each participant had an opinion on the subject and if the concepts were influential to the AEC industry to any extent. Responses are presented in Table 3.

Table 3. *Theme 1: Ability to Define/Understand the Concepts*

Theme definition: BIM/IDP is a project design, construction, and delivery process Having the ability to accurately provide definitions for each concept was analyzed.	
BIM/IDP haves	BIM/IDP have-nots
Faculty 1: BIM is essentially a network of communication platforms underpinned by certain computer applications. What I mean is that BIM is or is not any certain piece of software but many different types of software used to share and collaborate with project related data.	Faculty 2: BIM is Building Integrated Management [incorrect definition]. There is no mandate for students to use a particular software or software in general in the development of their projects.
Student 1: BIM is a tool, a tool that helps multiple disciplines involved in the design of a project to create a more harmonious or smooth delivery. It also allows for providing facilities maintenance throughout the buildings lifecycle.	Student 2: BIM automates the modeling process, it makes it easier to identify of-the-shelf products, but I have never actually used Revit (BIM software).

Table 3. *Theme 1: Ability to Define/Understand the Concepts (continued)*

Theme definition: BIM/IDP is a project design, construction, and delivery process
Having the ability to accurately provide definitions for each concept was analyzed.

BIM/IDP haves	BIM/IDP have-nots
Professional Practitioner 1: BIM, is a process to design and document buildings. It is the tool that architects, engineers, constructors, and owners are using to become more efficient in the AEC process.	Professional Practitioner 2: I have a limited understanding of BIM, but it appears to be a further refinement of CAD systems, an expansion of CAD systems, which does more than CAD, like production of shop drawings, purchase orders, tracking deliveries, scheduling, 3-D coordination of multiple trades (HVAC, structural steel, electrical, and so on).

Subtheme	Definition
BIM does not infer teaching software	3-D modeling software is only one aspect
	Have nots are still under the impression that BIM is strictly a new way to design and draw buildings using 3-D software.

Members of the BIM/IPD haves category strongly suggested that these current industry methodologies should be incorporated into the contemporary curriculum of NAAB architecture design schools. As expressed by one BIM/IPD have not group member, an architect with more 35 years of experience, "No question about it. These should absolutely be being taught . . . in making our industry more efficient." Additionally, a tenured professor from a top-10 university stated, "What I'm seeing in the industry is that every student needs to know Revit (a BIM modeling software program) in order to get a job in the industry." Some major architecture firms in New York City, Boston, Chicago, and Cincinnati that prefer to hire graduates of the local universities have expressed frustration because the students are not BIM-capable. In one such case,

students of the University of Cincinnati went to the dean of the architecture school and

asked, "What's going on with our education here? We can't get jobs, the school is not

teaching us what we need in order to get jobs" (Interview, 2013). The university began to

teach BIM after this complaint:

> According to Anton Harfmann, associate professor in UC's (University of Cincinnati) top-ranked School of Architecture and Interior Design (SAID), about 25 to 30 percent of architectural practices in the United States are making use of what's called Building Information Modeling (BIM) software, and that number is only expected to grow.
>
> He explained, "In the last five years, BIM technology has been increasingly adopted by firms because high-speed computing hardware is now so affordable and the software available now can carry enormous data sets that help precisely model a building and all of the structural and system relationships within it. BIM software is now a realistic tool vs. an experimental one."
>
> So that architecture students within UC's College of Design, Architecture, Art, and Planning (DAAP) can be prepared to work and lead in firms adopting this technology, sophomore students in Harfmann's required "Design Science" lecture course must complete design modeling assignments using the latest BIM technology. (Reilly, 2014, para. 3).

Contributing to this theme was one member of the BIM/IPD haves category who

was working at the time of the study for the U.S. General Services Administration (one of

the largest owner-operators of buildings in the world) in conjunction with the

Construction Industry Round Table, a conference of leading industry professionals that

examines in detail what is inhibiting productivity in the design and construction industry.

The results from these conferences in 2004 and 2006 indicated there are three key

behaviors needed between all parties to improve productivity: (a) collaboration (IPD)—

the greater the collaboration the greater success of the project; (b) sharing of

information—start shutting down the silo mentality that is deeply ingrained in the design

firms; and (c) 3-D modeling needs to become the norm, as was accomplished in the automotive and ship building industries (Interview, 2014).

Voicing a contrary opinion and providing a different contributing approach, one high-level academic faculty member stated, "The teaching and learning of BIM/IPD is the responsibility of the practitioner, meaning that the graduating student should receive on the job training within the organization for any design process that will be utilized" (Interview, 2014). As noted by Registered Architect 3, six out of 10 semesters spent in design school are focused on developing the concepts of "form making" and far less on the technical process. This architecture design school pedagogy, he stated, had sparked debates on whether or not the learning process of being able to technically analyze these forms should be learned in school or during the graduate's internship.

Theme 2: Enthusiasm or confusion. Familiarity with current trends in any industry most often produces emotions filled with enthusiasm and an optimistic outlook. This phenomenon became apparent in terms of the BIM/IPD haves category of participants. In contrast, however, the researcher often experienced the feelings of resistance or defensiveness from the BIM/IPD have nots category of participants. The interviews with the BIM/IPD have nots category participants sometimes seemed to take on the air of interrogation rather than an information-gathering discussion. In reviewing and analyzing the transcripts several times after the initial meetings, the researcher developed Theme 2, enthusiasm or confusion (see Table 4).

Table 4. *Theme 2: Enthusiasm or Confusion*

Theme definition: If familiar with the concepts, participants were enthusiastic; if unfamiliar with the concepts, participants expressed confusion almost to a point of defensiveness

BIM/IDP haves	BIM/IDP have-nots
Faculty 1: In terms of software authoring tools, the students are way ahead of the faculty, so the way we are teaching or instructing on software is changing. It is more of a peer to peer teaching strategy, what is really happening is that the more experienced students are helping the less experienced student but also helping the faculty.	Faculty 2: The idea of the integration of the multiple design disciplines happens here in this school. It doesn't happen through the matrix or format of a BIM software.
Student 1: Collaborative studio is a must take class, not just because it brings on a different perspective to the architecture student regarding the engineering that has to go into a building, but in understanding how by getting teams together from the onset makes for less mistakes and a more realistic deliverable. Leaving school with a real world application, that I will be able to use Day 1 in my new career.	Student 2: BIM can only be used on certain types of projects that have a predetermined set of vocabularies, and I heard that BIM can do some pretty crazy stuff.
Professional Practitioner 1: I have a very strong opinion that the curriculum of architecture schools needs to include the BIM & IPD concepts in the core not as electives. This coursework is foundational to changing efficiency in the AEC industry.	Professional Practitioner 2: Of what I know certain schools are very intensively BIM but mostly on 3-D drawing techniques. Everybody, meaning those in architecture schools, are showing 3-D work, computer generated renderings, but I'm fairly sure it is not performed in relationship to the BIM process.

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Table 4. *Theme 2: Enthusiasm or Confusion (continued)*

Subtheme	Definition
The BIM/IPD Haves participants were enthusiastic	Willingness to share their knowledge and experience
The BIM/IPD Have Nots participants expressed confusion	Became uncomfortable with the discussion almost to a point of defensiveness

Category 1, encompassing Theme 1 and Theme 2, demonstrated two analytic assumptions: (a) the pedagogical framework for an education as a master's-degreed M.Arch architect should include addressing current real-world industry methodologies and practices, allowing newly graduated students to be familiar with current industry trends; and (b) the foundational path for pursuing an education and professional as an architect is in a state of transformation, a divided state of those who have recognized the value and those who have lagged behind, considered in a frame of mind as slow adoption.

Analysis of responses to Research Question 1 indicated that the majority of participants (11 of 14) agreed that the methodologies being used at the time of the study in the industry to design, construct, and operate buildings had a definite place in the core curriculum in NAAB schools of architecture.

Category 2: Theme 3

Research Question 2 was, What are the current ideologies in NAAB schools regarding the use of BIM technology and IPD methodologies in architecture design school curricula?

