RELATING BUILDING INFORMATION MODELING & ARCHITECTURAL ENGINEERING CURRICULA

by

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A REPORT

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Abstract

Building Information Modeling (BIM) has been touted by industry leaders, professional societies and trade articles as the next 'big' industry trend shaping the delivery of commercial construction by architects, engineers and construction managers. BIM delivery has been presently utilized by over half of polled industry partners. And, withstanding a separate technological programming breakthrough, BIM will likely sustain high levels of growth in implementation in industry with the rise of the next generation of design and construction professionals and building owners in the next 50 years, making BIM delivery the primary means of commercial construction document and project delivery. Due to this growth and publicity, universities around the USA have been highly encouraged to implement BIM into their educational curricula fabric of course work, placing an ever increasing emphasis on a BIM skill set for their graduates. Taken together, surveys of Architectural Engineering programs current and planned implementation of BIM, potential employers' emphasis on recruiting graduates with BIM skills, reading and referencing of trade articles relating BIM to industry delivery trends, research on initial and sustained requirements and associated costs of hardware and software for universities specifically Architectural Engineering Programs to include BIM in their curriculums, this collation of research and information will trend towards suggestions and conclusions related to BIM's importance in Architectural Engineering curriculums of the present and future.

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Besides my advisor, I would like to thank the rest of my report committee: Prof. Charles Burton, and Assistant Prof. Raphael (Ray) Yunk, for their encouragement, insightful comments, and hard questions. And a special thank you to a KSU Developing Scholars student: Leo Hernandez for his never ending enthusiasm about BIM.

This report would not be possible without the anonymous survey responses from colleagues of the eighteen ABET Accredited Architectural Engineering undergraduate programs in the US and also the industry partners who employ their graduates.

Dedication

This report would be incomplete without a mention of the support given me by my cherished family, Josh Vogt (husband) and Dr. Denver & Ali Marlow (parents), to whom this report is dedicated. They are the underpinnings of my daily hard work and they are the ones who kept my spirits high when my own failed me. Without them lifting me up, this report would have seemed insurmountable.

CHAPTER 1 - Introduction

Building information modeling (BIM) has gained substantial popularity and is becoming the emerging processes that replace the traditional separation of design, construction and facilities management. BIM covers geometry, spatial relationships, light analysis, geographic information, quantities and properties of building components (for example manufacturers' details). BIM can be used to demonstrate the entire building life cycle, including the processes of construction and facility operation. Quantities and shared properties of materials can be extracted easily and scopes of work can be isolated and defined. Systems, assemblies and sequences can be shown in a relative scale with the entire facility or group of facilities.

With support from professional organizations such as American Institute of Architects (AIA), American Society of Civil Engineers (ASCE), and the Associated General Contractors of America (AGC), in turn with large scale building developers and Owners mandating BIM delivery on their projects; the Architecture/Engineering/Construction (AEC) design professionals and contractors responded with perceived full scale adoption of BIM as a method of document and building construction delivery.

This paper describes (1) a brief background on BIM and BIM technology, (2) the objectives, methodology and outcomes of two internet surveys, one sent to the eighteen ABET accredited architectural engineering (AE) programs and a second sent to the employers who hire undergraduate architectural engineers for the AEC industry, (3) the relationship of BIM education to the suggested ABET program requirements for educational program accreditations, (4) a return on investment for ARE programs who embrace the infusion of education of BIM , and (5) some suggested education curriculum implementation plans, conclusions and thoughts looking forward.

1.1 Defining BIM

What is (or) How do you define BIM? There are several slightly differing views of BIM and it’s definition. The following are a few of the more widely accepted definitions by the manufacturers of the mainstream BIM software.

- “A single repository including both graphical documents - drawings - and non-graphical documents - specification, schedules, and other data” - ArchiCAD

- “A modeling of both graphical and non graphical aspect of the entire Building Life cycle in a federated database management system” - Bentley
- “A building design and documentation methodology characterized by the creation and use of coordinated, internally consistent computable information about a building project in design and construction” - Autodesk

1.2 History of BIM Software(s)

What is the historical timeline of software releases for Revit?

Revit Architecture	Revit Structure	AutoCAD Revit MEP Suite
Revit Architecture 2011 April 2010	Revit Structure 2011 April 2010	AutoCAD Revit MEP Suite 2011 April 2010
Revit Architecture 2010 April 2009	Revit Structure 2010 April 2009	AutoCAD Revit MEP Suite 2010 April 2009
Revit Architecture 2009.1 Sept. 2008	NA	NA
Revit Architecture 2009 April 2008	Revit Structure 2009 April 2008	AutoCAD Revit MEP Suite 2009 April 2008
Revit Architecture 2008 April 2007	Revit Structure 2008 April 2007	AutoCAD Revit MEP Suite 2008 April 2007
Revit Architecture 9.1 Sept. 2006	Revit Structure 4 Sept. 2006	AutoCAD Revit MEP Suite 2.0 Sept. 2006
Revit Architecture 9 April 2006	Revit Structure 3 April 2006	AutoCAD Revit MEP Suite 1.0 April 2006
Revit Architecture 8.1 April 2005	Revit Structure 2 Sept. 2005	
Revit Architecture 8.0 August 2005	Revit Structure 1 June 2005	
Revit Architecture 7.0 December 2004		
Revit Architecture 6.1 March 2004		
Revit Architecture 6.0 December 2003		
Revit Architecture 5.5 April 2003		
Revit Architecture 5.1 May 2003		
Revit Architecture 5.0 December 2002		
Revit Architecture 4.5 May 2002		
Autodesk acquires Revit Technology Corporation - April 1, 2002		

Figure 1:1 Historical Timeline of Revit® Software Releases

Microstation:

1985 - Keith Bentley founds Bentley Systems, Inc.

1986 - Bricsnet's initial architectural modeling software product was developed for IBM UNIX by architect Erik De Keyser. The first CAD software created by Bentley Systems is called PseudoStation and it allowed users to view Intergraph IGDS drawings files without Intergraph software or hardware.

1987 - MicroStation is released with the ability to edit IGDS files. 50% of Bentley is purchased by Intergraph.

1987 - Bentley creates the first version of the DGN file format.

1995 - Bentley develops advanced solid modeling for MicroStation and releases MicroStation 95 for the Windows platform.

1996 - MicroStation/J V7 is released.

1997 - After obtaining Bricsnet's architectural modeling software which becomes the core technology for MicroStation TriForma, Bentley releases its first BIM application to run on MicroStation.

2002 - MicroStation V8 is released and the DGN file format changes for the one and only time since it's conception.

2007 - Generative Components is released enabling programmable modeling.

2008 - MicroStation V8i BIM applications are released enabling real time views of plans, sections, elevations and clipping planes.

Figure 1:2 Historical Timeline of Bentley Microstation® Software

ArchiCAD:

1982 - Development for ArchiCAD started in Budapest behind the Iron Curtain.

1987 - ArchiCAD is released. ArchiCAD is recognized as the first CAD product on a personal computer able to create both 2D and 3D drawings and considered the first BIM product.

2007 - Nemetschek AG purchases Graphisoft.

Figure 1:3 Historical Timeline of ArchiCAD® Software

CHAPTER 2 - Building Information Modeling (BIM) Technology / Software

2.1 Technology / Software

To quote the GSA (U.S. Government Services Agency) guide to 3D-4D Building Information Modeling: "There is a progression from 2D to 3D, 4D, and BIM. While 3D models make valuable contributions to communications, not all 3D models qualify as BIM models since a 3D geometric representation is only part of the BIM concept. Critical to successful integration of computer models into project coordination, simulation, and optimization is the inclusion of information—the "I" in BIM—to generate feedback. As a shared knowledge resource, BIM can serve as a reliable basis for decision making and reduce the need for re-gathering or re-formatting information."

ASHRAE (American Society of Heating Refrigeration and Air-Conditioning Engineers) further defines the different levels of BIM in "An introduction to BIM" as "A Building Information Model is a digital representation of the physical and the functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its life cycle from inception onward."

Two dimensional or three dimensional, Computer Aided Drafting is equivalent to conventional drafting, only performed on a computer. Unintelligent points, lines and symbols are used to convey design intent or detail construction means and methods. Most often plotted onto paper media and published in that form for drawings and specifications and delivered to the owner, contractor and reviewing authorities and agencies for approval and actual construction. The final 3D model includes three dimensional (3D) shape information, but does not include the 4D and 5D characteristics described below.

To create a BIM, a modeler uses intelligent objects to build the model. Building Information Modeling is the human activity of using BIM software and other related software, hardware and technologies to create and use in a building information model.

A 4D BIM model has objects and assemblies that have schedule and time constraint data added to them. The information can be contained in the BIM or can be linked or otherwise

associated (integrated and/or interoperable) with project design and construction activity scheduling and time sensitivity estimating and analysis systems.

A 5D BIM that has objects and assemblies that have a cost dimension added to them. The cost information can be contained in the BIM or can be linked or otherwise associated to the building objects.

Over the years, Engineers have primarily had two standards for 2D Drafting – AutoCAD (by Autodesk) and Microstation/IntelliCAD (By Intergraph, Now Bentley Systems). Although there have been other programs available, they were in the minority. Translating between these programs could at times prove to be painful, but over the years the problems were overcome. So for a while architects and engineers have been able to easily transfer 2D information back and forth, no matter the program.

Then as computers got stronger, the programs became better and more involved. First came 3D modeling and then intelligent AEC/MEP modeling and finally BIM as we know it today.

2.1 The Somewhat Ugly Truth

Software manufacturers will convey that their program is compatible with a competitors program, especially when a client currently uses different software. The truth is, with a few exceptions, that they don't. While the other program may be able to import a model the chances are any usable BIM intelligence will not exist after importing. The other problem not mentioned is when the models are transferred, they often will lose cohesion. Causing the modeler problems with corrupted models, and models where only some of the model imports, adding work and slowing the process down.

There has been progress in the industry to come up with a neutral standard for all BIM software. That format is known as Industry Foundation Class (IFC). The IFC specification is a neutral data format to describe exchange and share information typically used within the building and facility management industry sector. The IFC specification is developed and maintained by buildingSMART International, bSI, (formally known as International Alliance for Interoperability, IAI).

Currently, IFC supports primarily architectural and structural steel BIM Models. So models in Autodesk REVIT will open in Bentley or AutoCAD ADT and keep most of their intelligence.

The problem lies in jumping into BIM and not understanding what BIM is and the limitations of the software. That all said BIM still saves time, money and effort when properly executed. Even when 4D or 5D BIM modeling isn't an option, 3D modeling alone is worth the effort. What it truly takes for a project to be fully and accurately modeled in 4D or 5D BIM, is for the architects, engineers and contractors to be using the same software package.

Based on Autodesk Inc. support of free software downloads for educational purposes, this paper focuses mainly on Autodesk's Revit® software, but survey questions consider Bentley, ArchiCAD and other software(s) for data generation.

CHAPTER 3 - BIM & ABET Program Requirements

Architectural Engineering (AE) programs are committed to preparing students for the rigors of a career in design, engineering, and construction. Accredited by ABET (Accreditation Board for Engineering and Technology) for architectural engineering, an AE program provides a solid foundation in the fundamentals, and should include additional instruction in cutting-edge methodologies, such as design/build or sustainability. Accredited under the General Criteria and the Architectural Engineering Program Criteria by the Engineering Accreditation Commission of ABET, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012 - telephone: (410) 347-7700, http://www.abet.org.

Of particular importance to this report is a relatively new technology known as building information modeling (BIM) and its ability to mirror the real world of architecture and engineering in the classroom and industry.

A draft from February 14, 2010 includes comments on the ABET Program Criteria discussed during an AE Academic Council of AEI Conference Call dated February 11, 2010.

1. Curriculum

The program must demonstrate that graduates can apply mathematics through differential equations, calculus-based physics, and chemistry. The four basic architectural engineering curriculum areas are building structures, building mechanical systems, building electrical systems, and construction/construction management. Graduates are expected to reach the synthesis (design) level in one of these areas, the application level in a second area, and the comprehension level in the remaining two areas. The engineering topics required by the general criteria shall support the engineering fundamentals of each of these four areas at the specified level. Graduates are expected to discuss the basic concepts of architecture in a context of architectural design and history. The design level must be in a context that:

a. Considers the systems or processes from other architectural engineering curricular areas,

b. Works within the overall architectural design,

c. Includes communication and collaboration with other design or construction team members,

d. Includes ***computer-based technology*** and considers applicable codes and standards, and

e. Considers fundamental attributes of building performance and sustainability.

Figure 3:1 *DRAFT* ABET AE Curriculum Developed for Commentary 2010

The AE AC;s draft has opted for the wording “computer-based technology” to encompass several software technologies including but not limited to BIM software(s). Again showing a valued importance of educational advancements related to information technology in the undergraduate classrooms which reinforces the urgency of the findings of this report topic relating the current industry trends to the current curriculum trends.

A review of recent studies and university websites reveals that some undergraduate programs are making the leap to incorporate BIM in their curricula. For example Penn State University website notes introducing BIM by way of a two-day voluntary tutorial. The following survey results and conclusion will reflect how direct and timely responses to the question of information technology integration (ie: BIM integration) have, can and should be met.

CHAPTER 4 - Objectives of Survey(s)

4.1 Objective of Survey

Computer-aided drafting (AutoCAD) has been the most sophisticated modeling technique available to architects, engineers and construction managers and is perceived to be giving way to the more complex technology of building information modeling (BIM).

This report is an attempt to quantify through survey data what the eighteen ABET accredited architectural engineering undergraduate programs have done, if anything, to incorporate BIM in their curricula. And to tie that information to a second survey of technical professionals to confirm that BIM technology is truly a trend within the engineering industry and has become an emphasis for employers of undergraduate architectural engineering candidates.

4.2 Participants

4.2.1 ABET Accredited Architectural Engineering Programs

The colleges and universities who are ABET accredited Architectural Engineering (AE) programs were surveyed for this study. Although many AE programs have graduate programs, this study focused primarily on undergraduate curricula. At the time of the survey there were 18 institutions which offered undergraduate programs in architectural engineering. Each of the 18 institutions was contacted prior to collecting survey materials in order to gain contact information of the Program Chair/Head and one or more faculty who were well versed in AE program visioning, BIM, and possible BIM curricula. The survey was delivered via an emailed link to the Axio Survey Website. Responses were received from 12 separate institutions, about 66% of the total.