The NAAB had no inclusion requirement of BIM in its 2009 accreditation requirements (NAAB, 2009b) or in its 2013 accreditation draft requirements (NAABc, 2014). However, the NAAB included is this statement:

> PART TWO (II): SECTION 1 – STUDENT PERFORMANCE --
> EDUCATIONAL REALMS & STUDENT PERFORMANCE CRITERIA
> The accredited degree program must demonstrate that each graduate possesses the knowledge and skills defined by the criteria set out below. The knowledge and skills are the minimum for meeting the demands of an internship leading to registration for practice. (NAAB, 2009b)

Also, there was inclusion of an integrated building practice requirement (an IPD approach, though the NAAB failed to mention a collaborative, non-siloed component) defined as,

> **Realm B: Integrated Building Practices, Technical Skills and Knowledge:**
> Architects are called upon to comprehend the technical aspects of design, systems and materials, and be able to apply that comprehension to their services. Additionally they must appreciate their role in the implementation of design decisions, and the impact of such decisions on the environment. Students learning aspirations include:
>
> - Creating building designs with well-integrated systems.
> - Comprehending constructability.
> - Incorporating life safety systems.
> - Integrating accessibility.
> - Applying principles of sustainable design. (NAABb, 2009, p. 21)

Extracted from the participant interviews, but with a primarily academic-influenced focus, was a division on strict adherence to NAAB conditions or heeding to the call of industry. Like any new approach or changes to a traditional work process, resistance was expected (see Table 5). For example,

> "BIM doesn't work," that's very humorous and in many cases true. It doesn't work for someone whose expectations are too high, it doesn't work for someone who doesn't know how to use it, it doesn't work for someone unwilling to change the way they think, and it doesn't work for someone unwilling to change the way the work. (Deutsch, 2011, p. 24)

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Table 5. *Theme 3: Acceptance or Resistance*

Theme definition: There are two solidly firm camps (Groups) on the subject of BIM/IPD methodologies and where the introduction to the learning aspect begins: (a) in architecture education, or (b) in professional practice (on-the-job training)	
BIM/IDP haves	BIM/IDP have-nots
Faculty 1: It becomes harder and harder, meaning more difficult to find faculty who have experience of how buildings are being designed and built these days and to stay current as the profession is changing so quickly and so dramatically.	Faculty 2: I think there is a misperception about architecture schools in that we are somehow teaching students to become Lone Rangers and that they are going to be ill prepared for practice. When in a school like this one, which absolutely states, we do not feel that it is the role of a school of architecture, to train students for practice.
Student 1: In my experience here at Univ. No. 2, although they are teaching the BIM/IPD process, I feel that it could have been introduced even earlier in the program, such as in the Bachelor's degree program. I feel that by allowing a student at a younger level to participate in simple group projects rather than having four architecture students in a group clashing between design philosophies.	Student 2: We are taught no computer software programs at all in this school. We have a co-op program where we alternate every 4 months between school and work, and this is where we are expected to learn to use software.
Professional Practitioner 1: Generally BIM/IPD is providing opportunity to improve the industry, it provides opportunity for all involved: architects, engineers, etc., to take advantage of these methodologies as ways to investigate and solve problems and revamp the industry.	Professional Practitioner 2: I know of a few cases where they have started with BIM and then abandoned it. The project we were working on had lots of curves and we did not succeed so therefore we stopped. We learned that to abandon a project is not an uncommon occurrence, it seemed like everybody was trying and failing and then regroup, which seemed to be a pattern.

Table 5. *Theme 3: Acceptance or Resistance (continued)*

Subtheme	Definition
Acceptance	Fully engaged and committed to moving technology forward
Resistance	Status quo, "we've always done it this way and we will continue to teach/work this way"

In the academic environment, the majority of any courses slightly related to BIM/IPD were found as elective non-required courses. The BIM/IPD haves category academies have courses are named "Collaborative Studio" or "Systems Integration." These courses introduce the concepts of BIM/IPD and how leveraging 21st-century technology assists in better, well-thought-out designs and deliverable outcomes. The issue is that these courses were nonrequired, elective classes.

Category 3: Theme 4

Research Question 3 was, How does the BIM and IPD processes currently influence the AEC industry and the professional practice of architecture?

A pronounced theme was extracted from a BIM/IPD haves category participant who was a seminal researcher and professor at a prominent university, who stated, "The way we teach architects has to be re-examined, what I see is that professional practice is influencing the academy, and in reality it should be the other way around." This participant continued, "It is largely a generational thing; the older the faculty member is the less likely that faculty member has any interest in anything digital which, in turn, produces tons of resistance." These interview statements produced the rational for Theme 4: Generational (see Table 6).

Table 6. *Theme 4: Generational*

Theme definition: There are two solidly firm camps (groups) on the subject of BIM/IPD methodologies and where the introduction to the learning aspect begins: (a) in architectural education, or (b) in professional practice (on-the-job training)	
BIM/IDP haves	BIM/IDP have-nots
Faculty 1: Let me shed some perspective on this, academia prioritizes individual faculty research, so what happens is that the faculty has specialized interest. In pursuing those interest, whether or not they are tangible to architecture, is not where most of our students will end up. Furthermore, what I see is that the students are way ahead of the faculty in regards to technology with smart phones and tablets, we need to change the way we are instructing on software.	Faculty 2: I think you may be skipping something here, BIM and IPD are not really technologies that would be linked to our building technologies where a student is developing a building section or skin for a project. That is where those ideas of how projects are developed is in professional practice.
Student 1: Beyond just the practical reality of the fact that this is the way it is done in the real world, it allows the designer to view their design virtually on a screen in 3-D, which is very helpful. The faculties' knowledge is high level practical and conceptual, but their technical knowledge in digital tools as a group has both strengths and weaknesses, but overall the faculty is great.	Student 2: At this university I believe it is a cultural thing, like generational, depending on the age of the professor. Anything related to or consider technical, like any type of software, is expected to learn on your own time.

Table 6. *Theme 4: Generational (continued)*

Theme definition: There are two solidly firm camps (groups) on the subject of BIM/IPD methodologies and where the introduction to the learning aspect begins: (a) in architectural education, or (b) in professional practice (on-the-job training)	

BIM/IDP haves	BIM/IDP have-nots
Professional Practitioner 1: The technology is forcing a generational divide between the digital literate and the non-literates, a very difficult dichotomy because you have both scenarios "digital literate but not proficient in practice" and "proficient in practice but not proficient in technology," so how will it be that these two groups engage and leverage each other?	Professional Practitioner 2: My biggest issue is that computer software is a tool, a means not an end, and too many times people rely too heavily on the technology. I think to date my feeling is that it has been more negative than positive, for various reasons. In general, I think computer architecture became first when it was hand drafting, then CAD, now CAD to BIM, but people are not aware of how different it is. The computer is facilitating the ability to create forms that simply we were not able to do by hand, and it changed the kind of designs, both good and bad.

Subtheme	Definition
Pedagogy	Changing towards more collaborative work, less singular work
	Adapting to a fluid integration of digital methodologies
Faculty	Faculty and professors disconnected with industry technologies
Academic course name	None specifically named core curriculum BIM or IPD

Note. In 2009, NAAB accreditation conditions requirements in curriculum called for Integrated Building Practices, Technical Skills and Knowledge.

Summary of the Findings

Main Findings

Students demonstrated an acceptable level of receptiveness towards BIM and IPD

methodologies and also a basic level of understanding for collaboration, analytical

simulation, constructability, and building performance. The interviews showed that

students were more than willing to be exposed to these industry-wide concepts. They also

showed interest in how using BIM and IPD fostered the overall bottom-line benefits

contributing to their education. As stated by one student from the BIM/IPD haves

category,

> I grew up on a farm, in the agricultural industry, and I have seen within my
> lifetime the increased efficiencies there, but the construction industry continues to
> go down and down in efficiencies, something has to change and I believe
> BIM/IPD is a sound approach (Interview, 2014).

> The academy, however, in and of itself, rests on a split decision. The academy

must realize that the designing, planning, and construction of a building project is a

complex task that requires a tremendous amount of both knowledge and skill. Noted

seminal researchers stated,

> BIM provides a platform that allows practitioners, as well as students, a method
> for organizing information throughout all phases of the design process, and
> enables computer applications to use this information to perform analytical tasks
> to gain insight into the design performance (Messner, Holland, Poershke, Parfitt,
> & Pihlak, as cited in Deamer & Bernstein, 2011 p. 57).

> Furthermore, as affirmed by a professor and participant from the have nots

> category,

> There are a group of faculty interested in this method of teaching and those that
> feel that architecture school should still be a place of developing disciplinary
> expertise, and some faculty that posit this is a method of professional practice that
> is better taught on the job. (Interview, 2014)

Even well-tenured faculty flip back and forth from recognizing the benefits of

introducing these technological methodologies early in architects' educational curricula,

to going along with the status quo, continuing the way things have always been done.

Findings indicated that among the four schools of architecture represented in the present study, none has any type of software training in the curriculum. As noted by Deamer and Bernstein (2011), "Teaching digital tools by absorbing them into studio and/or representation courses in not highly effective, but will work if the tools are primarily linked with design projects" (p. 17). In all cases in this study, students were expected to learn the BIM software programs on their own, and many of the students came together in groups to learn and teach each other. All of this learning came from outside of the core curriculum.

Some of the students found that this need to learn from outside the core curriculum presented several problems. As stated by two graduate students in the BIM/IPD have nots group, a recent graduate volunteered to do a 2-day workshop, returning to the school to pass on what he had just recently learned from his new job. The recently graduated student was offering to teach BIM software to anyone who wanted to learn . . . the workshop was cancelled because no one signed up.

One of the main findings was culture. Culture related to the organization and the generation of top management or administrators. For example, for the architecture firm, findings indicated there was connection between a BIM culture and the size of the organization. The size of the organization often determined the size and scope of awarded commissions. Larger, more complex projects needed to be designed and constructed using higher levels of technology to be more successful. Additionally, findings indicated the size of academy was also a factor: larger schools were associated with the BIM/IPD haves and the smaller academies were found on the side of BIM/IP have nots, but still not within 100% actuality. For example, one major BIM/IPD university was large and had a

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great reputation for providing an outstanding education in architecture but had yet to introduce the BIM and IPD methodologies into the curricula.

Most universities have some aspect of technology incorporated into the curriculum; however, the majority of these technology subjects are outdated and do not properly address what students will need immediately in their professional careers.

Chapter 4 Summary

BIM and IPD methodologies have been identified as "disruptive" technologies for industry professionals and the academy (Deutsch, 2011; Eastman et al., 2011; Smith & Tardif, 2009). This label could not have been more apparent as the researcher conducted interviews with architecture academies in the New York City area. The researcher met with harsh and negative responses to his inquiries on current curriculum subject matter and pedagogies. A member of an Ivy League university school of architecture and planning stated, "I spoke with our Senior Associate Dean and unfortunately it is not possible for us to give permission on behalf of the university or on behalf of individuals to participate in the study. I apologize for the inconvenience" (Anonymous, personal communication, November 5, 2013). A similar response was provided by a member of another well-known institute of technology, an institution dedicated to leveraging advanced technologies in their academic offerings.

Not until the researcher attended the NIBS BuildingSMART Alliance annual conference in Washington, DC, in January 2014 was the researcher able to identify an NAAB school of architecture that would allow access to faculty and students. The NIBS conference focused on strategies to advance the AEC industry; it was here that many willing participants were identified. Those who were outside of the immediate

northeastern region of the United States had relationships with those who were more local to the researcher.

The experience was similar when contact was made with unknown professional practitioners from outside of the researcher's immediate network of associates. What the researcher experienced was that data collection was difficult within the academic environment as well as the professional arena when discussing a sensitive subject in a well-established profession.

The research questions explored and analyzed in this study and the findings resulting from posing those questions demonstrated the continued struggle between the profession and the academy. Both parties held strongly to their positions. Heated debate will likely continue. Should academia prepare students for current industry practice or should industry be taught on the job? Is there a need for this developing industry standard to be inserted into the curriculum? Does this integration add value for maximum student and AEC industry benefit? These issues are addressed in Chapter 5.

CHAPTER 5. CONCLUSIONS AND DISCUSSION

Introduction

Thinking about design, construction, and operations of structures (buildings, facilities, campuses, infrastructure) is one of the oldest professions and craft trades in human history, dating as far back as the Stone Age. It is the largest industry in the United States, according to the U.S. Department of Commerce, Bureau of Economic Analysis (2004). Furthermore, the AEC industry accounts for up to 10% of revenues generated from the gross domestic product of the world (Murie, 2007). The AEC industry trails behind the technology and agriculture industries. Ironically, it was determined through quantitative statistical analysis that the AEC industry spends only about 1.35% of these revenues on leveraging information technology (see Table 7). As Sacolick (2012) noted,

> Construction companies with less than $250 million in revenue invest about 1.6% of it on information technology, according to Gartner Research. Meanwhile, construction firms with $10 billion in revenue on average spend only 1.1% on IT. The construction industry is dead last in IT spending compared to 14 other industries measured by Gartner. (Sacolick, 2012, para. 1).

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Table 7. *Revenue Report from McGraw-Hill*

2012 IT spend as percentage of revenue		
Industry	Annual revenue approximately $250 million (%)	Annual revenue approximately $10 billion (%)
Banking	7.3	6.2
Construction and materials	1.6	1.1
Education	5.6	3.3
Federal government	10.8	7.9
State and local government	4.6	1.8
Software and Internet	8.4	5.4
Insurance	5.3	2.9
Healthcare	3.5	3.3
Media	5.4	3.2
Pharmaceuticals	3.0	2.6
Professional services	5.6	3.4
Retail and wholesale	1.9	.09
Telecommunications	4.9	3.8
Transportation	3.5	2.3
Utilities	4.2	1.7
Across all 15 industries	5.04	3.16

Note. **Data adapted from "Construction Industry Dead Last in IT Spend" [Web log message], 2012. Reprinted with permission.**

Experts believe that this lack of capital investing on IT processes is one of the primary root causes of the inefficiencies in the AEC industry. Furthermore, this key focus

area has to be addressed to dramatically shift the efficiencies in a positive direction in the

AEC industry. Merchant (as cited in Deamer & Bernstein, 2010) remarked,

> Industry fragmentation, lack of interoperability, and hardened business practices are often cited as reasons for the failure of the AEC industry to capitalize on the benefits of automation. Technology alone cannot force change but it has the potential to enable it. (Deamer & Bernstein, 2010, p. 160)

Additionally, another problem lies within the psyche of AEC contributors

(owners, architects, engineers, contractors, and subcontractors) who have accepted these

inefficiencies as standard business practice. In a typical traditional project set-up, project

teams generally set aside up to 15% of project budgets to manage lawsuits and litigation

at the close of a project.

In the United States, construction is often followed by litigation. A comment was

made in a Webinar viewed by the researcher: "Of course, this is the most expensive way

to solve design problems!" (Smith & Foster, 2011, p. 15). For example, in New York

City, one of the largest commercial business regions in the world, building are designed

and built using the "design-bid-build" contractual methodology. The design-bid-build

methodology has been described as, "design-bid-sue-build-sue again" methodology,

which has been accepted as standard operating procedure (B. Grifis, personal

communication, May 24, 2013).

Summary of the Results

The 21st-century architect must be able to manage the rapid pace of technological changes, the rate of global interconnectivity, and complex design issues that require multidisciplinary and collaborative solutions. As demonstrated by the themes derived from the findings, several simple changes can be implemented quickly to improve an M.Arch educational experience. For example, schools could introduce current industry methodologies to students early in the curricula so that students can properly define and understand the concepts behind the processes. Schools could encourage individuals in both academia and the profession, to build enthusiasm and interest in harnessing technology as they move forward into their new profession. Because the majority of engineering and construction management schools have already introduced BIM/IPD to their students, now is the time for NAAB to bring a more direct technology training to the core curriculum. Considering the generational theme, this change will consequentially evolve as time moves forward and the BIM/IPD and Smart Buildings design becomes the status quo.

Discussion of the Results

The results indicated the presence of an industry-wide trend in the United States to bring NAAB architecture design schools in alignment with current industry practices. Two things are clear. First, BIM threatens all of the hierarchies we have established in academia, between the divisions that have been made across disciplines, between the importance of the studio and the secondary nature of all of the other courses, and within the overall concept of design outcomes. This schism is not merely a case of whether BIM is determined to be a software tool, a professional organizational method, or a form of

design practice. Any and all of these designations are associated with a curriculum

structure that, to date, has been unreceptive to BIM.

Discussion of the Results in Relation to the Literature

Research associated with the study topic continues to be rapidly injected into

academic peer-reviewed journals. Here are two examples.

As noted by Deamer and Bernstein (2011),

> If BIM is to be taken seriously in academia—which is to say, required, design-focused, collaborative, and methodologically integrative—then BIM and the academy will need to emphasize not its efficiency, but its exploration of the unknown; not its effect on the marketability of its graduates, but its effect on their own willingness to embrace the risk of the marketplace. The tension between practice and the academy should not in any way go away; rather, the academy should embrace its traditional role as a challenge to the profession; to lead it, not follow it. If many of us believe that BIM is an opportunity for architecture to recapture its rightful place in the building industry, some of us also think that academia should seize it as an opportunity to reimagine the education of a designer/architect. (Deamer & Bernstein, 2011, p. 3)

Additionally, reports of quantitative research (Becerik-Gerber & Kensek, 2010) indicated

the following findings:

> . . . shows research areas practitioners are interested in (based on the first survey) and students' answers to the question of what areas will be most important in their profession when they graduate (based on the third survey). Building information technology and management (89%), IPD (87%), and BIM for sustainable design and construction (83%) were the top three choices of practitioners. The "other" category for practitioner answers included integrated structural analysis, real estate/portfolio analysis, web- enabled technologies, field BIM, interoperability, BIM quality assurance, and code compliance. (Becerik-Gerber & Kensek, 2010, p. 139)

Industry literature continues to rapidly contribute to the validation of implementing much

more technology into higher level architecture design education. The topic of BIM and

IPD continues to heat up, both in industry and academia, becoming a top-of-mind and

mainstream topic of discussion. The data supporting the issues are gaining momentum.