Survey participants included responses from AE programs University of Texas at Austin, University of Colorado at Boulder, Illinois Institute of Technology (IIT), Pennsylvania State University, Drexel University, California Polytechnic State University, Milwaukee School of Engineering, Missouri University of Science and Technology, University of Wyoming, University of Nebraska-Lincoln, and Kansas State University.

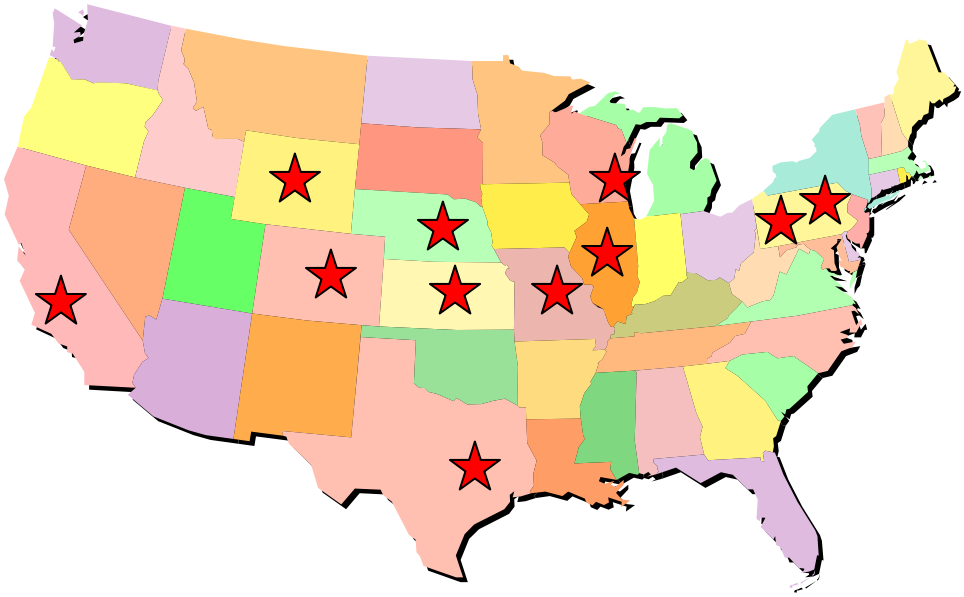

Figure 4:1 US Map of AE Program Respondents

The respondents were asked to provide background information regarding their programs enrollments size. Below is the percentage of responses, by range of undergraduate enrolment. The most common program size was 301-400 undergraduates with 11-25 graduate students.

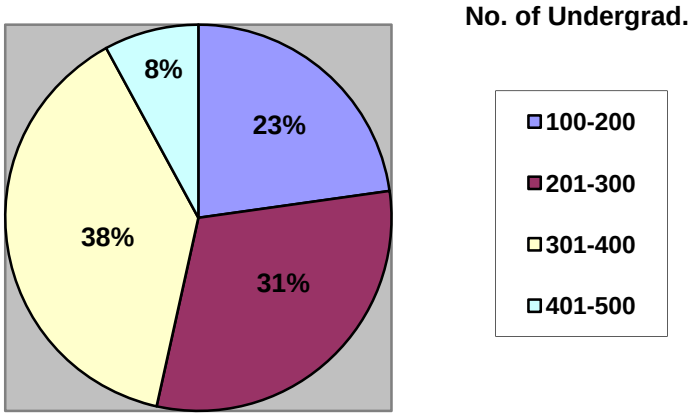

Figure 4:2 Current AE Undergraduate Program Enrollments

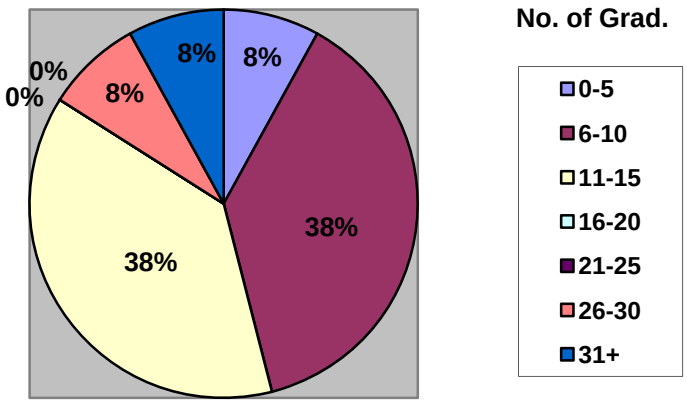

Figure 4:3 Current AE Graduate Program Enrollments

In addition to undergraduate and graduate enrollment numbers, respondents were asked to select the level of importance within their curricula regarding the following statements.

The shaded cells within the table reflect some of the more telling responses as to trends in AE program curricula and instructional methodologies.

Importance Level within Curricula

	None	Low	Average	High	Critical	Above Average
Integration of building elements (Structural./MEP/ FP/L/IT/TD)	0%	8%	15%	15%	**62%**	**77%**
Core design fundamentals & skills for AEC industry	0%	0%	0%	31%	**69%**	**100%**
Sustainable Design Concepts	0%	8%	15%	**46%**	31%	**77%**
Student preparation for LEED AP Exam	8%	0%	**62%**	31%	0%	31%
Student prep for HPBDP	8%	31%	**54%**	8%	0%	8%
Topics related to Lean Construction	0%	**39%**	**31%**	**31%**	0%	31%
Computer-based instruction (any format)	0%	8%	**38%**	**38%**	**15%**	**52%**
Distance learning	0%	**46%**	23%	8%	0%	8%

Note: HPBDP – ASHRAE's High Performance Building Design Professional certification

Above Average consists of a combined % of High + Critical

Table 4:1 AE Curricula Topic Emphasis

Note that of the surveyed statement(s) the core design fundamentals and integration were 77%, 100% respectively, showing a continued and consistent emphasis of AE program curricula to teach and reinforce core engineering fundamentals as their primary pursuit. Also showing a strong 77% above average rating is the concept of infusion of sustainable design and construction concepts within AE programs. One would argue that these sustainable concepts have always been embedded into core engineering concepts, but only more recently have they become a topic that is emphasized and being tagged as "sustainable" when discussed in lectures and laboratories throughout college campuses.

The only section to receive slightly more diverse, but still above 50% of above average respondents, was Computer Based Learning (Any Type). One could draw the conclusions, that similar to "sustainable" concepts and its rise in popularity within AE curricula in the last decade that a similar rise has begun to occur with computer-based instruction. Albeit not solely restricted to BIM software(s), computer based instruction is trending towards becoming a "must have" within AE curriculums whether it be Microsoft Excel®, Trane Trace ®, RISA®, AGi32 ®, AutoCAD® or other software(s). And few would argue that the instrumental and newest computer based software for design engineers on the market today are the BIM software(s) which would lead one to conclude that BIM is propelling this shift in importance and that computer based instruction will track the same upward swing as "sustainability" has shown in the past decade.

4.2.2 Industry Employers of Architectural Engineering Undergraduates

The industry employers of architectural engineers were also surveyed for this study. In order to generate an exhaustive list of survey participants, employer contact lists were obtained from Kansas State University. Also Engineering News Record (ENR) Magazine was referenced for additional national firms and contacts were generate from company website profiles and posted contact information. The survey was delivered via an emailed link to the Axio Survey Website. Responses were received from 18 separate corporations, about 13.85% of the total. And important to note that 44.44% of respondents either were headquartered or operated regional offices in Kansas.

The majority of the industry employer respondents were of companies totaling 1-50 employees at a respondent rate of 39%, with second largest respondents group of companies

totaling 101-200 employees at a respondent rate of 22%, and the third largest respondents were of companies totaling 401-500 employees at a respondent rate of 11%.

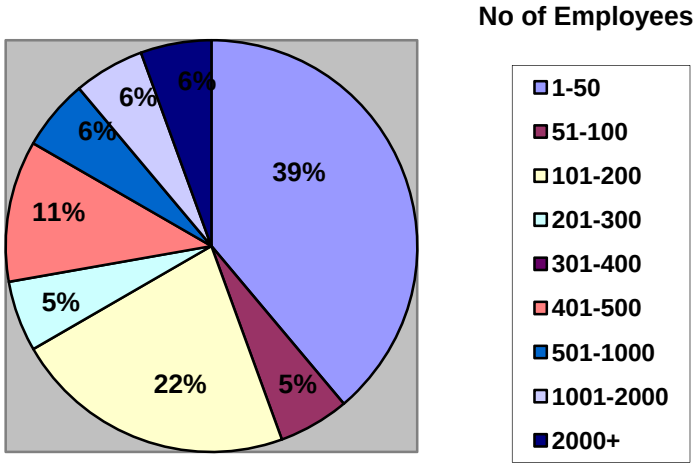

Figure 4:4 Percentage of Number of Employees

The industry employer respondents reported revenue received for design purposes as shown above are then compared below to a recent McGraw-Hill Construction survey completed in July, 2009 to show validity due to MS Report Survey's low respondent rate.

Reported Revenue	MS Report Survey (2010) N=18	McGraw-Hill Survey (2009) N=790
<$500K	5.56%	25%
$500K-$5M	33.33%	29%
$5M-$10M	22.22%	12%
$10M+	27.80%	32%

Table 4:2 Employer Survey – Reported Revenue for Design Purposes

In order to better understand the workforce and recruiting of each industry employer, employers were asked to estimate the number of AE educated employees on their staff. 44% of the respondents had between 11-25 AE graduates currently employed in their firm. This is roughly 1/8 to 1/2 of their firm's total employees depending on total size

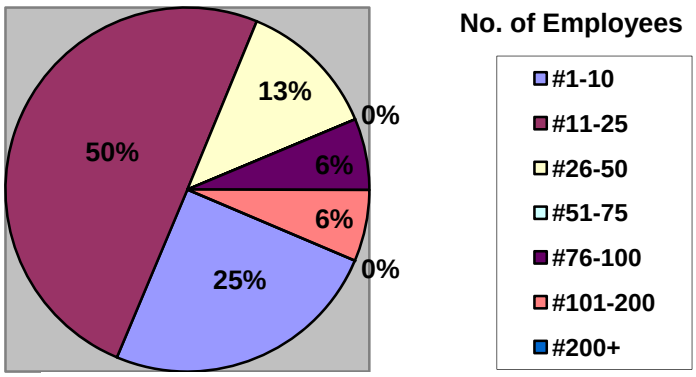

Figure 4:5 Percentages of AE Employees

shown above. These high AE employee numbers help to validate the collected data and conclusions drawn when relating BIM education within AE programs and their curricula.

CHAPTER 5 - Methodology

5.1 Questionnaire

5.1.1 ABET Accredited Architectural Engineering Programs

The questionnaire that was developed for this study requested quantitative and qualitative information from the respective respondents. The first section asked for demographic information about the institution.

The second section concerned the curriculum at each institution. The survey asked if AutoCAD and BIM are taught as stand-along courses or infused into the curricula across multiple classes. How courses are being taught? Distance or on campus? It also asked separate questions about the incorporation of elements of BIM into other courses. In addition, it asked respondents to specify which vendors' software applications they use in their curricula.

The third section asked questions about the perceived usefulness of BIM technology, and about the obstacles to changing curricula and developing/implementing a new course. If a BIM introductory course is being taught? And if not, why not? Respondents were asked to determine in their opinion, when during an undergraduate degree should a BIM introductory course be taught? And finally, if any programs are currently promoting BIM software use as part of competition team submittals?

5.1.2 Industry Employers of Architectural Engineering Undergraduates

The questionnaire that was developed for this study requested quantitative and qualitative information from the respective respondents. The first section asked for demographic information about the industry employer's company.

The second section concerned the attitude towards BIM delivery at each company, and to gain a historical perspective and areas in which AutoCAD and BIM delivery methods are being utilized. In addition, it asked respondents to specify which vendors' software applications they use in their day-to-day operations.

The third section asked questions about the perceived future of BIM software adoption and the document delivery process. What BIM skills their company would like to see when hiring new interns or college graduates? And their companies inclination to offer higher starting salaries to undergraduates with BIM skill?

5.2 Statistical Analysis

This analysis includes only descriptive statistics and no comparative statics. No other statistical analysis was completed.

CHAPTER 6 - Summary of Survey Responses

6.1 Summary

6.1.1 ABET Accredited Architectural Engineering Programs

6.1.1.1 Background of AutoCAD and BIM Coursework

Respondents reported that 38% teach one required class in either AutoCAD or BIM as a standalone course in their program. An additional 38% reported requiring two AutoCAD and/or BIM classes for undergraduate graduation. 62% of AE program respondents require a BIM introductory course for undergraduate graduation. Although a staggering 69% of respondents selected BIM requirements in undergraduate educations as being Above Average (High or Critical). 75% of respondents felt that BIM skills sets should be a learned skill upon graduation whether taught in the classroom or learned from another source (Co-op, Intern, Self instruction, vendor tutorials, etc...).

2D AutoCAD is considered the current "workhorse" of the design industry, 54% of respondents agreed or strongly agreed that with the onset of BIM, "2D CAD is now very inefficient compared to true BIM workflow software in design." And 61% believe that adoption of BIM technology in education within their AE program has (or would) lead to higher salary offers for our AE graduates entering the job markets today.

77% of AE program respondents feel that the education and use of computer technology in the classroom adequately prepares their undergraduates for positions in the consulting/design industry, which strongly correlates to the 75% of respondents above, who are requiring one or two AutoCAD and/or BIM courses as part of their AE graduation requirements.

An overwhelming 100% of respondents believe that BIM will eventually become the primary form of document delivery for Architects/Engineers/Contractors, surpassing AutoCAD.

The large majority of AE programs offering BIM course(s) began between 2006-2009. Currently only one program is offering BIM education through distance learning beginning in 2010 and only one program is considering offering BIM education for continuing education credits or professional development hours in the foreseeable future.

Autodesk AutoCAD has been the standard electronic drafting method for the past twenty years. In order to understand how this correlates to AE program curricula and the potential shift

to BIM document delivery several questions were asked regarding the current use of AutoCAD in course and curricula.