In contrast to these data, many AEC contributors (i.e., owners, architects, and contractors) remain confused about most of the terminology, and the nomenclature, and also on simply how to deal with inevitable change. Examples of the proposed architecture BIM/IPD curriculum are available. One example of a possible approach to incorporating BIM into architecture studio core curriculum was developed by Özener (2009) through doctoral research, which he defined as Studio21 (see Appendix C).

Another credible example of a BIM curriculum structure presented from Autodesk (see Appendix D). The Autodesk BIM curriculum is a robust, comprehensive, and standard industry approach that has proven successful to introducing the concepts of BIM/IPD to both students and professionals (Autodesk, n.d.). Furthermore, these resources available now and are free to faculty, students, and practitioners, and do a credible position on teaching the basic fundamentals and principles of BIM and IPD.

Limitations

Limitations to the researcher were geographic locale and availability of willing participants.

Recommendations for Further Research

There are 154 NAAB schools of architecture in the United States, and it was not feasible to include each program. Further research could be included to explore other various regions of the U.S. and/or to conduct a legitimate unbiased quantitative examination of all NAAB accredited schools to see if BIM interest in the core curriculum is substantiated. A quantitative study should be conducted to produce hard numbers in a scientific approach. To validate and authenticate to those two diverse groups that really believe this is a paradigm shift in the industry and those that do not. Additionally, a

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quantitative examination could help in determining whether or not it is the responsibility of academia to introduce the concepts or does in bear on the professional practitioners' office to train newly hired graduates.

As noted by the Bernstein, a seminal resource in the field of architecture education and practice, "Of the 154 schools of NAAB architecture, 128 of them claim to have BIM/IPD in the curriculum, however, each school is self-reporting, and the reality is that this is simply not the case" (P. Bernstein, personal communication, August 25, 2013). Furthermore, as University Professor 5 stated,

> This university builds some pretty fantastic buildings, they built to a 200-year lifecycle, and they require all project managers and all construction trades that will be working within that project, to be capable of delivering a BIM product. Whereas, in the school of architecture, we talk about BIM, but there is no formal indoctrination or training in it. This is an indication that there is a separation between the office of design and construction and the academic side of the learning and practice of architecture.

Conclusion

When exploring educational pedagogy in the curriculum of a traditional school, matters become complicated. There are two firmly divided attitudes and opinions bearing heavily on one significant theme: the generational divide.

In contemporary architecture schools, there is a focus on less singular heroic work and more focus on a collaborative nature. There is a more fluid integration with digital technology entering the academy by students through outside influences, and it is time that faculty take notice. There is no doubt that "BIM is the wave of the present" (R. A. M. Stern, personal communication, 2014), and the emerging generation of architect will be expected to be fully BIM/IPD-literate.

The overarching message conveyed throughout the AECO industry is that the industry must improve the way its members conduct their approach to designing and constructing buildings. Change orders, project scheduling overruns, low technology, and high litigation must not continue. This paradigm shift can be accomplished through change management, leadership, and champions across all AECO contributors. By breaking out of the silos that prohibit effective collaboration, and by incorporating proven effective digital design workflows of BIM and IPD, positive change can result (Taylor & Bernstein, 2009). It is apparent that generational factors and factions dominate the roadblock. The industry must move out from under the old way of design buildings and into the 21st century. BIM and IPD are the path forward. University Professor 5 summed up the argument with this statement:

> My philosophy with BIM and IPD is that it goes hand in hand, basically inseparable. We should embrace that! Meaning in academia, and utilize it not only for the construction of the building, but for the design of the building, which can then can be incorporated into the BIM and used for fabrication. In a typical design building, the architect, structural engineer, and other engineering disciplines, have to work hand in hand, the overall look is architecture but the building must still stand up, so the models are used to insure constructability and then on down to fabrication, and to facility operations. (University Professor 5)

Seminal researchers have agreed with this statement and reported their belief that academia has a responsibility to initiate the inclusion of BIM and IPD into NAAB graduate level architecture design schools (Deamer & Bernstein, 2011; Becerik-Gerber & Kensek, 2010; Messner, et al. as cited in Deamer & Bernstein, 2011). The results of the present research indicate that U.S. NAAB schools of architecture should think smart. Now is the time to integrate BIM and IPD (coupled to combine Smart Building design theory) into NAAB schools of architecture design curriculum. It is time to strive for

higher efficiencies in the industry and to assist in delivering a higher level end product. We must put the architect back on top as the leader and empower orchestration of innovation and creativity of the built environment.

REFERENCES

Abdul-Alim, J. (2013, May 28). Georgetown study says not all college degrees are created equal [Web log message]. *Diverse Issues in Higher Education*. Retrieved from http://diverseeducation.com/article/53569/

Ackerman, J. S. (1954). Architectural practice in the Italian Renaissance. *Journal of the Society of Architectural Historians, 13*(3) 3–11. doi: http://dx.doi.org/10.2307/987700

American Institute of Architects (AIA). (n.d.). *History of the American Institute of Architects.* Retrieved from http://www.aia.org/about/history/ AIAB028819

American Institute of Architects (AIA). (n.d.). *Integrated practice: Integrated project delivery.* Retrieved from http://www.aia.org/about/initiatives/AIAS076981

American Institute of Architects (AIA). (2007). *Integrated Project Delivery: A guide.* Retrieved from http://info.aia.org/siteobjects/files/ipd_guide_2007.pdf

American Institute of Architects (AIA). (2011). *Integrated Practice/Integrated Project Delivery. IPD Definition; 2011 Position statement on Project Delivery.* Retrieved from http://www.aia.org/aiaucmp/groups/aia/documents/pdf/aiab089099.pdf.

American Institute of Architects (AIA). (2014). *Find an architect.* Retrieved from http://architectfinder.aia.org/frmLandingPage.aspx.

Ambrose, M. A. (2012). Agent provocateur—BIM in the academic design studio. *International Journal of Architectural Computing, 10,* 53–66. doi: http://dx.doi.org/10.1260/1478-0771.10.1.53

Azhar, S. (2011). Building Information Modeling (BIM): Trends, benefits, risks, and challenges for the AEC Industry. *Journal of Management in Engineering*, *11*(3), 241–252.

Autodesk Incorporated. (n.d.). BIM Curriculum. Retrieved from http://bimcurriculum.autodesk.com

Barison, M. B., & Santos, E. T. (2010). BIM teaching strategies: An overview of the current approaches. In W. Tizani (Ed.), *Proceedings of the International Conference on Computing in Civil and Building Engineering (ICCCBE 2010).* Nottingham, England: Nottingham University Press.

Baxter, P., & Jack, S. (2008). Qualitative case study methodology: Study design and implementation for novice researchers. *Qualitative Report, 13,* 544-559. Retrieved from http://www.nova.edu/ssss/QR/QR13-4/baxter.pdf

Becerik-Gerber, B., & Kensek, K. (2010). Building Information Modeling in architecture, engineering, and construction: Emerging research directions and trends. *Journal of Professional Issues in Engineering Education & Practice, 136,* 139–147. doi: http://dx.doi.org/10.1061/(ASCE)EI.1943-5541.0000023

Becerik-Gerber, B., Jazizadeh, F., Li, N., and Calis, G. (2012). Application areas and data requirements for BIM-Enabled facilities management. *Journal of Construction Engineering and Management, 138*(3), 431–442.

Bitterman, S. (Ed.). (2011). *Skanska Coast to Coast: The BIM issue* [Special issue]. Retrieved from http://www.usa.skanska.com/Global/brochure/coasttocoast/Finals/2011_no02.pdf

Blanchard, P. N., & Thacker, J. W. (2007). *Effective training: Systems, strategies, and practices* (3rd ed.). Upper Saddle River, NJ: Pearson Prentice Hall.

Bruton, D. (2012). Design education and institutional transformation. In N. Gu & X. Wang (Eds.), *Computational design methods and technologies: Applications in CAD, CAM, and CAE education* (pp. 351–364). Hershey, PA: Information Science Reference. http://dx.doi.org/10.4018/978-1-61350-180-1.ch020

Bryman, A. (n.d.). Professor of Social Research: Loughborough University, UK. Retrieved from http://www.referenceworld.com/sage/socialscience/triangulation.pdf

Burke, P. (1999). *The Italian renaissance: Culture and society in Italy* (2nd ed). Princeton, NJ: Princeton University Press.

Cheng, R. (2011). Facing the fact of BIM: Architectural curricula past, present, and future. In P. Deamer & P. G. Bernstein (Eds.), *BIM in academia* (pp. 12-21). New Haven, CT: Yale School of Architecture.

Clayton, M. J., Johnson, R. E., Vanegas, J. A., Özener, O., Nome, C. A., & Culp, C. E. (2009). Downstream of design: Lifespan costs and benefits of building information modeling. Technical Report. College Station, TX: CRS Center for Leadership and Management in the Design and Construction Industry.