The respondents were asked at which point an AutoCAD introductory course was taught. 88% total of respondents indicated that an AutoCAD introductory course was taught either freshman or sophomore year's 44% each respectively, while an additional 11% of respondents said that undergraduates were unrestricted as to when they completed an AutoCAD course. In additional several programs responded that they are currently providing additional courses to extend AutoCAD instruction. These courses range from Advanced AutoCAD, CAD requirements in senior capstone courses, and all senior design courses and upper level studio courses where students are either given the option or required to produce work in AutoCAD. Three respondents stated specifically that their program is now giving the student the option in upper level design and studio courses to produce the work in Revit in place of AutoCAD.

An overwhelming 100% of respondents require AutoCAD for undergraduate AE program requirements for graduation.

6.1.1.2 Program Provided Software

Respondents were asked to select all the program provided software(s) they currently make available to their students in localized computer labs. The results are as follows; note the darker shaded cells represent 50+% adoptions:

Vendor Software	% of Respondents Providing Software
Autodesk AutoCAD (plain)	100%
Autodesk ADT	54%
Autodesk ABS	38%
Autodesk Revit Architecture	92%
Autodesk Revit MEP	69%
Autodesk Revit Structures	77%
Autodesk Navisworks	23%
Bentley Microstation	23%

Graphisoft ArchiCAD	8%
Nemetsheck Vectorworks	0%
Google Sketch-Up	62%
Google Sketch-Up Pro	15%
Adobe Pro	46%
Adobe Illustrator	39%
Adobe Photoshop	46%
Risa 3D	31%
AGi32	38%
Visual Basic or Professional	31%
Trane Trace 700	46%
eQuest	62%
Primavera	54%
Other	31%

Note: Other responses included - Mat Lab, ETABS, Energy019, Mat Lab Maple, SAP, RAM+, visual analysis for structural design

Table 6:1 AE Programs Providing Computer Lab Software for Students

6.1.1.3 BIM Introductory Courses

Of the AE programs requiring a BIM introductory course for graduation 100% of them are teaching a form of Autodesk Revit. Of the above, 75% of those courses are being instructed in Revit Architecture, 15% in Revit Structures and 10% non-reporting. The majority of respondents would place this BIM introductory course in the sophomore year, followed secondly be freshman year and lastly by senior year.

For those programs not requiring a BIM introductory course, some are however offering BIM introductory courses for elective credit. Of those not requiring a BIM course for graduation, 79% of respondents are offering the course for elective credit. Again with a sole emphasis, 100% respondents offering Revit Architecture or Revit Structures. When BIM is offered as an elective 74% of them are offering it at a senior level. It could be speculated that this is due to complimentary electives within engineering being loaded towards the end of an undergraduate curricula plan.

6.1.1.4 Extension of BIM Coursework Examples

Several programs expressed utilizing or extending BIM education into other classrooms beyond the introductory course. Below are their responses:

"We are aiming to embed BIM throughout courses, instead of having specific BIM courses. For example, when teaching construction scheduling, we teach students how to create 4D models."

"We implement BIM into junior year design studio and senior year capstone course."

"I intend to introduce BIM tools in a required sophomore course this spring."

"We teach AutoCAD freshman year but students learn BIM within our two architectural design sequences CAE 468 and 469. The amount of BIM is about 1 course worth of material. Both are required for graduation. Most students use BIM in their capstone design course and students frequently use it in projects in other senior design courses."

"All our design labs (ARCE 731, 452, 451, 372) and Interdisciplinary Capstone ARCE 415 use BIM."

"Steel Lab, Timber Lab, Concrete Lab, students create structural documents such as framing plans, elevations, and connection details. Students use Revit to product the model and documentation."

"Integrated Building Envelopes and our Collaborative Design Studio where students work in multi-disciplinary teams and share information using a digital model."

Figure 6:1 AE Program Responses Regarding Infusion or Extension of BIM Coursework

When asked, respondents chose from a list of statements in the table below that best reflect how BIM education is currently being expressed in their program's other courses above and beyond a strict introductory course, the results are as follows; note the darker shaded cells represent 50+% adoptions:

Other levels of BIM are expressed in coursework beside introductory software courses.	% of Respondents
We do not mention BIM in our courses, materials, seminars or course concepts	0%
We mention BIM in our courses conceptually	46%
We bring industry seminar speakers in to discuss/show examples of BIM execution on projects	54%
We are teaching BIM in our courses	77%
We are teaching BIM advanced courses	23%
WE have infused BIM projects into 1 or more traditional core concept courses	46%
We have infused BIM projects into 1 or more design courses	54%
We offer Topics or Project courses in BIM specific research projects or application projects for individuals who wish to advance BIM coursework beyond current course offerings.	15%
Other	23%

Note: Other responses included:

- Using BIM in capstone design course
- Students pursue BIM related projects as part of their graduate project/thesis

Table 6:2 Other BIM Education Formats

Areas where BIM is being taught and evaluated are numerous. When asked, the respondents showed a strong consensus of teaching and evaluating a student's ability to apply the 3D visualization and rendering aspects of BIM software(s).

The results are as follows; note the darker shaded cells represent 50+% consensuses in teaching/evaluation of BIM within a course:

Areas where BIM is being taught/evaluated in a course:	% of Respondents
4D Scheduling/Productivity	23%
Optimization (Lean Construction)	8%
Cost Control / Estimating	31%
Constructability / Interference Checks	31%
Engineering Calculations (ductwork sizing, piping sizing, structural member sizing, etc...)	31%
Visualization / Rendering / Marketing Aspect	62%
Sustainability / Energy Modeling	54%
Commissioning	0%
Facility Management / Operation & Maintenance Scheduling	8%
Site Planning	38%
Risk Management	8%
Interoperability with other software packages	38%
None of the above	8%
NR	15%

Table 6:3 Areas of BIM being Taught/Evaluated

Note the correlation between BIM and the previously provided responses related to a high level of curricula geared towards sustainability.

6.1.1.5 BIM Related Student Competitions

In the past twenty years student competitions have become an integral way for student to expand upon classroom knowledge in national or international competitive environments. Competitions help in creating positive competitive rivalries and opportunities for student

leadership and public speaking experience which expand beyond the undergraduate program of study. Relating student competitions to BIM, respondents were asked to select or provide student competition teams that are currently utilizing BIM as part of their competition submissions.

The results are as follows; note the darker shaded cells represent the highest competition adoption of BIM:

Student Competition(s)	% of Respondents Using BIM
Reno BIM Competition	0%
ASC Competitions	0%
Revit Architecture Competitions	0%
ASCE – Charles Pankow AE Competition	31%
ASHRAE Student Design Competition	23%
SEI/ASCE Student Structural Design Competition	8%
Other	23%
None	15%

Note: Other responses included – Solar Decathlon, AISC/ACSA Steel Competition, IESNA Howard Brandston Student Lighting Education Grant

Table 6:4 Student Competitions Submitted in BIM

6.1.1.5 Opportunities for BIM Minors, Master of Science or PhD

As colleges and programs explore opportunities for emphasis and minors, the question was posed how many of the current AE programs offer an emphasis or minor in BIM. 100% of respondents replied that they do not currently offer these options to undergraduates. But related to research, the respondents were asked how many of them offer a Master of Science or PhD in BIM or BIM related research. 23% of the respondents replied that they do provide such opportunities for their student researchers.

6.1.1.6 Looking Forward & BIM Education

In addition to strict response survey questions, two final questions were posed to the respondents. The first asked them to include any further comment or information on where their AE program stands regarding BIM education and secondly to include their own perspective of administrative support and advancement of BIM education at their university/program over the next 1, 5, 10 years.

Below are the most impactful statements received regarding the above question(s):

Question: Please include any further information on where your program stands regarding BIM education.

"We are implementing several experimental courses at this time to encourage collaboration with BIM as an enabling platform. One is a BIM Design Studio course which is offered across AE, Architecture and Landscape Architecture. Another is a team senior design project course where we team structural, construction, lighting/electrical and mechanical students together to analyze a building and make recommended improvements based on analysis through BIM applications and workflows."

"We are developing graduate BIM courses based on scripting."

"We have incorporated BIM as a major part of our senior level architectural design/studio courses and encourage its use in our design engineering courses. Most students use BIM, at least in part, during their design capstone."

"We are not using BIM with structural design and it is rarely used with energy modeling but we would like to update our courses."

"Students have the opportunity to take additional AutoCAD and BIM courses offered by the College of Architecture as technical electives. Graduate students do this more than undergraduates."

"I teach an Intelligent Buildings class of which the first half of the course is BIM-focused....many if not most of them (students) rapidly adopt BIM for projects in other classes."

"Just started the BIM class a year ago and it is moving in the right direction."

"Most faculty agree that 3D modeling is the wave of the future. As instructors, the goal is to determine the best way to use BIM tools as an educational tool in addition to being used as a production and coordination tool."

Question: Please include your own perspective of administrative support and advancement of BIM education at your university/program over the next 1, 5, and 10 year period(s).

"We have strong support for BIM initiatives. Having research sponsors and strong industry advocates has been valuable in gaining this support."

"The largest challenge is the training of the faculty in interoperability issues. Most faculty are experts in their defined analytical tools, but the integration of the tools is where we encounter the challenges. We started a BIM Wiki at bim.wikispaces.com aiming to capture relevant knowledge for our students but this is a challenge to upkeep."

"I believe that our administration recognizes the potential benefits of BIM, and sees it as a potential integrative element in undergraduate and graduate ARE curricula. Unfortunately, the current economic situation and decreasing availability of funds for universities in general make it likely that a significant new funding will not be invested in revamping undergraduate curricula around BIM."

"Our university has Autodesk comprehensive licenses so we have access to all the Revit products, but many computer labs are not capable of really running it. We need to get faster computers with more memory to make it more available."

"We do not have any faculty with BIM training as regular faculty. Some of our adjunct professors are more proficient and they are the ones who are doing the training. We are planning on starting to incorporate it in our CEM courses with a new faculty hire."

"The biggest issue for us is the faculty, not the students. We have site licenses for the necessary software and adequate lab facilities. Most faculty, however, do not see the relevance to their research interests and are reluctant/unwilling to spend the time to learn BIM in order to incorporate it into their courses."

"There is high support of BIM education in AE. The biggest hurdle is with true interdisciplinary efforts due to conflicting student / faculty schedules and lack of compensation for more than one faculty member involved in a course."

"I believe our industry advisory council will recommend that BIM be a required class and we will likely need to have a faculty dedicated to teaching CAD/Revit/BIM on a full time basis."

"Administrative support will remain strong and we will continue to advance BIM education in our program. We are currently searching for a lecturer who can continue and expand our expertise in BIM and our ability to more fully integrate it into the program."

"BIM is the pencil of the future. It is the communication tool that will be used. We should not teach BIM, but instead require the students to use it."

"Currently funding efforts are coming from the private sector, which are understandably interested in seeing their BIM packages introduced at the undergraduate level. The problem with this is that the power of BIM in not related to one particular package versus another – it's interoperability that BIM promises and comes close to delivering. In our own undergraduate curriculum, we are trying to emphasize the software-independent aspects of BIM. In our graduate curriculum, we are just beginning to develop courses and projects intended to make our current BIM software come closer to fulfilling its promise."

"When there is an easier way to interface BIM to standard energy modeling programs like eQuest or EnergyPlus we will try to incorporate it in our modeling classes."

"I don't see our older faculty who teach structures looking to incorporate BIM into those classes."

"While the industry advisory council is pushing for more BIM technology, they strongly recommend that students be able to communicate with hand drawing/sketching."

Figure 6:3 Perceived Administrative Support & Additional Comments

6.1.2 Industry Employers of Architectural Engineering Undergraduates

6.1.2.1 AE Educated Employees

Each employer was asked to respond to a series of questions related to their recruitment and employee demographic. Each firm was asked to roughly estimate the number of AE undergraduate engineers working at their firms. 75% of respondents believed to have between 1 to 50 employees with AE engineering degrees. Remembering from prior data that the employer responded profile showed that the majority of the industry employer respondents were of companies totaling 1-50 employees at a respondent rate of 39%. The follow chart depicts percentage of responses per employee number range. 51% of respondents noted 76-100 AE educated employees as the highest employee bracket.

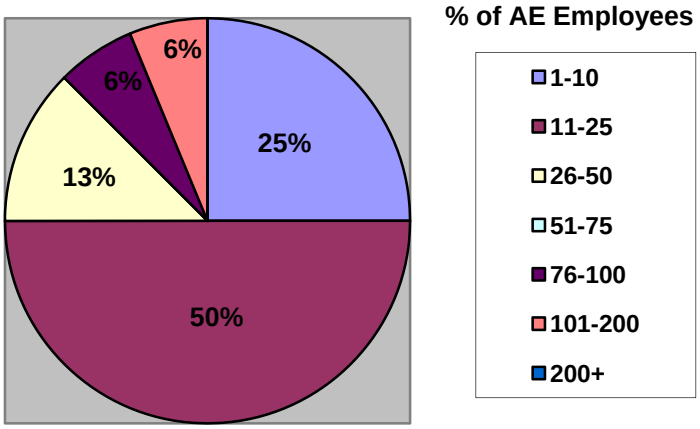

Figure 6:4 Percentage of AE Engineer Employees per Employee Range Specified

Each employer was also asked to select from a provided list the number or AE programs that they currently actively recruit from on an annual basis. 38.9% of respondents currently actively recruit from more than five AE programs in the United States. This response was followed closely by four programs (22.22%), three programs (22.22%), and two programs (16.67%) and no respondents recruiting at less than two AE programs.