Cornell University. (n.d.). History of Cornell's College of Architecture, Art, Planning: Charles Babcock. Retrieved from http://rmc.library.cornell.edu/Aap-exhibit/AAP3.html

Creswell, J. W. (2009). *Research design: Qualitative, quantitative, and mixed methods approaches* (3rd ed.). Thousand Oaks, CA: Sage.

Deamer, P., & Bernstein, P. G. (Eds.). (2010). *Building (in) the future: Recasting labor in architecture.* New York, NY: Princeton Architectural Press.

Deamer, P., & Bernstein, P. G. (Eds.). (2011). *BIM in academia.* New Haven, CT: Yale School of Architecture.

Demkin, J. A. (Ed.). (2008). *The American Institute of Architects: The architect's handbook of professional practice* (14th ed.). Hoboken, NJ: John Wiley & Sons.

Deutsch, R. (2011). *BIM and integrated design: Strategies for architectural practice.* Hoboken, NJ: Wiley.

Dispenza, K. (2013). *IPD with Autodesk.* Retrieved from http://buildipedia.com/aec-pros/design-news/ipd-with-autodesk

Duan, X.-R. (2004). A model curriculum for computer aided design (CAD) associate degree programs. *Journal of Industrial Technology, 20*(2), 1-9. Retrieved from http://www.atmae.org/?page=JTMAE

Eastman, C., Teicholz, P., Sacks, R., & Liston, K. (2011). *BIM handbook: A guide to Building Information Modeling for owners, managers, designers, engineers, and contractors* (2nd ed.). Hoboken, NJ: Wiley.

Erhan, H. I., Ben Youssef, B., Berry, B. (2012). Teaching spatial thinking in design computational contexts: Challenges and opportunities. In N. Gu, & X. Wang (Eds.), *Computational design methods and technologies: Applications in CAD, CAM, and CAE Education* (pp. 365–389). Hershey, PA: Information Science Reference. doi: http://dx.doi.org/10.4018/978-1-61350-180-1.ch021

Gagné, R. M., & Briggs, L. J. (1974). *Principles of instructional design*. New York, NY: Holt, Rinehart and Winston.

Gallaher, M. P., O'Connor, A. C., Dettbarn, J. L., Jr., and Gilday, L. T. (2004). *Cost analysis of inadequate interoperability in the U.S. capital facilities industry.* Washington, DC: National Institute of Standards and Technology. Retrieved from http://fire.nist.gov/bfrlpubs/build04/art022.html

Gay, L. R., Mills, G. E., & Airasian, P. (2006). *Educational Research: Competencies for Analysis and Applications* (8th ed.). Upper Saddle River, NJ: Pearson.

Georgia Tech. (2013a). Georgia Tech School of Architecture. MS (Arch) Digital Design & Fabrication. Retrieved from http://www.arch.gatech.edu/academics/masters/msarch_ddf

Georgia Tech. (2013b). Georgia Tech School of Architecture. COA8901 – Building Information Modeling Case Studies. Retrieved from http://www.arch.gatech.edu/content/coa-8901-building-information-modeling-case-studies

Gül, L. F., Williams, A., & Gu, N. (2012). Constructivist learning theory in virtual design studios. In N. Gu, & X. Wang (Eds.), *Computational design methods and technologies: Applications in CAD, CAM, and CAE education* (pp. 139–162). Hershey, PA: Information Science Reference. doi: http://dx.doi.org/10.4018/978-1-61350-180-1.ch009

Hamilton, D. K., & Watkins, D. H. (2009). *Evidence-based design for multiple building types.* Hoboken, NJ: Wiley.

Heidenheimer, A. J., Hugh, H., & Adams, C. T. (1983). *Comparative public policy* (2nd ed.). New York, NY: St. Martin's Press.

Joannides, M. M., Olbina, S., & Issa, R. R. A. (2012). Implementation of Building Information Modeling into accredited programs in architecture and construction education. *International Journal of Construction Education and Research, 8*(2), 83-100. doi: http://dx.doi.org/10.1080/15578771.2011.632809

Katz, A. (2012). *Green building facts.* Retrieved from http://www.usgbc.org/articles/green-building-facts

Kensek, K. M., & Peng, J. (Eds.). (2012). The USC BIM symposium. Practical BIM 2012: Management, implementation, coordination, and evaluation. Retrieved from http://www-bcf.usc.edu/~kensek/Practical%20BIM%202012%20-%20for%20personal%20use%20only.pdf

Kieran, S., & Timberlake, J. (2004). *Refabricating architecture: How manufacturing methodologies are poised to transform building construction.* New York, NY: McGraw-Hill.

Kieran, S., & Timberlake, J. (2008). *Loblolly House: Elements of a new architecture.* New York, NY: Princeton Architectural Press.

Kolarevic, B., & Malkawi, A. M. (Eds.). (2005). *Performative architecture: Beyond instrumentality.* New York, NY: Spon Press.

Kostof, S. (Ed.). (1977). *The architect: Chapters in the history of the profession.* Los Angeles, CA: University of California Press.

Krefting, L. (1991). Rigor in qualitative research: The assessment of trustworthiness. *The American Journal of Occupational Therapy, 45*(3), 214-222.

Krygiel, E., & Nies, B., 2008. *Green BIM: Successful sustainable design with building information modeling*. Indianapolis, IN: Wiley.

Kymmell, W. (2008). *Building information modeling: Planning and managing construction projects with 4D CAD and simulations*, *McGraw-Hill Construction series*. New York: McGraw-Hill.

Lowry, B. (1965). *Renaissance architecture.* New York, NY: G. Braziller.

Mason, M. (2010). Sample size and saturation in PhD studies using qualitative interviews. *Forum: Qualitative Social Research, 11*(3), 1–19. Retrieved from http://www.qualitative-research.net/index.php/fqs

Massachusetts Institute of Technology (MIT). (n.d.). *SA+P timeline.* Retrieved from http://architecture.mit.edu/architectural-design/program/overview

McGraw Hill Construction. (2009). The business value of BIM: Getting Building Information Modeling to the bottom line. Retrieved from http://images.autodesk.com/adsk/files/final_2009_bim_smartmarket_report.pdf

McGraw Hill Construction. (2013, January 31). BIM adoption expands from 17% in 2007 to over 71% in 2012, according to McGraw Hill Construction Report [Press release]. Retrieved from http://www.construction.com/about-us/press/bim-adoption-expands-from-17-percent-in-2007-to-over-70-percent-in-2012.asp

Merriam, S. B. (1998). *Case study research in education: A qualitative approach* (2nd ed.). San Francisco, CA: Jossey-Bass.

Monson, C. (2010). Student collaboration as the foundation for learning BIM software: Ideas from a project-based introduction. Retrieved from http://projects.buildingsmartalliance.org/files/?artifact_id=5361

Murie, F. (2007). Building safety-An international perspective. *International Journal Occupational Environmental Health*, *13*, 5–11.

Muzvimwe, M. (2011, September 20). *5-D BIM explained.* Retrieved from http://www.fgould.com/uk-europe/articles/5d-bim-explained/

National Architectural Accrediting Board (NAAB). (n.d.). *Architecture programs.* Retrieved from http://www.naab.org/architecture_programs/home

National Architectural Accrediting Board (NAAB). (2009). 2009 Conditions for Accreditation. Retrieved from http://naab.org/f/documents/home.aspx?path=Public+Documents

National Architectural Accrediting Board (NAAB). (2013). 2014 Conditions for Accreditation (First Draft). Retrieved from http://naab.org/f/documents/home.aspx?path=Public+Documents

National Institute of Building Sciences (NIBS). (2007). *National Building Information Modeling standard, Version 2, Part 1: Overview, principles, and methodologies.* Retrieved from http://www.nationalbimstandard.org/nbims-us-v2/

New York State Education Department (NYSED). (2014). Office of the professions: Verification searches: architect. Retrieved from http://www.op.nysed.gov/opsearches.htm#nme

Ockman, J., & Williamson, R. (Eds.). (2012). *Architecture school: Three centuries of eduating architects in North America.* Cambridge, MA: The MIT Press.

Özener, O. (2009). *Studio education for integrated practice using Building Information Modeling* (Doctoral dissertation). Retrieved from http://repository.tamu.edu/

Peterson, F., Hartmann, T., Fruchter, R., & Fischer, M. (2011). Teaching construction project management with BIM support: Experience and lessons learned. *Automation in Construction, 20,* 115–125. http://dx.doi.org/10.1016/ j.autcon.2010.09.009

Picciano, A. G. (2001). *Distance learning: Making connections across virtual time and space.* Upper Saddle River, NJ: Merrill, Prentice Hall.

Prial, F. J. (1984, May 13). Wiring buildings for intelligence. *The New York Times.* Retrieved http://www.nytimes.com.