6.1.2.2 Transition from AutoCAD to BIM Technologies and other Software(s)

83% of employer respondent utilize 2D AutoCAD for project delivery. Employees currently executing AutoCAD include:

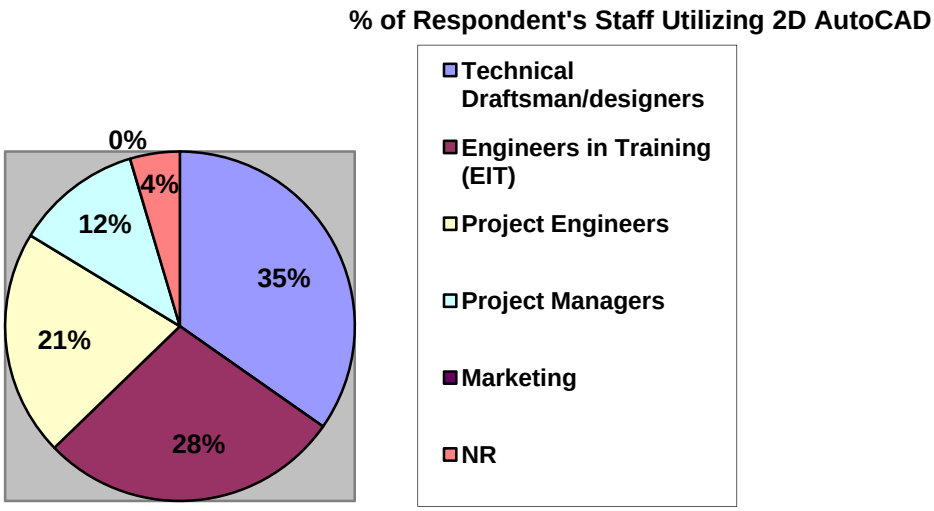

Figure 6:5 Percentages of Respondent's Staff Utilizing 2D AutoCAD

22% of respondents agreed or strongly agreed that "2D CAD is very inefficient to a true BIM workflow." And 55% of respondents felt that BIM technologies will surpass AutoCAD as the software of choice within six years.

Respondents were asked to select all software(s) they currently purchase and implement in their design processes other than BIM software(s). Their responses are as follows; note the darker shaded cells represent 50+% consensuses in corporate utilization:

Software(s) owned & operated licenses:	% of Respondents
Autodesk AutoCAD	83%
Google Sketchup	11%
Adobe Pro	25%
Adobe Illustrator	17%
Adobe Photoshop	6%
RISA 3D	17%
AGi32	39%
Trane Trace	61%
eQuest	22%
Other	11%

Note: Other included – SKM, EDR, ComCheck, Microsoft Excel (qty. 2), AutoCAD MEP,

Table 6:5 Company Owned & Operated Software(s) Licenses

6.1.2.3 Company Attitudes Towards BIM Delivery & Timelines

The respondents were asked to select the highest level of BIM currently being executed by their firm. Of the options provided, 44% of respondents are utilizing BIM and plan to continue when the project(s) lend themselves to such applications. Another 22% have infused BIM into their core business, recruiting and marketing strategies, followed by the late adopters of 22% who do not mention BIM in any marketing or business materials.

Each respondent was asked to select the statement that best fit their company's current attitude regarding BIM workflow, software and project delivery. The table below reflects the percentage of respondents per statement, and the McGraw-Hill survey responses are provided to show validity due to low response rates.

Note that of the provided responses 73% were utilizing BIM software(s) in project delivery and as an analysis tool.

Company attitude towards BIM software(s):	% of Respondents	% of McGraw-Hill Survey Respondents
We have used it but decided not to use them anymore	0%	2%
We have not used them and have no interest in using them.	0%	19%
We have not used them, but are open to exploring its potential value to us	0%	51%
We have not used it and believe it will be valuable for us but not begun evaluating it	0%	16%
We have not used it but are actively evaluating it	11%	13%
We are using BIM software on certain projects of scale/complexity	67%	30%
We are using BIM software on all our project delivery	6%	0%
NR	16%	0%

Table 6:6 Company Attitudes Towards BIM Software

One year later than the McGraw Hill survey, this survey shows good correlation towards the adoption of BIM project delivery by firms with 30% of its respondents using BIM for projects of a certain scale/complexity.

Of the companies surveyed, 39% of respondents selected 2008-2009 as the year(s) in which their company began BIM project delivery, followed secondly by earlier adopters in 2004-2005 with 17% of respondents. All of respondents believed that their companies invest between $0 and $100,000 dollars annually on BIM software, training and support. And this investment produces diverse percentages of projects per company between the respondents.

See the table below for the number of projects produced with BIM technology in 2009 to present (Feb. 2010):

Percentage of Projects Delivered in BIM (2009 – Feb 2010)	% of Respondents Projects Currently in BIM	% of Respondents Projects anticipated in BIM within 2 years	McGraw Hill Survey % of Respondents Projects Currently in BIM	McGraw Hill Survey % of Respondents Projects anticipated in BIM within 2 years
0% of projects	0%	0%	0%	0%
1%-15% of projects	28%	6%	41%	35%
16%-30% of projects	11%	6%	20%	21%
31%-60% of projects	22%	28%	19%	28%
61%+ of projects	11%	22%	21%	27%
NR	28%	0%	0%	0%

Table 6:7 Percentages of BIM Projects Delivered

Note the correlated percentage shift towards higher percentages of BIM projects being delivered in the next two years in both survey's results.

More respondents than not are choosing not to outsourced training of BIM software and skills, but instead have opted for in-house training and online tutorials. And whether the training

be outsourced or in-house, most companies are choosing two days of training at a respondent rate of 17%, followed closely by one day, three days or one week all at a respondent rate of 11%.

Of the companies having invested in BIM software, the following software(s) received the highest percentage of respondents in descending order.

BIM software(s) owned & operated:	% of Respondents
Autodesk Revit MEP	50%
Bentley Microstation	17%
Autodesk Revit Structures	11%
Autodesk Building Systems (ABS)	11%
Autodesk Architectural Desktop (ADT)	6%
Autodesk Revit Architecture	0%
Bentley Architecture	0%
Graphisoft ArchiCAD	0%
Nemetschek Vectorworks	0%

Table 6:8 BIM Software(s) Owned & Operated

Of those respondent utilizing BIM software and technologies, they were asked to select all the areas that their company is currently maximizing on the execution of different BIM capabilities. Their responses are as follows; note the darker shaded cells represent 50+% consensuses in corporate BIM utilization:

Areas where BIM is being executed within their company:	% of Respondents
4D Scheduling/Productivity	11%
Optimization (Lean Construction)	6%
Cost Control / Estimating	6%
Constructability / Interference Checks	56%
Engineering Calculations (ductwork sizing, piping sizing, structural member sizing, etc...)	17%

Visualization / Rendering / Marketing Aspect	44%
Sustainability / Energy Modeling	17%
Commissioning	0%
Facility Management / Operation & Maintenance Scheduling	0%
Site Planning	0%
Risk Management	0%
Interoperability with other software packages	6%

Table 6:9 Areas of BIM being Executed by Companies

Note that from the above question, the most selections by a single respondent was six of the items listed above and the least from a single respondent was none of the items listed above.

78% of respondents reported that BIM will be *High or of Critical Importance* in the AEC industry within the next five years.

6.1.2.4 Companies not utilizing BIM Software or Technology

For those late adopters who are currently not utilizing or implementing BIM at their companies, it was important to determine why? Those respondents were asked a view a series of statements and then to select on a scale of 1-5 (1 being No Influence upon their decisions and 5 being the Greatest Influence upon their decisions) which they believed were having the greatest influence on their program's late adoption of BIM.

Those statements receiving either a 4 or 5 rating are listed below in percentage of responses:

Statement of reason:	% of Respondents	% of McGraw-Hill Respondents
Not enough demand from clients and/or other firms on projects	22%	67%
Haven't had sufficient time to evaluate it	6%	49%

Functionality doesn't apply well to what we do	6%	35%
Insufficient BIM-compatible content available for my needs	6%	32%
Poor interoperability	6%	22%
Concerns about insurance/liability	6%	20%
Finding or training skilled engineers and designers to use the software effectively	6%	17%
Other	6%	0%

Note: Other included – Structurally the BIM aspect is minimal. We use Revit and we are ok with it as long as the architectural model is good. We can see potential advantages and liabilities. We don't get paid for the extra work.

Table 6:10 Companies Greatest Influences and Reasons Not to Utilize BIM

In both this survey and the McGraw-Hill survey, "Demand for clients and/or other firms" on a project received the highest percentage of responses as having the greatest influence on their companies decision to not implement BIM workflows at their company.

6.1.2.5 Corporate Recruiting Trends

In evaluating the importance of BIM education in AE curriculums it was important to ascertain the importance of BIM undergraduate education and BIM skill levels from the companies who recruit those graduates. In order to do gain this data, respondents were asked a series of questions related to BIM undergraduate education.

First they were asked to rate on a scale of critical importance to no importance several general issues related to AE undergraduate curriculums.

The responses are as follows; note the darker shaded cells represent 50+% consensuses in skills deemed high or critical:

Importance of the following AE curriculum issues:	% of Respondents rating the statement High or Critical
Interns/new college graduates with core design fundamentals and engineering skills	61%
Interns with complimenting BIM skills	22%

New graduates with complimenting BIM skills	28%
Interns or graduates with energy modeling skills utilizing BIM	28%
Sustainable design concepts on projects	56%
Employees becoming LEED Accredited Professionals	44%
Employees becoming ASHRAE High Performance Building Design Professionals (HBDP)	17%
Employees who are skilled in visual conceptualization of building integration techniques	61%
Understanding of and skilled to execute "Lean design/construction"	28%
Employees who have participated in one or more computer based instruction courses	44%
Employees who have participated in one or more self paced distance-learning courses	44%

Table 6:11 Importance of Differing Skills to Employers of AE Interns/Undergraduates & Employees

Next they were asked if they believed if the level of technology education at the institutions from which they recruit was adequate. 100% of respondents to the question agreed that current technologies are being covered adequately. But an additional 83% of respondents felt that BIM design and document delivery will continue to increase in the market, leading them to further respond that 45% of respondents agreed or strongly agreed that "an adoption of BIM technology education as a core AE curriculum component would likely lead their companies to offer higher hourly wages and salaries to those students with BIM skills vs. those who did not have BIM skills in the next five years." Of those willing to consider higher salaries, 22% of respondents would offer 4-6% higher salaries to BIM educated engineers. One respondent went so far as to say that they would be soon restricting recruitment to only programs that had incorporated Revit ® MEP into their curricula.

6.1.2.6 Corporate Input on BIM in AE Curriculums

Respondents were asked to consider at which point during an AE undergraduate curriculum a BIM introductory course or introduction to BIM software topics should be taught. Almost all of respondents at 72% selected an upperclassman status as being the ideal time in an undergraduate career (ie: Junior, Senior, Super Senior/Fifth Year); with 11% of respondents having no option and 17% non-reporting.

In addition, the respondents were asked their opinion as to what other courses might AE undergraduates have the opportunity learn or further enhance BIM skills with class projects and assignments? Their responses are listed in descending order from greatest percentage of respondent's selections to least.

Other options for BIM coursework/class projects:	% of Respondents
Advanced M/E/P/FP design courses	56%
Energy Modeling Courses	56%
Advanced structural design courses	44%
Advanced topics in BIM	44%
Introductory M/E/P/FP design courses	33%
Estimating courses	33%
Sustainability courses	28%
Construction scheduling courses	28%
Introductory structural design courses	22%
Other	11%
No other or No Response	23%

Note: Other included – For typical structural courses you may get too advanced from having design info. For example a bar joist.

Table 6:12 Other Options for BIM Coursework or Class Projects

Finally respondents were asked two open ended questions regarding "BIM specific skills that they would like to see when hiring new interns or new college graduates from an AE program?" The responses were varied but with a few consistent themes, the first being that introduction of BIM skills and software capabilities and limitations are important for an undergraduate intern/new hire, secondly that understanding the design problem and being able to

visualize in 3D whether with pen and paper or with a software product is invaluable, and finally that additional training and exposure in all areas of design and BIM for a new intern or graduate is anticipated in the a workplace environment upon graduation.

See the responses below in full text.

"Real project experience. Students should be provided a real project problem in any given industry and show how they utilize any given BIM software of their choice to solve the problem. Understanding of the program."

"Actual practical application of BIM - not just an introductory course."

"We would like for them to have a basic understanding of the program. General familiarity with program navigation, load calculations (MEP-S), and energy modeling are very desirable."

"Working knowledge of the (BIM) concepts, at a minimum."

"Knowledge of BIM and its inner workings would be enough. Most training can be done on the job at this time. This may change within the next year or two."

"At least, basic knowledge of how the software integrates with each of the MEP disciplines."

"A good understanding of the software, both its potential and its limitations, and the ability to visualize MEP designs in 3-dimensions while understanding the constraints of the buildings."

"Familiar with Revit MEP."

"Architectural Lighting Calculations, power density."

"Knowledge of what it will do is good because it will open their eyes to the uses in the future. This is an added value to a project. On some jobs it is valuable on others it is not. Depends on the client and the building."

"User interface and knowledge of MEP systems."

"We expect an AE graduate to understand how a building is constructed and how systems relate and interact to make a complete facility. We do not expect the AE graduate to be a technician and ready to produce a drawing with a specific program - we will train them to use the tool."

"Basic drawing skills and conflict checking so they can hit the ground running. We'll take it from there and we don't want to overdo it just make sure they have basic skills and can communicate about the software."

"It isn't as important that they have a huge knowledge of BIM, just understand the basics of it."

Figure 6:6 Employer Feedback Regarding Engineering and BIM Skills

The final employer survey question asked them to share any additional comments regarding BIM technology and/or BIM technology education in AE curriculums. The responses are as follows:

"It is not a matter of if - it's a matter of when. This will change the construction industry like nothing else in the past 30 years."

"It took programs way too long to implement a requirement for CAD courses. It is my recommendation that BIM be required soon as that is what employers will expect. Similar to CAD, soon this will be an expected skill, not something employers will want to spend money on training."

"It is a great idea to get students involved early. This would give them a greater potential in the work place upon graduation. However, advanced knowledge will not be required until BIM surpasses AutoCAD 2D."

"BIM Technology will most likely be the preferred software platform going forward in the Construction industry; therefore it would be in a program's best interest to start instruction and education of this technology."

"The buzz words in the industry today are BIM, IPD, and LEAN Construction. In reality those three processes are all going to merge together to completely change the landscape of A/E/C relationships. BIM is only one component and is software dependent more than the others. IPD and LEAN Construction are the two forces that will shape relationships and how firms work together. Students need to understand these processes and have an open mind to changing how the industry works."

"Use of BIM in completing Senior Design Projects."

"I think it would definitely be a positive for undergraduate curriculum. But it is best to know basics and reasons for basic decisions."

"The biggest advantage of BIM is in estimating. It makes the contractor's job easier. The arch and eng now have to create the information for takeoffs."

"Structurally it could be beneficial because it could incorporate design information helpful for remodeling. Very useful in a manufacturing plant. Not so for a Quiktrip."

"We all assume it helps reduce conflicts and catches mistakes but these buildings are still built by hand and don't match the drawings. The easier it becomes the more it will be used."

"Energy Modeling is the most important concept for future engineers."

"Do not take away from core engineering skills to teach a technical skill. Use the BIM technology only to reinforce the engineering skill."

"We are always willing to help with presenting our projects to the students."

"I think BIM is basically where we were with AutoCAD 20 years ago, although it will become more widely used at a faster pace."

Figure 6:7 Final Employer Thoughts Regarding BIM

CHAPTER 7 - Undergraduate Programs Rate on Investment (ROI)

7.1 ROI 101

ROI analysis is one of many ways to evaluate a proposed investment. It compares the gains anticipated from an investment against the cost of the investment.

Earnings/Cost = ROI

7.1.1 ROI of BIM Investment for Educational Purposes

Thus if an AE program is looking to determine its ROI for providing and instructing BIM they would be calculated using the following equation and example:

$$\frac{\dfrac{(Average\ AE\ Starting\ Salary\ \times BIM\ Salary\ Percentage\ Increase)}{Student}}{\left(\left(\dfrac{\left(\dfrac{computer\ license\ cost}{year}\right)(No.of\ comptuers\ )}{No.of\ students}\right)\times(AE\ program\ duration)\right)} = ROI$$

Equation 1 - BIM ROI *(simple)*

The standard cost of an Autodesk Service Pack including Revit Architecture license is $5,400 per license. Average Kansas State University AE instructional labs house 50 computers for educational purposes. With an average of 400 students in an AE program the cost per student to equip such labs, equates to $675 per student annually multiplied by a five year duration equaling $3375 per student.

An average salary for December 2009 AE graduates from Kansas State University was $53,000. If employers are willing to invest 5-7% more in salaries or hourly wages for students with BIM experience. This would be an increase of between $2,650 and $3,710 per student.

Thus $3,375 falls within the range of increased salary percentages per student and therefore would be considered a good investment of educational dollars. This is not considering student equipment fees or individual course material costs that can vary substantially from institution to institution.

Figure 7:1 ROI Example Calculation

Costs for site licenses will only decrease with time and more and more users drive market costs down.

Also it is important to note that the ROI for student at a major university is 100% regarding Autodesk Revit products, as students receive all Autodesk software's as FREE downloads with their educational email "john.doe@umb.edu" extension for 12 months to a personal PC or laptop. These downloads are available at www.autodesk.edu/edcommunity after formally setting up an educational account with Autodesk.

CHAPTER 8 - Suggested Model for Undergraduate Curriculum Implementation

8.1 BIM: An Educational Need?

Although these two surveys stand to enforce the need for BIM education in AE curricula, other studies in both architecture and construction science also suggest the educational need for BIM technology and theories in undergraduate programs.

Dean (2007) carried out a research study to examine if BIM should be taught as a subject to the construction management students. He conducted two questionnaire surveys targeted at general contractors and ASC construction management programs in the Southeast. Based on the gathered data, he concluded in general the construction management programs should teach BIM to their students. The main reasons behind this conclusion were:

- Approximately 70% of the industry participants indicated that they are either using or considering using BIM in their companies. This trend indicates that the BIM utilization in the construction industry is going to increase.
- Approximately 75% of survey participants consider employment candidates with BIM skills to have an advantage over candidates who lack BIM knowledge.

In other study, Woo (2006) pointed out that properly structured BIM courses would provide industry-required knowledge to prepare students for successful careers in the AEC industry. Instead of teaching a separate course, he suggested to reconfigure the existing construction courses to integrate BIM into the course content.

"If we are to someday have widespread integrated practice within the industry, it must first be adopted in the classroom....with project teams grouped to represent the different disciplines of the construction industry." "Centers of higher education in the AEC have to recreate this collaborative experience in the academic world" (Camps 2008)

"Students must be trained to design for assembly and perhaps disassembly as we recycle/reuse buildings in the future." (Camps 2008)

8.2 Proposed Curricula Modifications to Incorporate BIM

8.2.1 Basic Introduction to BIM Software

Based on the above survey findings and trends, conclusions are reached regarding the necessity of BIM education in an undergraduate AE program. But how does an AE program hope to implement BIM effectively? Based on employer survey response, 61% of respondents felt that a basic introduction to BIM software technology was an important step in the visualization and conceptual understanding of integration and constructability issues. An equal 61% of respondents noted that core engineering concepts are still the primary focus of an undergraduate course.

8.2.2 When should BIM course(s) be taught?

There is some discrepancy regarding when during an AE program a BIM technology course should be presented within an undergraduate curricula. Educational respondents indicated at a level of 88% that a BIM technology introduction course should be taught during freshman or sophomore year, while 72% of employer respondents felt that a BIM technology introduction course would be best taught in junior or senior year. This discrepancy is likely due to differences in anticipated course materials, and the ability to convey technical or real world applications. The primary focus though is that 100% of respondents felt that BIM will become the primary means of document delivery in the next five years. So whether the course is taught early or later in an undergraduate curriculum, it should be implemented now in order to graduate incoming freshman in 2010 with BIM skills in 2014 or 2015.

8.2.3 Which courses make the most sense to incorporate BIM?

The greatest percentage of respondents felt that one if not all of the courses listed below were best suited for BIM to be incorporated into the course content. The first being a stand-alone introduction course, the second being integration of BIM into design studio/drafting type courses, third being sustainability or energy modeling courses and finally cap-stone design courses. Other courses receiving strong responses included upper level structural and upper level MEP design courses as well as student competition courses for credit.

Again the question of total BIM immersion into curricula is difficult, as several respondents provided comments of wanting further BIM curricula integration but lacking the

faculty or resources to execute the program shift. Truly, just as with learning any software or design tool, students should have the ability to apply BIM software in multiple courses and to have the opportunity for repetitive applications. This will allow the students not only to learn the required inputs and user functions but also be able to assess the outputs as reliable and accurate. A single course exposure to any software, including BIM software technologies, will likely become forgotten or obsolete by the time the student attempts to re-engage the BIM workflow process after graduation or during a summer internship.

8.2.4 Which Software Platform Should AE Programs Standardize On?

An overwhelming 80%+ of departments have Autodesk Revit Suite (Architecture, MEP, Structural) which correlates nicely to the 72% of companies utilizing one or more of the Revit Suite of software(s). And of those employers utilizing BIM technology software(s) 100% of them were utilizing Autodesk's Revit software(s). This unanimous adoption of employers to Autodesk Revit software helps in guiding universities regarding which software package to invest their technology and equipment fees budgets.

8.3 Faculty Qualified to Teach BIM

One of the largest concerns voiced by the education respondents were the challenges associated with the multi-disciplinary aspects of BIM technology in a classroom setting. To be most effective BIM models should be utilized in conjunction with multiple disciplines for coordination and interference checking and full building models can be cumbersome and difficult to operate. It is also difficult to find professionals well versed in multiple disciplines (MEP, structural, construction) that can speak to all of the uses and applications that BIM software technologies can offer. And if one faculty is not "broad" enough technically to cover all of the disciplines, then multiple faculty would need to incorporate BIM technologies into their courses. This becomes problematic, as respondents noted the lack of interest or available time of faculty to learn new technologies or to invest the effort to create real world BIM application projects for courses such as MEP design, structural design, estimating and scheduling. Several respondents from schools in large urban areas are depending on adjunct faculty or industry professionals to instruct on BIM technologies and skills.

CHAPTER 9 - Conclusions

9.1 Survey Conclusions

"Recognition of the benefits of BIM grows, and the abilities of design professionals, contractors, fabricators and suppliers to work effectively in this new environment will increasingly become a competitive differentiator." (McGraw-Hill 2008) This survey strongly correlates the conclusions drawn by the McGraw-Hill survey of 2008 relating BIM to the competitive design/construction environment. In challenging economic times, BIM can be both a recruiting advantage for AE undergraduate programs and a sought after skill from its students. These BIM skills will not only allow for its graduates to become gainfully employed but can also be critical to a program's survival over time. Programs that can boast 100% employment rates and strong starting salaries will likely attract and retain larger numbers of graduates than programs that do not. BIM is one of many tools in the toolbox to allow an AE program to continue to be highly successful at both.

BIM technology rapidly reaches high market penetration Contractors have continued to adopt building information modeling technology, according to a recent survey. Building Design+Construction magazine has reported that 83% of the largest engineering, architecture and design firms in the U.S. possess at least one in-house BIM seat license.

Also, as re-tooling of the current job force continues, BIM technologies and BIM application courses will only increase, requiring AE programs and campus continuing education to consider also re-tooling of their program curricula in order to meet market demands for BIM courses.

Although upfront investment expenses of BIM technologies for AE programs are currently equal to the employer's projected 5-7% increase in salaries offered to students with BIM skills. The path towards total adoptions by the AEC market will lead companies to <u>expect</u> AE program curricula to follow its lead instead of just encouraging it. Currently employers expect that all AE undergraduates have some formalize training in AutoCAD upon entering the job market. It can only be assumed that costs related to BIM instruction will continue to decrease and salaries will continue to increase until ROI for BIM instruction in AE program far outweighs the above listed struggles to implement the changes.

9.2 Disclaimer

The opinions and recommendations expressed in this paper are the author's personal opinions and do not represent the official position of any participating organizations.

9.3 Resources that can help you get smarter about BIM (McGraw-Hill 2008)

Corporate

McGraw-Hill Construction: www.construction.com

Architectural Record: www.archrecord.construction.com

Engineering News-Record: www.enr.com

Autodesk: www.autodesk.com

Associations

American Council of Engineering Companies: www.acec.org

American Institute of Architects: www.aia.org/ip

American Society of Civil Engineers: www.asce.org

Architectural Engineering Institute (AEI): www.aeinstitute.org

Associated General Contractors of America: www.agc.org

buildingSMART Alliance: www.buildingsmartalliance.org

Charles Pankow Foundation: www.pankowfoundation.org

Design-Build Institute of America: www.dbia.org/pubs/

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Azhar, S.; Hein, M; and Sketo, B. (2008). *"Building Information Modeling: Benefits, Risks and Challenges"*, Proceedings of the 44th ASC National Conference, Auburn, Alabama, USA.

Burr, K.L. (2009) "Creative Course Design: A Study in Student-Centered Course Development for a Sustainable Building/BIM Class." *Proceedings of the 45th ASC Annual Conference*, Gainesville, Florida, April 1-4, 2009.

McGraw-Hill Construction. (2008). *Building Information Modeling: Transforming Design and Construction to Achieve Greater Industry Productivity*, McGraw-Hill Construction, New York.

Sabongi, F.J. (2009). "The Integration of BIM in the Undergraduate Curriculum: An Analysis of Undergraduate Courses." *Proceedings of the 45th ASC Annual Conference*, Gainesville, Florida, April 1-4, 2009.

Taylor, J.M; Liu, J.; and Hein, M.F. (2008). "Integration of Building Information Modeling (BIM) into an ACCE Accredited Construction Management Curriculum." *Proceedings of the 44th ASC National Conference*, Auburn, AL, April 2-5.

Appendix A - Employer Survey Questions

1. Please enter the following information about your company.
Name of Company:
Headquarter Locations:
Size of company (total employees in all locations):
(Choose from drop down list)
 1-50
 51-100
 101-200
 201-300
 301-400
 401-500
 501-1000
 1000-2000
 2000+
Reported revenue received for design purposes
(Choose from drop down list)
 <$500,000
 $500,000 - $5Mil
 $5 M - $10 Mil
 $10 Mil - $25 Mil
 $25 Mil - $100 Mil
 $100 Mil - $500 Mil
 $500Mil- $1Bil
 $1B +
2. Please enter the following information about yourself:
First & Last Name:
Title:
Email (in order to receive complimentary copy of findings):
Years experience in your field:
3. Please select roughly the current number of AE educated graduates you currently having working for your firm:
 1-10
 10-25
 26-50
 51-75
 76-100
 101-200
 200
4. Please select historically the number or AE schools that you currently recruit from:
 0
 1
 2
 3
 4
 5

 6
 7
 8
 9
 10
 Other (please specify)

5. Which of the following best describes the attitude towards BIM at your company?
 We have used it but decided not to use it anymore
 We have not used it and have no interest in using it
 We have not used it but are open to exploring its potential value for us
 We have not used it and believe it will be valuable for us but have not begun evaluating it
 We have not used it but are actively evaluating it

6. Does your firm currently incorporate BIM software as a method of project delivery?
 Yes
 No
 I don't know

What year did BIM project delivery become part of your corporation?
 Earlier than 2001
 2002-2003
 2004-2005
 2006-2007
 2008-2009
 2010
 We have not yet used BIM
 Never

What percentage of your company's projects did you use BIM in 2009 to present?
 0%
 1%-15%
 15%-30%
 30%-60%
 More than 60%

What percentage of your company's project do you expect will be using BIM 2 years from now?
 0%
 1%-15%
 15%-30%
 30%-60%
 More than 60%

Does your firm currently outsource user training related to a BIM software?
 Yes, (please specify how many employees , when and which BIM software) _____
 No

What are the approximate hours of training per employee? (Either in-house or outsourced)
 0 hours
 1 hour
 ½ day
 1 day
 2 days
 3 days
 1 week