Punch, K.F. (1998). *Introduction to social research: Qualitative and quantitative approaches.* Thousand Oaks, CA: Sage.

Reilly, M. B. (2013, May 31). *UC News: UC's integration of technology into architecture curriculum wins AIA award.* Retrieved from http://www.uc.edu/ news/NR.aspx?id=17829

Rosenfield, K. (2012, January 4). Study shows architecture graduates with highest unemployment rate [Web log message]. Retrieved from http://www.archdaily.com/197351

Rosenfield, K. (2012, November 21). United States best architecture schools [Web log message]. Retrieved from http://www.archdaily.com/295331

Rouse, M. (2011). *What is CAD (computer aided design)?* Retrieved from http://whatis.techtarget.com/definition/CAD-computer-aided-design

Sabol, L. (2008). Design + Construction Strategies: The Power of Process in the Built Environment. Building Information Modeling & Facility Management. Retrieved from http://dcstrategies.net/files/2_sabol_bim_facility.pdf

Sacks, R., & Barak, R. (2010). Teaching Building Information Modeling as an integral part of freshman year civil engineering education. *Journal of Professional Issues in Engineering and Practice, 136,* 30–38. http://dx.doi.org/10.1061/ (ASCE)EI.1943-5541.0000003

Sacolick, I. (2012, November 28). Construction industry dead last in IT spend [Web log message]. *Engineering News-Record.* Retrieved from http://enr.construction.com/technology/construction_technology/2012/1203-gartner-stats-aec-dead-last-in-it-spend.asp

Salmon, J. L. (2010, December 2). Critical elements of IPD: Welcome to the collaborative revolution [Web log message]. Retrieved from http://collaborativeconstruction.blogspot.com/2010/12/critical-elements-of-ipd.html

Samson, M. D. (2005). Bauhaus. In T. Adam (Ed.), *Germany and the Americas: Culture, politics, and history* (Vol. 1: A–F, pp. 122–126). Santa Barbara, CA: ABC Clio.

Shelden, D. R. (2012). Building Information Modeling and professional practice. In N. Gu & X. Wang (Eds.), *Computational design methods and technologies: Applications in CAD, CAM, and CAE education* (pp. 83–100). Hershey, PA: Information Science Reference. http://dx.doi.org/10.4018/978-1-61350-180-1.ch006

Sinopoli, J (2010). *Smart Buildings Systems for architects, owners and builders.* Burlington, MA: Elsevier Inc.

Smith, D. K., & Foster, B. (2011, November 4). *BIM implications for facility management* [Webinar]. National Institute of Building Sciences and AIA|CAFM Knowledge Group. Retrieved from http://www.youtube.com/watch?v=o7uj6uVJTps

Smith, D. K., & Tardif, M. (2009). *Building Information Modeling: A strategic implementation guide for architects, engineers, constructors, and real estate asset managers.* Hoboken, NJ: Wiley.

Stake, R. E. (1995). *The art of the case study research.* Thousand Oaks, CA: Sage.

Stevens, S. (2013). *America's top architecture schools 2014.* Retrieved from http://archrecord.construction.com/features/Americas_Best_Architecture_Schools /2013/Americas_Best_Architecture_Schools-2014-1.asp

Strauss, A., & Corbin, J. M. (1998). *Basics of qualitative research: Techniques and procedures for developing grounded theory.* Thousand Oaks, CA: Sage.

Taylor, J. E., & Bernstein, P. G. (2009). Paradigm trajectories of Building Information Modeling practice in project networks. *Journal of Management in Engineering, 25,* 69–76. http://dx.doi.org/10.1061/(ASCE)0742-597X(2009)25:2(69)

Teicholz, P. (2013). AECbytes: Analysis, research, and reviews of AEC technology. Labor-Productivity Declines in the Construction Industry: Causes and Remedies (Another Look). Retrieved from http://www.aecbytes.com/viewpoint/2013/issue_67.html

Teicholz, P. (Ed.). (2013). *BIM for facility managers.* Hoboken, NJ: John Wiley & Sons.

Tombesi, P., & Deamer, P. (2011). Integrative training for integrative practice. In P. Deamer & P. G. Bernstein (Eds.), *BIM in academia* (pp. 22–27). New Haven, CT: Yale School of Architecture.

U.K. Office of Government Commerce. (2007). *Achieving excellence in construction procurement guide, 5,* p. 6. Retrieved from http://webarchive.nationalarchives.gov.uk/20110601212617/http:/www.ogc.gov.uk/ppm_documents_construction.asp

U.S. Department of Commerce, Bureau of Economic Analysis. (2004). *2002 economic census: Table 1. Advance summary statistics for the United States.* Retrieved from http://www.census.gov/econ/census02/advance/TABLE1.HTM

U.S. Department of Commerce, Bureau of Economic Analysis. (2012). 2*007 economic census: Table 1. Advance summary statistics for the United States.* Retrieved from http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?fpt=table

Wood, M. N. (1999). *From craft to profession: The practice of architecture in nineteeth-century America.* Berkeley, CA: University of California Press.

World Architecture Community. (n.d.). *Smart buildings design theory.* Retrieved from http://www.worldarchitecture.org/theory-issues/egh/smart-building-design-architecture-theory-issues-pages.html

Yatt, B. D. (1999). *A history of the architecture profession.* Retrieved from http://archprac.cua.edu/aprp/olce/educ/history.htm

Yin, R. K. (2009). *Case study research: Design and methods* (4th ed.). Thousand Oaks, CA: Sage.

APPENDIX A. STATEMENT OF ORIGINAL WORK

Academic Honesty Policy

Capella University's Academic Honesty Policy (3.01.01) holds learners accountable for the integrity of work they submit, which includes but is not limited to discussion postings, assignments, comprehensive exams, and the dissertation or capstone project.

Established in the Policy are the expectations for original work, rationale for the policy, definition of terms that pertain to academic honesty and original work, and disciplinary consequences of academic dishonesty. Also stated in the Policy is the expectation that learners will follow APA rules for citing another person's ideas or works.

The following standards for original work and definition of *plagiarism* are discussed in the Policy:

Learners are expected to be the sole authors of their work and to acknowledge the authorship of others' work through proper citation and reference. Use of another person's ideas, including another learner's, without proper reference or citation constitutes plagiarism and academic dishonesty and is prohibited conduct. (p. 1)

Plagiarism is one example of academic dishonesty. Plagiarism is presenting someone else's ideas or work as your own. Plagiarism also includes copying verbatim or rephrasing ideas without properly acknowledging the source by author, date, and publication medium. (p. 2)

Capella University's Research Misconduct Policy (3.03.06) holds learners accountable for research integrity. What constitutes research misconduct is discussed in the Policy:

Research misconduct includes but is not limited to falsification, fabrication, plagiarism, misappropriation, or other practices that seriously deviate from those that are commonly accepted within the academic community for proposing, conducting, or reviewing research, or in reporting research results. (p. 1)

Learners failing to abide by these policies are subject to consequences, including but not limited to dismissal or revocation of the degree.

Statement of Original Work and Signature

I have read, understood, and abided by Capella University's Academic Honesty Policy (3.01.01) and Research Misconduct Policy (3.03.06), including the Policy Statements, Rationale, and Definitions.

I attest that this dissertation or capstone project is my own work. Where I have used the ideas or words of others, I have paraphrased, summarized, or used direct quotes following the guidelines set forth in the APA *Publication Manual*.

Learner name and date	Aaron J. Gonzales	July 14, 2014
Mentor name and school	Dr. Jason K. Ward	School of Education

APPENDIX B. NAAB CONDITIONS FOR ACCREDITATION. PART 2:

EDUCATIONAL OUTCOMES AND CURRICULUM (P. 20-27)

2009 Conditions for Accreditation

The National Architectural Accrediting Board, Inc.

Approved July 10, 2009

Effective April 1, 2010 for all accreditation actions or visits scheduled to take place after January 1, 2011. This includes all visits for continuing accreditation, initial or continued candidacy, initial accreditation, focused evaluations, nomenclature change requests, and requests for extension of term.

**PART TWO (II): SECTION 1 – STUDENT PERFORMANCE -- EDUCATIONAL REALMS & STUDENT
PERFORMANCE CRITERIA**

The accredited degree program must demonstrate that each graduate possesses the knowledge and skills defined by the criteria set out below. The knowledge and skills are the minimum for meeting the demands of an internship leading to registration for practice.

The school must provide evidence that its graduates have satisfied each criterion through required coursework. If credits are granted for courses taken at other institutions or online, evidence must be provided that the courses are comparable to those offered in the accredited degree program.

The criteria encompass two levels of accomplishment10:

· *Understanding*—The capacity to classify, compare, summarize, explain and/or interpret information.