 Other (please specify) _____
Which BIM software does your company own and operate most often on projects?
 Autodesk Architectural Desktop (ADT)
 Autodesk Building Systems (ABS)
 Autodesk Revit Architecture
 Autodesk Revit Structures
 Autodesk Revit MEP
 ArchiCAD
 Bentley Microstation
 Bentley Architecture
 Graphisoft ArchiCAD
 Nemetschek Vectorworks
What is the highest level of BIM currently been executed by your firm? (Check all that apply)
 We do not mention BIM in any of our marketing
 We mention BIM in our marketing, have the capability but have yet to execute a project in BIM
 We have utilized BIM on past projects and do not plan to continue in the future
 We are utilizing BIM on a few projects and plan to continue when the project lends itself
 We are utilizing BIM on a majority of our projects.
 We have infused BIM projects our core business and marketing strategies.
 We only utilize BIM on our projects.
 Other (please specify) _____
If they check box 4,5,6,7,8 of above question, then ask: Please choose areas where BIM is being utilized: (Choose all that apply)
 4D scheduling / Productivity
 Optimization
 Cost Control / Estimating
 Constructability / Interference Checks
 Engineering Calculations (ductwork sizing, pipe sizing, structural member sizing....)
 Visualization / Renderings / Marketing Aspects
 Sustainability / Energy Modeling
 Commissioning
 Facility Management / Operation & Maintenance Scheduling
 Site Planning
 Risk Mitigation
 Interoperability with other software packages
-ORIf
they checked box 1,2,3 of above question, then ask: Please rate the importance of each of the following reasons for not implementing BIM at your company. Using a scale of 1 to 5, with 1 being no influence and 5 being the greatest influence on your decision to not use BIM.
 Not enough demand from clients and/or other firms on projects
 Haven’t had sufficient time to evaluate it
 Software is too expensive
 Functionality doesn’t apply well enough to what we do
 Requires hardware upgrades that are too expensive
 Insufficient BIM-compatible content available for my needs

 Software too difficult to use
 Poor interoperability with CAD applications
 Concerns about insurance/liability
 We believe the current methods we use are better
 Finding or training skilled engineers and designers to use the software effectively
 Other (please specify) _____

7. Evaluate the importance of the following issues related to BIM at your firm:
Scale: None, Low, Average, High, Critical
 Interns/new college graduates with core design fundamental engineering skills
 Interns with complimenting BIM skills
 New graduates with complimenting BIM skills
 Interns or graduates with energy modeling skills utilizing BIM
 Sustainable design concepts on projects
 Employee's becoming Accredited Professional - LEED
 Employee's becoming Accredited Professional –ASHRAE's High Performance Building Design Professional (HBDP)
 Employee's who are skilled in visual conceptualization of building integration techniques
 Understanding of and skills to execute "Lean design/construction"
 Employees who have participated in one or more computer-based instruction courses
 Employees who have participated in one or more self paced distance-learning courses

8. Determine the level at which you agree with the following statement? "2D CAD is very inefficient compared to a true BIM workflow."
 Strongly Agree
 Agree
 Neither agree nor disagree
 Disagree
 Strongly Disagree

9. How important do you believe BIM will be to the AEC industry in 5 years?
 No importance
 Low importance
 Moderate importance
 High importance
 Very high importance

10. Determine the level at which you agree with the following statement? "An adoption of BIM technology education as a core AE curriculum component, would likely lead our company to offer higher hourly wages or salaried positions to those students with BIM skills vs. those who do not have BIM skills in the next 5 years?"
 Strongly Agree
 Agree
 Neither agree nor disagree
 Disagree
 Strongly Disagree

If "Agree or Strongly Agree" above, ask "What percent "higher" salary would your firm consider offering, all other selection criteria being equal?"
 0%
 1-3%
 4-6%

 7-9%
 10-13%
 14%+

11. Determine the level at which you agree with the following statement? “Do you believe that the level of technology education at the institutions from which you recruit, adequately prepares those potential employees for positions at your firm?”

 Strongly Agree
 Agree
 Neither agree nor disagree
 Disagree
 Strongly Disagree

12 . Determine the level at which you agree with the following statement? “Do you believe the use of BIM design and document delivery in the marketplace will continue to increase?”

 Strongly Agree
 Agree
 Neither agree nor disagree
 Disagree
 Strongly Disagree

13. Determine the level at which you agree with the following statement? “BIM will surpass AutoCAD 2D in the next generation and become the primary form of document delivery for the AEC industry as a whole?”

 Strongly Agree
 Agree
 Neither agree nor disagree
 Disagree
 Strongly Disagree

If “Strongly Agree or Agree” is selected, ask
“When do you foresee BIM surpassing AutoCAD 2D.

 It already has occurred
 1 year
 2 years
 3 years
 4 years
 5 years
 6 years
 7 years
 8 years
 9 years
 10 year
 More than 10 years (please specify) _____

14. Our firm regularly utilizes these software programs during the design process: (Check all that apply)

 Autodesk AutoCAD (plain)
 Autodesk Architectural Desktop (ADT)
 Autodesk Building Systems (ABS)
 Autodesk Revit
 Autodesk Navisworks
 ArchiCAD
 Bentley Microstation

 Bentley Architecture
 Graphisoft ArchiCAD
 Nemetschek Vectorworks
 Google Sketch-Up
 Adobe Pro
 Adobe Illustrator
 Adobe Photoshop
 RISA 3D
 AGi32
 Visual Professional
 Trane Trace 700
 eQuest
 Other (please specify)

15. Does your firm utilize AutoCAD 2D for project delivery?
 Yes
 No

(If yes, gate to question below)
(If no, gate to question 16)

Which employees utilize AutoCAD more than 50% of their regular workday? (Choose all that apply)
 Technical draftsman/designers
 Engineer in Training (EIT) (recent graduates)
 Project Engineers
 Project Managers
 Marketing

Does your firm currently outsource user training related to AutoCAD software?
 Yes, (please specify how many employees , and when) _____
 No

What year did AutoCAD project delivery become part of your corporation?
 Earlier than 1980
 1980-1990
 1990-2000
 2000-Present
 We intend to but are waiting for the right prototype project
 Never

(continue to question 16)

16. What form of graphical document delivery does your firm primarily use instead of AutoCAD?
 (Text Box)

17. In your opinion, at which point in an AE undergraduate curriculum should a BIM introductory course be taught?
 Freshman
 Sophomore
 Junior
 Senior
 Super Senior (For 5 Year Programs)
 Anytime during underclassman career (Fresh/Soph)
 Anytime during upperclassman career (Jr/Sr/SSr)
 Not restricted as to when students complete course work

 I do not have an opinion

18. In your opinion, what other courses might AE undergraduate curriculums use as vehicles to enhance BIM skills with class projects and assignments?

 Introductory structural design courses
 Advanced structural design courses
 Introductory M/E/P/FP design courses
 Advanced M/E/P/FP design courses
 Advanced topics in BIM
 Energy modeling courses
 Sustainability courses
 Estimating courses
 Construction Scheduling courses
 No Others
 Other (Text Box)

19. What BIM skills specifically would you like to see when hiring a new intern or new college graduate from an AE program?

 Text Box

20. Please include any additional comments regarding BIM technology? And BIM technology in undergraduate AE curriculum? Etc....

 Text Box

Appendix B - Raw Employer Survey Data

Q2: Headquarter locations:	44.44% from KS
Headquarter in Menasha WI - 16 offices, the largest is in Lenexa KS (my office)	
Lawrence, KS	
Little Rock, Arkansas	
South Bend, Indiana	
Madison, WI	
Chicago, IL	
San Jose, CA	
Houston, TX	
Houston, TX	
Lenexa, KS with branch offices in Phoenix, Las Vegas, Tampa, Dallas, Houston and Lowell	
4304 Bell Street Kansas City, Mo 64111	
Omaha, NE	
930 Central Kansas City, MO 64105	
Lawrence, Kansas	
Topeka, KS	
Denver	
Wichita, Kansas	
8325 Lenexa Drive Lenexa, KS 66062	

Q3: Size of company (total employees in all locations):)		
1	1-50	38.89%
2	51-100	5.56%
3	101-200	22.22%
4	201-300	5.56%
5	301-400	0.00%
6	401-500	11.11%
7	501-1000	5.56%
8	1001-2000	5.56%
9	2000+	5.56%

Q4: From the drop down list select the reported revenue received for design purposes			McGraw/Hill Survy	
1	<$500,000	5.56%		25%
2	$500K-$5Mil	33.33%		29%
3	$5Mil -$10Mil	22.22%		12%
4	$10Mil-$25Mil	5.56%	$10Mil+	32%
5	$25Mil-$100Mil	22.22%		
6	$100Mil-$500Mil	0.00%		
7	$500Mil-$1Bil	0.00%		
8	$1Bil+	0.00%		

Q8: Years of experience:	
1-10	16.67%
11-20	27.78%
21-30	33.33%
31+	11.11%

Q9: Please select roughly the current number of AE educated graduates you have working for your firm.	
1-10	22.22%
11-25	44.44%
26-50	11.11%
51-75	0.00%
76-100	5.56%
101-200	5.56%
200+	0.00%

Q10: Please select historically the number of AE schools that you currently recruit from:	
0	0.00%
1	0.00%
2	16.67%
3	22.22%

	4	22.22%	
	5+	38.89%	
Which of the following best describes the attitude towards BIM at your company?			
We have used it but decided not to use it anymore		0.00%	2%
We have not used it and have no interest in using it		0.00%	19%
We have not used it but are open to exploring its potential value for us		0.00%	51%
We have not used it and believe it will be valuable for us but have not began evaluating it		0.00%	16%
We have not used it but are actively evaluating it		11.11%	13%
We are using BIM on certain projects of scale/complexity		66.67%	30%
We are using BIM on all our project delivery		5.56%	
Q13: Does your firm currently incorporate BIM software as a method of project delivery?			
YES		61%	
NO		28%	
Q14: From the drop down list select which year BIM project delivery became a part of your corporation			
Earlier than 2001		0%	19%
2002-2003		11%	3%
2004-2005		17%	7%
2006-2007		11%	24%
2008-2009		39%	28%
2010+		0%	20%
We have not yet used BIM		0%	
Never		0%	
Q15: How much money does your company invest in BIM each year?			
$0-$10K		11%	
$10-$50K		17%	
$50-$100K		22%	
$100K-$300K		6%	
$300K-$500K		0%	
$500K+		0%	
Q16: What percentage of your company's projects did you use BIM in 2009 to present?			
0%		0%	
1%-15%		28%	41%
15%-30%		11%	20%
30%-60%		22%	19%
More than 60%		11%	21%
Q17: What percentage of your company's projects do you expect will be using BIM 2 years from now?			
0%			
1%-15%		6%	35%
15%-30%		6%	21%
30%-60%		28%	18%
More than 60%		22%	27%
Q18: Does your firm currently outsource user training related to a BIM software?			
Yes		28%	
No		33%	
Of yes's 4-5 employes per organization were trained on Revit.			
Q20: What are the approximate hours of training per employee? (Either in-house or outsourced)			
0 hours		0%	
1 hour		0%	
½ day		0%	
1 day		6%	
2 days		11%	
3 days		17%	
1 week		11%	
Other		11%	
40 when you account for our ongoing monthly inhouse seminars			

This varies per employee. Some may get 2-3 weeks a year and others may not be using it, will get none.

Q22: Which BIM software does your company own and operate most often on projects?	
Autodesk Architectural Desktop (ADT)	6%
Autodesk Building Systems (ABS)	11%
Autodesk Revit Architecture	0%
Autodesk Revit Structures	11%
Autodesk Revit MEP	50%
Bentley Microstation	17%
Bentley Architecture	0%
Graphisoft ArchiCAD	0%
Nemetschek Vectorworks	0%

Q23: What is the highest level of BIM currently been executed by your firm? (Check all that apply)	
We do not mention BIM in any of our marketing	22%
We mention BIM in our marketing, have the capability but have yet to execute a project in BIM	6%
We have utilized BIM on past projects and do not plan to continue in the future	0%
We are utilizing BIM on a few projects and plan to continue when the project lends itsel	44%
We are utilizing BIM on a majority of our projects	0%
We have infused BIM projects our core business and marketing strategies	22%
We only utilize BIM on our projects.	0%
Other (please specify) _____	0%

Q24: Please choose areas where BIM is being utilized: (Choose all that apply)	* The most by a single respondent was doing 6 of these items, the least 0
4D scheduling / Productivity	11%
Optimization	6%
Cost Control / Estimating	6%
Constructability / Interference Checks	56%
Engineering Calculations (ductwork sizing, pipe sizing, structural member sizing....	17%
Visualization / Renderings / Marketing Aspects	44%
Sustainability / Energy Modeling	17%
Commissioning	0%
Facility Management / Operation & Maintenance Scheduling	0%
Site Planning	0%
Risk Mitigation	0%
Interoperability with other software packages	6%

Q25: Please rate the importance of each of the following reasons for not implementing BIM at your company. Using a scale of 1 to 5, with 1 being no influence and 5 being the greatest influence on your decision to not use BIM.	Percentage of 4 or 5 Rating	McGraw/Hill - Percentage of 4 or 5 Rating
Not enough demand from clients and/or other firms on projects	22%	67%
Haven't had sufficient time to evaluate it	6%	49%
Software is too expensive	0%	41%
Functionality doesn't apply well enough to what we do	6%	35%
Requires hardware upgrades that are too expensive	0%	33%
Insufficient BIM-compatible content available for my needs	6%	32%
Software too difficult to use	0%	24%
Poor interoperability with CAD applications	6%	22%
Concerns about insurance/liability	6%	20%
We believe the current methods we use are better	0%	18%
Finding or training skilled engineers and designers to use the software effectively	6%	17%
Other	6%	0.0

Structurally the BIM aspect is minimal. We use Revit and we are ok with it as long as the architectural model is good. We can see potential advantages and liabilities. We dont get paid for extra work

Q27: Evaluate the importance of the following issues related to BIM at your firm: Scale: None, Low, Average, High, Critical	Percentage of High & Critical
Interns/new college graduates with core design fundamental engineering skills	61%