· *Ability*—Proficiency in using specific information to accomplish a task, correctly selecting the appropriate information, and accurately applying it to the solution of a specific problem, while also distinguishing the effects of its implementation.

The NAAB establishes performance criteria to help accredited degree programs prepare

students for the profession while encouraging educational practices suited to the individual degree program. In addition to assessing whether student performance meets the professional criteria, the visiting team will assess performance in relation to the school's stated curricular goals and content. While the NAAB stipulates the student performance criteria that must be met, it specifies neither the educational format nor the form of student work that may serve as evidence of having met these criteria. Programs are encouraged to develop unique learning and teaching strategies, methods, and materials to satisfy these criteria. The NAAB encourages innovative methods for satisfying the criteria, provided the school has a formal evaluation process for assessing student achievement of these criteria and documenting the results.

For the purpose of accreditation, graduating students must demonstrate understanding or ability as defined below in the Student Performance Criteria (SPC):

II.1.1 Student Performance Criteria: The SPC are organized into realms to more easily understand the relationships between individual criteria.

Realm A: Critical Thinking and Representation:
Architects must have the ability to build abstract relationships and understand the impact of ideas based on research and analysis of multiple theoretical, social, political, economic, cultural and environmental contexts. This ability includes facility with the wider range of media used to think about architecture including writing, investigative skills, speaking, drawing and model making. Students' learning aspirations include:

· Being broadly educated.
· Valuing lifelong inquisitiveness.
· Communicating graphically in a range of media.
· Recognizing the assessment of evidence.
· Comprehending people, place, and context.
· Recognizing the disparate needs of client, community, and society.

A.1. Communication Skills: *Ability to* read, write, speak and listen effectively.

A. 2. Design Thinking Skills: *Ability to* raise clear and precise questions, use abstract ideas to interpret information, consider diverse points of view, reach well-reasoned conclusions, and test alternative outcomes against relevant criteria and standards.

A. 3. Visual Communication Skills: *Ability to* use appropriate representational media, such as traditional graphic and digital technology skills, to convey essential formal elements at each stage of the programming and design process.

A.4. Technical Documentation: *Ability* to make technically clear drawings, write outline specifications, and prepare models illustrating and identifying the assembly of materials, systems, and components appropriate for a building

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design.

A.5. Investigative Skills: *Ability to* gather, assess, record, apply, and comparatively evaluate relevant information within architectural coursework and design processes.

A. 6. Fundamental Design Skills: *Ability to* effectively use basic architectural and environmental principles in design.

A. 7. Use of Precedents: *Ability* to examine and comprehend the fundamental principles present in relevant precedents and to make choices regarding the incorporation of such principles into architecture and urban design projects.

A. 8. Ordering Systems Skills: *Understanding* of the fundamentals of both natural and formal ordering systems and the capacity of each to inform two- and three-dimensional design.

A. 9. Historical Traditions and Global Culture: *Understanding* of parallel and divergent canons and traditions of architecture, landscape and urban design including examples of indigenous, vernacular, local, regional, national settings from the Eastern, Western, Northern, and Southern hemispheres in terms of their climatic, ecological, technological, socioeconomic, public health, and cultural factors.

A. 10. Cultural Diversity*: Understanding* of the diverse needs, values, behavioral norms, physical abilities, and social and spatial patterns that characterize different cultures and individuals and the implication of this diversity on the societal roles and responsibilities of architects.

A.11. Applied Research: *Understanding* the role of applied research in determining function, form, and systems and their impact on human conditions and behavior.

Realm B: Integrated Building Practices, Technical Skills and Knowledge: Architects are called upon to comprehend the technical aspects of design, systems and materials, and be able to apply that comprehension to their services. Additionally they must appreciate their role in the implementation of design decisions, and the impact of such decisions on the environment. Students learning aspirations include:

· Creating building designs with well-integrated systems.
· Comprehending constructability.
· Incorporating life safety systems.
· Integrating accessibility.
· Applying principles of sustainable design.

B. 1. Pre-Design: *Ability* to prepare a comprehensive program for an architectural project, such as preparing an assessment of client and user needs, an inventory of space and equipment requirements, an analysis of site conditions (including existing buildings), a review of the relevant laws and standards and assessment of their implications for the project, and a definition of site selection and design assessment criteria.

B. 2. Accessibility: *Ability* to design sites, facilities, and systems to provide independent and integrated use by individuals with physical (including mobility), sensory, and cognitive disabilities.

B. 3. Sustainability: *Ability* to design projects that optimize, conserve, or reuse natural and built resources, provide healthful environments for occupants/users, and reduce the environmental impacts of building construction and operations on future generations through means such as carbon-neutral design, bioclimatic design, and energy efficiency.

B. 4. Site Design: *Ability* to respond to site characteristics such as soil, topography, vegetation, and watershed in the development of a project design.

B. 5. Life Safety: *Ability* to apply the basic principles of life-safety systems with an emphasis on egress.

B. 6. Comprehensive Design: *Ability* to produce a comprehensive architectural project that demonstrates each student's capacity to make design decisions across scales while integrating the following SPC:

    A.2. Design Thinking Skills
    A.4. Technical Documentation
    A.5. Investigative Skills
    A.8. Ordering Systems
    A.9. Historical Traditions and Global Culture
    B.2. Accessibility
    B.3. Sustainability
    B.4. Site Design
    B.5. Life Safety
    B.8. Environmental Systems
    B.9. Structural System

B. 7 Financial Considerations: *Understanding* of the fundamentals of building costs, such as acquisition costs, project financing and funding, financial feasibility, operational costs, and construction estimating with an emphasis on life-cycle cost accounting.

B. 8 Environmental Systems: *Understanding* the principles of environmental systems' design such as embodied energy, active and passive heating and cooling, indoor air quality, solar orientation, daylighting and artificial illumination, and acoustics; including the use of appropriate performance assessment tools.

B. 9. Structural Systems: *Understanding* of the basic principles of structural behavior in withstanding gravity and lateral forces and the evolution, range, and appropriate application of contemporary structural systems.

B. 10. Building Envelope Systems: *Understanding* of the basic principles involved
in the appropriate application of building envelope systems and associated assemblies relative to fundamental performance, aesthetics, moisture transfer, durability, and energy and material resources.

B. 11. Building Service Systems: *Understanding* of the basic principles and appropriate application and performance of building service systems such as plumbing, electrical, vertical transportation, security, and fire protection systems.

B. 12. Building Materials and Assemblies: *Understanding* of the basic principles utilized in the appropriate selection of construction materials, products, components, and assemblies, based on their inherent characteristics and performance, including their environmental impact and reuse.

Realm C: Leadership and Practice:
Architects need to manage, advocate, and act legally, ethically and critically for the good of the client, society and the public. This includes collaboration, business, and leadership skills. Student learning aspirations include:

· Knowing societal and professional responsibilities.
· Comprehending the business of building.
· Collaborating and negotiating with clients and consultants in the design process.
· Discerning the diverse roles of architects and those in related disciplines.
· Integrating community service into the practice of architecture.

C. 1. Collaboration: *Ability* to work in collaboration with others and in multidisciplinary teams to successfully complete design projects.

C. 2. Human Behavior: *Understanding* of the relationship between human behavior, the natural environment and the design of the built environment.

C. 3 Client Role in Architecture: *Understanding* of the responsibility of the architect to elicit, understand, and reconcile the needs of the client, owner, user groups, and the public and community domains.

C. 4. Project Management: *Understanding* of the methods for competing for commissions, selecting consultants and assembling teams, and recommending project delivery methods.

C. 5. Practice Management: *Understanding* of the basic principles of architectural practice management such as financial management and business planning, time management, risk management, mediation and arbitration, and recognizing trends that affect practice.

C. 6. Leadership: *Understanding* of the techniques and skills architects use to work collaboratively in the building design and construction process and on environmental, social, and aesthetic issues in their communities.

C. 7. Legal Responsibilities: *Understanding* of the architect's responsibility to the public and the client as determined by registration law, building codes and regulations, professional service contracts, zoning and subdivision ordinances, environmental regulation, and historic preservation and accessibility laws.

C. 8. Ethics and Professional Judgment: *Understanding* of the ethical issues involved in the formation of professional judgment regarding social, political and cultural issues in architectural design and practice.

C.9. Community and Social Responsibility: *Understanding* of the architect's responsibility to work in the public interest, to respect historic resources, and to improve the quality of life for local and global neighbors.

PART TWO (II): SECTION 2 – CURRICULAR FRAMEWORK

II.2.1 Regional Accreditation: The institution offering the accredited degree program must
be or be part of, an institution accredited by one of the following regional institutional accrediting agencies for higher education: the Southern Association of Colleges and Schools (SACS); the Middle States Association of Colleges and Schools (MSACS); the New England Association of Schools and Colleges (NEASC); the North Central Association of Colleges and Schools (NCACS); the Northwest Commission on Colleges and Universities (NWCCU); and the Western Association of Schools and Colleges (WASC).

The APR must include a copy of the most recent letter from the regional accrediting commission/agency regarding the institution's term of accreditation.

II.2.2 Professional Degrees and Curriculum: The NAAB accredits the following professional degree programs: the Bachelor of Architecture (B. Arch.), the Master of Architecture (M. Arch.), and the Doctor of Architecture (D. Arch.). The curricular requirements for awarding these degrees must include professional studies, general

studies, and electives. Schools offering the degrees B. Arch., M. Arch., and/or D. Arch. Are strongly encouraged to use these degree titles exclusively with NAAB-accredited professional degree programs.

The number of credit hours for each degree is specified below. Every existing accredited program must conform to the following minimum credit hour requirements by January 1, 2015.

· **Doctor of Architecture.** Accredited degree programs awarding the D. Arch. Degree must require either an undergraduate baccalaureate degree; or a minimum of 120 undergraduate semester credit hours; or the undergraduate-level quarter-hour equivalent, and a minimum of 90 graduate-level semester credit hours; or the graduate level quarter-hour equivalent, in academic coursework in professional studies and electives.

· **Master of Architecture.** Accredited degree programs awarding the M. Arch. Degree must require a minimum of 168 semester credit hours; or the quarter-hour equivalent, of which at least 30 semester credit hours; or the quarter-hour equivalent, must be at the graduate level, in academic coursework in professional studies and electives.
· **Bachelor of Architecture.** Accredited degree programs awarding the B. Arch. Degree must require a minimum of 150 semester credit hours or the quarter-hour equivalent, in academic coursework in general studies, professional studies and electives.

Curricular requirements are defined as follows:

· **General Studies.** A professional degree program must include general studies in the arts, humanities, and sciences, either as an admission requirement or as part of the curriculum. It must demonstrate that students have the prerequisite general studies to undertake professional studies. The curriculum leading to the architecture degree must include at least 45 credit hours, or the quarter-hour equivalent, outside of architectural studies either as general studies or as electives with other than architectural content.

For the M. Arch. and D. Arch., this calculation may include coursework taken at the undergraduate level.

· **Professional Studies.** The core of a professional degree program consists of the required courses that satisfy the NAAB Student Performance Criteria. The accredited degree program has the flexibility to require additional courses including electives to address its mission or institutional context.

· **Electives.** A professional degree program must allow students to pursue their special interests. The curriculum must be flexible enough to allow students to complete minors or develop areas of concentration, inside or outside the program.

Table 1
Minimum Credit Distribution

General (non-architecture) Studies 45 Semester-Credit-Hour Minimum*	Professional Studies
· Required courses with other than architectural content	· Courses with architectural content required of all students
· Elective courses with other than architectural content	· Elective courses with architectural content

*Or the quarter-hour equivalent

The APR must include the following:
· Title(s) of the degree(s) offered including any pre-requisite degree(s) or other preparatory education and the total number of credits earned for the NAAB-accredited degree or track for completing the NAAB-accredited degree.
· An outline, for each accredited degree program offered or track for completing the NAAB-accredited degree, of the curriculum showing the distribution of general studies, required professional courses (including prerequisites), required courses, professional electives, and other electives.
· Examples, for each accredited degree offered or track for completing the NAAB-accredited degree, of the minors or concentrations students may elect to pursue.
· A list of the minimum number of semester credit hours or the equivalent number of quarter credit hours required for each semester or quarter, respectively.
· A list identifying the courses and their credit hours required for professional content and the courses and their credit hours required for general education for each accredited degree program offered or track for completion of the NAAB-accredited degree.
· A list of off-campus programs, description of facilities and resources, course requirements, and length of stay.

II.2.3 Curriculum Review and Development
The program must describe the process by which the curriculum for the NAAB-accredited degree program is evaluated and how modifications (e.g., changes or additions) are identified, developed, approved, and implemented. Further, the NAAB expects that programs are evaluating curricula with a view toward the advancement of the discipline and toward ensuring that students are exposed to current issues in practice. Therefore, the program must demonstrate that licensed architects are included in the curriculum review and development process.

The APR must include a description of the composition of the program's curricular review process including membership of any committees or panels charged with responsibility for curriculum assessment, review, and development. This description should also address the role of the curriculum review process relative to long-range planning and self-assessment. (NAABb, 2009).

APPENDIX C: AUTODESK BIM CURRICULUM

Welcome to the Autodesk® BIM Curriculum for faculty and students. The Autodesk BIM Curriculum was created to prepare learners for professional practice in architecture, engineering, and construction management. The site has an abundance of learning materials, YouTube videos, exercises, assessments, and much more to teach Building Information Modeling (BIM) and sustainable design practices, along with integrated project delivery (IPD) concepts.

Students will learn how to design and communicate more fluidly, test and plan using BIM models, and utilize cloud services along with mobile devices within an IPD framework. With a strong focus on sustainability, conceptual design concepts with new focus on computational design, the comprehensive teaching tools provide students the extra edge to excel in their design projects, studies, and studio.

Faculty can supplement their courses with the curriculum materials and provide additional video tutorials to inspire design and get started quickly. The BIM Curriculum contains instructor guides, presentations, video tutorials, and assessment questions that are easily incorporated into lesson plans.

For additional resources, check out the Autodesk Sustainability Workshop and New Building Performance Analysis Certificate (BPAC).

This curriculum is designed to help prepare the next generation of architecture, engineering, and construction management students for professional practice by exploring Building Information Modeling (BIM) sustainable design practices along with integrated project delivery (IPD) concepts. Students and graduates can more fluidly design and communicate, test and plan using BIM models in an IPD framework. The BIM Curriculum contains an Instructor Guide that highlights essential concepts and learning goals and is accompanied by comprehensive teaching tools, a student workbook, instructional videos and datasets.

Using Autodesk Revit Software with the BIM Curriculum As you work through the BIM curriculum, we hope you will follow along with exercises and video tutorials to ensure your complete understanding of the concepts presented in the Lessons. If you are using Autodesk® Revit® 2014 then you will have access to the functionality of all the Revit disciplines (Architecture, MEP and Structural Engineering) in one interface. If you are using an older version of the Revit products (Revit Architecture, Revit Structure, Revit MEP) then you will need to open each one separately to access the specific functionality you need. To get a better understanding of how to use the tools from all three disciplines in the unified interface in Revit 2014 we recommend reviewing the following video.

Autodesk Revit 2014 - Integrated Modeling Helps You Shine

Unit 1 – BIM Modeling Basics
        Lesson 1: Modeling Building Elements
        Lesson 2: Building Envelope
        Lesson 3: Curtain Systems
        Lesson 4: Interiors and Circulations
        Lesson 5: Families and Components
        Lesson 6: View and Visualization
        Lesson 7: Materials, Lighting, and Rendering

Unit 2 – BIM Modeling Advanced
        Lesson 1: Area and Space Planning
        Lesson 2: Phased Project Design
        Lesson 3: Design Options
        Lesson 4: Detailed Design/Construction Documents
        Lesson 5: Detailed Design/Schedules and Quantities

Unit 3 – BIM Design Methods
        Lesson 1: Program, Site, Set Up
        Lesson 2: Parametric Modeling with Design Options
        Lesson 3: Exploring Options through Analysis
        Lesson 4: Pattern Based Families

Unit 4 – Multidisciplinary Coordination
        Lesson 1: Preparing to Share Models
        Lesson 2: Modeling Structural Elements
        Lesson 3: Modeling Electrical Systems
        Lesson 4: Modeling Plumbing Systems
        Lesson 5: Modeling Mechanical Systems
        Lesson 6: Coordination and Interference Checking
        Lesson 7: BIM 360 Glue and Field

Unit 5 – Integrated Project Delivery
        Lesson 1: Modeling Integration and Management
        Lesson 2: Identifying and Resolving Issues
        Lesson 3: Scheduling and 4-D Simulation
        Lesson 4: Presenting the Project Model

Unit 6 – Green Building Design
        Lesson 1: Passive Design
        Lesson 2: Material Properties and Energy Impact
        Lesson 3: Water Use and Collection
        Lesson 4: Power Use and Generation
        Lesson 5: Daylighting

Unit 7 – Extending BIM Beyond Design
    Lesson 1: Modeling for Construction
    Lesson 2: 4-D Simulation and Construction Planning
    Lesson 3: Model-Based Estimating and Quantity Takeoff
    Lesson 4: Using BIM for Fabrication
    Lesson 5: Using BIM for Operations and Facilities Management

Unit 8 – Computational Design
    Lesson 1: Getting Situated
    Lesson 2: Interacting with Nodes
    Lesson 3: Data Management
    Lesson 4: Computational Logic
    Lesson 5: Parametric Assembly

(Autodesk, n.d.).