☐ Interns with complimenting BIM skills	22%
☐ New graduates with complimenting BIM skills	28%
☐ Interns or graduates with energy modeling skills utilizing BIM	28%
☐ Sustainable design concepts on projects	56%
☐ Employee's becoming Accredited Professional - LEEC	44%
☐ Employee's becoming Accredited Professional –ASHRAE's High Performance Building Design Professional (HBDP	17%
☐ Employee's who are skilled in visual conceptualization of building integration technique:	61%
☐ Understanding of and skills to execute "Lean design/construction'	28%
☐ Employees who have participated in one or more computer-based instruction course:	44%
☐ Employees who have participated in one or more self paced distance-learning course:	44%
Q28.1: How important do you believe BIM will be to the AEC industry in 5 years?	
High & Critical	78%
Average	11%
Q29.1: Determine the level at which you agree with the following statement?	Percentage of High & Critical
2D CAD is very inefficient compared to a true BIM workflow.	22%
Do you believe that the level of technology education at the institutions from which you recruit, adequately prepares those potential employees for positions in your firm?	61%
Do you believe the use of BIM design and document delivery in the marketplace will continue to increase?	83% *this was 100% the rest were unresponded
Q30: Determine level at which you agree with the following statement: 'An adoption of BIM technology education as a core AE curriculum component, would likely lead our company to offer higher hourly wages or salaried positions to those students with BIM skills vs. those who do not have BIM skills in the next 5 years. '	Percentage of Agree & Strongly Agree
☐ Strongly Agree	6% *Total is 45%
☐ Agree	39%
Q31: What percent 'higher' salary would your firm consider offering, all other selection criteria equal?	
☐ 0%	0%
☐ 1-3%	7%
☐ 4-6%	22%
☐ 7-9%	0%
☐ 10-13%	11%
☐ 14%+	0%
Q32: Determine level at which you agree with the following statement: 'BIM will surpass AutoCAD 2D in the next generation and become the primary form of document delivery for the AEC industry as a whole. '	
Agree and Strongly Agree	56%
Q33: When do you foresee BIM surpassing AutoCAD 2D?	
Less than 5 years	33%
6+ years	22%
Q34: Our firm regularly utilizes these software programs during the design process: (Check all that apply)	
☐ Autodesk AutoCAD (plain)	78%
☐ Autodesk Architectural Desktop (ADT)	11%
☐ Autodesk Building Systems (ABS)	11%
☐ Autodesk Revit	72%
☐ Autodesk Navisworks	17%
☐ ArchiCAD	0%
☐ Bentley Microstation	17%
☐ Bentley Architecture	0%
☐ Graphisoft ArchiCAD	0%
☐ Nemetschek Vectorworks	0%
☐ Google Sketch-Up	11%

☐ Adobe Pro	25%
☐ Adobe Illustrator	17%
☐ Adobe Photoshop	6%
☐ RISA 3D	17%
☐ AGi32	39%
☐ Visual Professional	17%
☐ Trane Trace 700	61%
☐ eQuest	22%
☐ Other (please specify)	11%
SKM, EDR, ComCheck, Microsoft Excell, AutoCAD MEP	
Microsoft Excel	
Q37: Does your firm utilize AutoCAD 2D for project delivery?	
Yes	83%
No	0%
NR	17%
Q38: Which employees utilize AutoCAD 2D more than 50% of their regular workday? (Choose all that apply)	
Technical draftsman/designers	83%
Engineer in Traiing (EIT) (recent graduates)	67%
Project Engineers	50%
Project Managers	28%
Marketing	0%
NR	11%
Q39: What year did AutoCAD project delivery become part of your corporation?	
Earlier than 1980	5%
1980-1990	50%
1990-2000	28%
2000-Present	0%
We intend to but are waiting for the right prototype project	0%
Never	0%
NR	11%
Q40: Does your firm currently outsource user training related to AutoCAD software?	
Yes	17%
No	67%
NR	17%
All of our designers, engineers, and drafters receive outisde training every two years at a min.	
We currently have 6 Techs. 2 have Revit training. Others have some training.	
Q43: In your opinion, at which point in an AE undergraduate curriculum should a BIM introductory course be taught?	
Freshman	0%
Sophomore	0%
Junior	17%
Senior	6%
Super Senior (for 5 year program)	6%
Anytime during underclassman career (Fresh/Soph)	6%
Anytime during upperclassman career (Jr/Sr/SSr)	39%
Not restricted as to when students complete course work	0%
I do not have an opinion	11%
NR	17%
Q44: In your opinion, what other courses might AE undergraduate curriculums use as vehicles to enhance BIM skills with class projects and assignments? (Check all that apply)	
Introductory structural design courses	22%
Advanced structural design courses	44%
Introductory M/E/P/FP design courses	33%

Advanced M/E/P/FP design courses	56%
Advanced topics in BIM	44%
Energy Modeling courses	56%
Sustainability courses	28%
Estimating courses	33%
Construction Schedule courses	28%
No others	6%
Other	11%
NR	17%

Lighting Design
For a typical structure you may get some advantage from having design info for say a bar joist. In most cases it just helps in estimating which doesnt help us. Actual constr. prob wont match design.

Q46: What BIM skills specifically would you like to see when hiring new intern or new college graduate from an AE program?

Real project experience. Students would be provided a real project problem in any given industry and show how they utilize any given BIM software of there choice to solve the problem. Understanding of the program.
Actual practical application of BIM - not just an introductory course.
We would like for them to have a basic understanding of the program. General familiarity with program navigation, load calculations(MEP-S), and energy modeling are very desirable.
Working knowledge of the concepts, at a minimum.
Knowlege of BIM and its inner workings would be enough. Most training can be done on the job at this time. This may change within the next year or two.
At least, basic knowledge of how the software integrates with each of the MEP disciplines.
A good understanding of the software, both it's potential and it's limitations, and the ability to visualize MEP designs in 3-dimensions while understanding the constraints of the buildings.
Familiar with Revit MEP
Architectural Lighting Calculations, power density,
Knowledge of what it will do is good because it will open their eyes to the uses in the future. This is an added value to a project. On some jobs it is valuable on others it is not. Depends on the client and the building.
user interface and knowledge of MEP systems
We expect a AE graduate to understand how a building is constructed and how systems relate and interact to make a complete facility. We do not expect the AE graduate to be a technician and ready to produce a drawing with a specific program - we will train them to use the tool.
Basic drawing skills and conflict checking so they can hit the ground running. We'll take it from there and we don't want to overdo it just make sure they have basic skills and can communicate about the software
??
It isn't as important that they have a huge knowlegde of BIM, just understand the basics of it.

Q47: Please include any additional comments regarding BIM technology and BIM technology in undergraduate AE curriculum:

It is not a matter of if - its a matter of when. This will change the construction industry like nothing else in the past 30 years.
It took the department way too long to implement a requirement for CAD courses. It is my recommendation that BIM be required soon as that is what employers will expect. Similar to CAD, soon this will be an expected skill, not something employers will want to spend money on training.
None
none
It is a great idea to get students involved early. This would give the a greater potential in the work place upon graduation. However, advanced knowlege will not be required until BIM supasses AutoCAD 2D.
BIM Technology will most likely be the preferred software platform going forward in the Construction industry; therefore it would be in KSU's best interest to start instruction and education of this technology.

The buzz words in the industry today are BIM, IPD, and LEAN Construction. In reality those three processes are all going to merge together to completely change the landscape of A/E/C relationships. BIM is only one component and is software dependent more than the others. IPD and LEAN Construction are the two forces that will shape relationships and how firms work together. Students need to understand these processes and have an open mind to changing how the industry works.
Use of BIM in completing Senior Design Projects
I think it would definitely be a positive for undergraduate curriculum, Best to know basics and reasons for basic decisions.

The biggest advantage is in estimating. It makes the contractors job easier. The arch and eng now have to create the information for takeoffs. Structurally it could be beneficial because it could incorporate design information helpful for remodeling. Very useful in a manufacturing plant. Not so for a Quiktrip. We all assume it helps reduce conflicts and catches mistakes but these buildings are still built by hand and don't match the drawings. The easier it becomes the more it will be used.
Energy Modeling is the most important concept for future engineers
Do not take away from core engineering skills to teach a technical skill. Use the BIM technology only to reinforce the engineering skill.
We are willing to help with presenting our projects to the students
??

I think BIM is basically where we were with AutoCAD 20 years ago, although it will become more widely used at a faster pace.

Figure 9:1 Raw Employer Survey Results

Appendix C - AE Educator Survey Questions

1. Please enter the following information about your Program/Degree.
Institution/College/University (Drop down list to include):
Cal Poly San Luis Obispo, Drexel University, Illinois Institute of Technology, Kansas State University, Milwaukee School of Engineering, North Carolina A&T State College, Oklahoma State University, Penn State University, Tennessee State, University of Colorado, University of Kansas, University of Miami, Missouri University of Science and Technology, University of Nebraska – Omaha, University of Oklahoma, University of Texas, University of Wyoming, Other (please specify) _____
School/College (Drop down list to include):
College of Engineering, College of Architecture & Planning, College of Science & Technology, Other (please specify) _____
Program (Drop down list to include):
Architectural Engineering, Other (please specify) _____
2. Please enter the following information about yourself:
First & Last Name:
Title:
Email (in order to receive complimentary copy of findings):
3. Please select the current enrollment of your AE undergraduate program:
 1-100 undergraduates
 101-200 undergraduates
 201-300 undergraduates
 301-400 undergraduates
 401-500 undergraduates
 501-600 undergraduates
 600+
 Unknown
4. Please select the current enrollment of your AE graduate/PhD program:
 1-5 graduate students
 6-10 graduate students
 11-15 graduate students
 16-20 graduate students
 21-25 graduate students
 26-30 graduate students
 30+ graduate students (Please specify) _____
5. Please select the number of primarily hand drafting courses (or studios) required for undergraduate graduation:
 0
 1
 2
 3
 4
 5
 Other (please specify)
6. Please select the number of required of primarily computer aided drafting or building information modeling courses required for undergraduate graduation:

 0
 1
 2
 3
 4
 5
 Other (please specify)
7. Evaluate the importance of the following issues related to BIM in your AE department:
Scale: None, Low, Average, High, Critical
BIM in Undergraduate Education
BIM in Graduate Education
BIM skill sets upon graduation from another source (Co-Op, Intern, Self Taught)
Integration of building design elements in Undergraduate Education (Structural, Mechanical/Plumbing, Electrical/Lighting, Fire Protection, IT/Controls, Voice/Data)
Student preparation of core design fundamentals and skills for entering the AEC consulting markets upon graduation
Sustainable Design Concepts
Student preparation for Accredited Professional - LEED
Student preparation for Accredited Professional –ASHRAE's High Performance Building Design Professional (HPBDP)
Lean design
Incorporating computer-based instruction into the curriculum in any format
Incorporating distance-learning into the curriculum
Incorporating hybrid (distance & face-to-face) learning environments into the curriculum
8. Determine the level at which you agree with the following statement? "2D CAD is very inefficient compared to a true BIM workflow."
 Strongly Agree
 Agree
 Neither agree nor disagree
 Disagree
 Strongly Disagree
9. Determine the level at which you agree with the following statement? "The adoption of BIM technology education within my program has (or would) lead to greater pay (salary) for AE's at all levels within the profession?"
 Strongly Agree
 Agree
 Neither agree nor disagree
 Disagree
 Strongly Disagree
10. Determine the level at which you agree with the following statement? "Do you believe the use technology education within your program adequately prepares your graduates for jobs in the consulting/design industry?"
 Strongly Agree
 Agree
 Neither agree nor disagree
 Disagree
 Strongly Disagree
11 . Determine the level at which you agree with the following statement? "Do you believe the use of

BIM in the marketplace will continue to increase? Eventually becoming the primary form of document delivery for Architects/Engineers/Contractors?”

- ☐ Strongly Agree
- ☐ Agree
- ☐ Neither agree nor disagree
- ☐ Disagree
- ☐ Strongly Disagree

12. Our college or department computer lab(s) have these software’s available to students: (Check all that apply)

- ☐ Autodesk AutoCAD (plain)
- ☐ Autodesk Architectural Desktop (ADT)
- ☐ Autodesk Building Systems (ABS)
- ☐ Autodesk Revit
- ☐ Autodesk Navisworks
- ☐ ArchiCAD
- ☐ Bentley Microstation
- ☐ Bentley Architecture
- ☐ Graphisoft ArchiCAD
- ☐ Nemetschek Vectorworks
- ☐ Google Sketch-Up
- ☐ Adobe Pro
- ☐ Adobe Illustrator
- ☐ Adobe Photoshop
- ☐ RISA 3D
- ☐ AGi32
- ☐ Visual Basic or Visual Professional
- ☐ Trane Trace 700
- ☐ eQuest
- ☐ Other (please specify)

13. Does your AE program require a BIM introductory course for undergraduate graduation?

- ☐ Yes, (please specify title of course) _____
- ☐ No

(If yes, gate to question 14a – 14f)
(If no, gate to question 14g)

14a. Which BIM software is taught in the introductory course?

- ☐ Autodesk Architectural Desktop (ADT)
- ☐ Autodesk Building Systems (ABS)
- ☐ Autodesk Revit Architecture
- ☐ Autodesk Revit Structures
- ☐ Autodesk Revit MEP
- ☐ ArchiCAD
- ☐ Bentley Microstation
- ☐ Bentley Architecture
- ☐ Graphisoft ArchiCAD
- ☐ Nemetschek Vectorworks

14b. At which point in the undergraduate curriculum is a BIM introductory course taught?

- ☐ Freshman
- ☐ Sophomore

 Junior
 Senior
 Super Senior (For 5 Year Programs)
 Anytime during underclassman career (Fresh/Soph)
 Anytime during upperclassman career (Jr/Sr/SSr)
 Not restricted as to when students complete course work

14c. AE there additional courses that utilize (or extend) BIM education in the classroom?
 Yes (please specify title(s) of course(s)) _____
 No

14d. What year did BIM course(s) become part of your required or elective course offering(s)?
 Earlier than 2000
 2000-2002
 2003-2005
 2006-2009
 2010

14e. Do you currently offer any of your BIM course(s) thru distance education?
 Yes (please specify title(s) of course(s)) _____
 No

If yes, do you offer any of your BIM course(s) thru distance education for continuing education or professional development hours required for licensure?
 Yes (please specify title(s) of course(s)) _____
 No

14f. Does your program encourage(through course credit or individual/team efforts) participation in any student competitions that reinforce BIM technology?
 Reno BIM Competition for Construction Management
 ASC Construction Management Competition – Commercial Team
 Revit Architecture Contest (TurboSquid.com)
 ASCE – Charles Pankow Foundation Annual Architectural Engineering Student Competition
 ASHRAE Student Design Competition
 SEI/ASCE Student Structural Design Competition
 Other (please specify title(s) of competitions. _____
 No

14g. Does your AE program offer a BIM introductory course as an elective for undergraduate graduate credit?
 Yes, (please specify title of course) _____
 No
 (If yes, gate to questions 14a-14f, 15,16...)
 (If not, gate to question 17)

15. Does your program offer a Bachelor of Science with an emphasis or minor in BIM?
 Yes, (please specify) _____
 No
 I don't know

16. Does your program offer a Master of Science or an Engineering PhD in BIM or BIM research?
 Yes, (please specify) _____
 No
 I don't know

17. What level of BIM education is currently being expressed in other courses? (Check all that apply)
 We do not mention BIM in any of our courses, seminars or course concepts

 We mention BIM in our courses conceptually
 We bring in industry seminar speakers to discuss BIM concepts and execution on projects
 We AE teaching a BIM introductory course.
 We AE teaching Advanced BIM courses.
 We have infused BIM projects into 1 or more traditional core concept courses.
 We have infused BIM projects into 1 or more design courses.
 We offer Topics or Project courses in BIM specific research projects or application projects for individuals who wish to advance BIM coursework beyond current course offerings.
 Other (please specify) _____

If they check box 5,6,7,8 of above question 17, then ask: Please choose areas where BIM is being taught/evaluated.

 4D scheduling / Productivity
 Optimization
 Cost Control / Estimating
 Constructability / Interference Checks
 Engineering Calculations (ductwork sizing, pipe sizing, structural member sizing....)
 Visualization / Renderings / Marketing Aspects
 Sustainability / Energy Modeling
 Commissioning
 Facility Management / Operation & Maintenance Scheduling
 Site Planning
 Risk Mitigation
 Interoperability with other software packages

If they checked box 1,2,3 of above question 11, then ask: Why, in your opinion, the lack of BIM course(s) into your program's instructional curriculum is due to: (Check all that apply)

 Funding for training or procuring a faculty member to teach BIM course(s)
 Funding for computer laboratories with required hardware
 Funding to purchase BIM software for campus computer laboratories
 Deemed high importance by faculty. But lack of multiple faculty's experience/training on BIM and the ways best to incorporate BIM into the classroom stall efforts to properly implement BIM projects and assignments
 Deemed low importance by faculty
 Deemed low importance by advisory council and/or employers of your graduates
 None of the above
 Other (please specify) _____

18. Does your AE program require a AutoCAD introductory course for undergraduate graduation?

 Yes, (please specify title of course) _____
 No

(If yes, gate to question 19a – 19d)
(If no, gate to question 19e)

19a. At which point in the undergraduate curriculum is a AutoCAD introductory course taught?

 Freshman
 Sophomore
 Junior
 Senior
 Super Senior (For 5 Year Programs)
 Anytime during underclassman career (Fresh/Soph)
 Anytime during upperclassman career (Jr/Sr/SSr)

 Not restricted as to when students complete course work

19b. AE there additional courses that utilize (or extend) AutoCAD education in the classroom?

 Yes (please specify title(s) of course(s)) _____

 No

19c. What year did AutoCAD course(s) become part of your required or elective course offering(s)?

 1990-1995

 1996-2000

 2001-2005

 2006-2010

 I'm unsure

19d. Do you currently offer any of your AutoCAD course(s) thru distance education?

 Yes (please specify title(s) of course(s)) _____

 No

19e. Does your AE program offer an AutoCAD introductory course as an elective for undergraduate graduate credit?

 Yes, (please specify title of course) _____

 No

 (If yes, gate to questions 17a-17d)

 (If not, gate to question 20)

20. Please include any further information on where your program stands regarding BIM education. Feel free to include hyperlinks to websites, syllabuses, etc...

21. Please include your own perspective of administrative support and advancement of BIM education in your curriculum over the next 1, 5 and 10 years?

22. Please include any additional comments/concerns regarding BIM technology in AE education curriculums that you might wish to share.

Appendix D - Raw AE Educator Survey Data

1

First & Last Name, Title, Email	Q8: Current enrollment of your AE undergraduate program:		Q9: Primarily hand drafting courses (or studios) required for undergraduate graduation:	Q10: Please select the current enrollment of your AE graduate/PhD program:	Q11: number of required of primarily (CAD) and/or (BIM) courses required for undergraduate graduation:	Q12.1: BIM in Undergraduate Education	Q12.2: BIM in Graduate Education
John Messner Associate Professor of Architectural Engineering jmessner@engr.psu.edu	100-200 undergraduates	23%	0 - 23%	0-5 : 23%	0: 8%	None: 8%	None: 15%
Richard E. Klingner LP Gilvin Professor klingner@mail.utexas.edu	201-300 undergraduates	31%	1 - 54%	6-10: 0	1: 38%	Low: 0%	Low: 15%
JoAnn Silverstein Professor and Chair joann.silverstein@colorado.edu	301-400 undergraduates	39%	2 - 15%	11-15: 31%	2: 38%	Average: 23%	Average: 31%
Ralph Muehleisen Assistant Professor, Director of the Architectural Engineering Program muehleisen@iit.edu	401-500 undergraduates	8%	3- 8%	26-30: 15%	3: 8%	High: 38%	High: 23%
James E. Mitchell - Associate Professor & Director of the AE Program Department of Civil, Architectural & Environmental Engineering Alumni Engineering Labs - Room 280H Drexel University 3141 Chestnut Street Philadelphia, PA 19104 (215) 895-1374 - (215) 895-1363 Fax EMail: James.Mitchell@Drexel.edu Web: http://www.pages.drexel.edu/~mitcheje/index.shtml Calendar: http://tinyurl.com/yrf2uc Google Map to Office: http://tinyurl.com/2pa4yf Map in Building: http://tinyurl.com/3be5h7				30+ : 31%	4: 8%	Critical: 31%	Critical: 15%
Robert J Holland Assoc Prof of Architecture and Architectural Engineering RJHolland@psu.edu							
David Fritchen Dept Head dfritch@ksu.edu							
Al Estes Professor and Head acestes@calpoly.edu							
Stuart Baur Asst. Professor baur@mst.edu							
John Zachar Program Director zachar@msoe.edu							
David Bagley Professor and Head bagley@uwyo.edu							
Kevin Dong kdong@calpoly.edu							
Clarence E. Waters Ph.D., P.E., F.AEI. Director of Architectural Engineering CWaters@UNL.EDU							

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Q12.3: BIM skill sets upon graduation from another source (Co-Op, Intern, Self Taught)	Q12.4: Integration of building design elements in Undergraduate Education (Structural, Mechanical/Plumbing, Electrical/Lighting, Fire Protection, IT/Controls, Voice/Data)	Q12.5: Student preparation of core design fundamentals and skills fo entering the AEC (Arch/Engineering/Construction) consulting market upon graduation	Q12.6: Sustainable Design Concepts	Q12.7: Student preparation for Accredited Professional - LEED	Q12.8: Student preparation for Accredited Professional ASHRAEs High Performance Building Design Professional (HPBDP)	Q12.9: Lean design and construction
None: 0%	None: 0%	None: 0%	None: 0%	None: 8%	None: 8%	None: 0%
Low: 15%	Low: 8%	Low: 0%	Low: 8%	Low: 0%	Low: 31%	Low: 39%
Average: 69%	Average: 15%	Average: 0%	Average: 15%	Average: 62%	Average: 54%	Average: 31%
High: 15%	High: 15%	High: 31%	High: 46%	High: 31%	High: 8%	High: 31%
Critical: 0%	Critical: 62%	Critical: 69%	Critical: 31%	Critical: 0%	Critical; 0%	Crititcal: 0%

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Q12.10: Incorporating computer-based instruction into the curriculum in any format	Q12.11: Incorporating distance-learning into the curriculum	Q12.12: Incorporating hybrid (distance & face-to-face) learning environments into the curriculum	Q13: 2D CAD is very inefficient compared to a true BIM workflow software in design.	Q14: The adoption of BIM technology education within my department's AE program has (or would) lead to a higher salary offer for our AE graduates entering the job market?	Q15: Do you believe the education and use of computer technology within your program's curriculum adequately prepares your graduates for jobs in the consulting/design industry?
None: 0%	None: 0%	None: 23%	Strongly Agree: 31%	Strongly Agree: 15%	Strongly Agree: 23%
Low: 8%	Low: 46%	Low: 46%	Agree: 23%	Agree: 46%	Agree: 54%
Average: 38%	Average: 23%	Average: 15%	Neither: 38%	Neither: 23%	Neither: 23%
High: 38%	High: 8%	High: 15%	Disagree: 8%	Disagree: 8%	Disagree: 0%
Critical: 15%	Critical: 0%	Critical: 0%	Strongly Disagree: 0%	Strongly Disagree: 0%	Strongly Disagree: 0%
				Unable to form Opinion: 8%	Unable to form Opinion: 0%

Q16: Do you believe the use of BIM in the marketplace will continue to increase? Eventually becoming the primary form of document delivery for Architects/Engineers/Contractors?	Q17. Software(s) that you make available to your students in department computer lab(s): (Select all that apply)		Q19: Does your AE program require a BIM introductory course for undergraduate graduation?	Q20: Which BIM software is primarily taught in the introductory course?	Q21: At which point in the undergraduate curriculum is a BIM introductory course taught?	Q22: Are there other AE courses that utilize (or extend) BIM education in the classroom? Please explain / list class ex. 'ARE 780 - Senior Project' or leave blank if there are none.
Strongly Agree: 85%	Autodesk AutoCAD (plain)	100%	Yes - 62%	Autodesk Revit Architecture: 46%	Freshman: 15%	We are aiming to embed BIM throughout courses, instead of having specific BIM courses. For example, when teaching construction scheduling, we teach students how to create 4D CAD models. I found it a bit difficult to answer question 16 and 17 since we teach students how to use Revit in their sophmore year, but this is not specifically a BIM course since BIM is not equal to Revit.
Agree: 15%	ADT	54%	No- 38%	Autodesk Revit Structure: 15%	Sophomore: 38%	ArE320L (junior year design studio) ArE 465 (senior year capstone course
Neither: 0%	ABS	38%		N/R: 38%	Junior: 0%	
Disagree: 0%	Autodesk Revit Architecture	92%			Senior: 8%	We teach Autocad freshman year but students learn BIM within our two course Architectural Design sequence CAE 468 and 469. The amount of BIM is about 1 course worth of material. Both 468 and 469 are required for graduation. Most students use BIM in their capstone design course and students frequency use it in projects in their other senior design courses.
Strongly Disagree: 0%	Autodesk Revit MEP	69%			N/R: 18%	
Unable to form Opinion: 0%	Autodesk Revit Structural	77%				
	Autodesk Navisworks	23%				
	ArchiCAD	8%				All design labs (ARCE 731/452/451/372 Interdisciplinary Capstone Cours ARCE 415
	Bently Microstation	23%				
	Bently Architecture	8%				When have an intro BIM class in the Freshman year and a refresher class in the Junior year in prep for Senior Project, where we expect BIM to be used.
	Graphisoft ArchiCAD	0%				ARE 3600 - Architectural Design I ARE 4600 - Architectural Design II
	Nemetsheck Vectorworks	0%				ARCE 372: Steel Lab, ARCE 451: Timber Lab, ARCE 452: Concrete Lab. Students create structural documents such as framing plans, elevations, and connection detl's. Students use Revit to produce the model and documentation ARCE 410: Integrated Building Envelopes; ARCE 460/ARCE 453: Collaborative Design Studio. Students work in multi-disciplinary teams and share information using a digital model.
	Google Sketch-UP	62%				Integrated in many courses
	Google Sketch-UP PRO	15%				
	Adobe Pro	46%				
	Adobe Illustrator	38%				
	Adobe Photoshop	46%				
	Risa 3D	31%				
	AGI32	38%				
	Visual Basic/Professional	31%				
	Trane Trace 700	46%				
	eQuest	62%				
	Primavera	54%				
	Other	31%				
	#NAME?					
	- Perform 3D: MatLab: ETABS					
	- Energy-10 Matlab Maple Sap RAM +					
	- Visual Analysis for Structural design					

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Q23: What year did BIM course(s) become part of your required or elective course offering(s)?	Q24: Do you currently offer any of your BIM course(s) thru distance education? Please list course information, credit hours, etc...If yes, do you also offer any of your BIM course(s) through distance education for continuing education credits or professional development hours required for licensing? If yes, please explain.	Q25.Does your program enourage (through course credit) participation in any student competitions that reinforce the use of BIM technology?		Q27: Does your AE program offer a BIM course as an elective for undergraduate credit?	Q28: Which BIM software is primarily taught in the elective introductory course?
2003-2005: 15%	No	Reno BIM comp.	0%	Yes: 31%	Autodesk Revit Architecture: 23%
2006-2009: 46%		ASC		No: 8%	Autodesk Revit Structures: 8%
N/R: 38%		Revit Arch	0%	N/R: 62%	N/R: 69%
		ASCE - Charles Pankow...student comp	31%		
		ASHRAE Student Design Comp	23%		
		SEI/ASCE Student Structural Design Comp	8%		
		Other	23%		
		None	15%		
		N/R	38%		
		Other :			
		- Solar Decathlon			
		- AISC/ACSA Steel Comp			
		- IESNA Howard Brandston Student Lighting Edu Grant			

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Q29: At which point in the undergraduate curriculum is a BIM elective introductory course taught?	Q30: Are there other AE courses that utilize (or extend) BIM education in the classroom? Please explain or leave blank if there are none.	Q31: What year did BIM course(s) become part of you elective course offering(s)?	Q32: Do you currently offer any of your BIM course(s) thru distance education? Please list course information, credit hours, etc...If yes, do you also offer any of your BIM course(s) through distance education for continuing education credits or professional development hours required for licensing? If yes, please explain.	Q33.Does your program encourage (through course crecit) participation in any student competitions that inforce the use of BIM technology?
Senior: 23%		2003-2005: 8%	CNS544 Prb/Const Science - Topic-Building Information Modeling (2 cr hr) CNS544 Prb/Const Science - Topic-Intro to Revit (2 cr hr)	Reno BIM comp.
Not restricted: 8%		2006-2009: 23%		ASC
N/R: 69%		N/R: 69%		Revit Arch
				ASCE - Charles Pankow...student comp
	I intended to introduce BIM tools in a required sophomore course this spring.			ASHRAE Student Design Comp
	Yes, 4th year architectural design			SEI/ASCE Student Structural Design Comp
				Other
				None
				N/R

Q35: Does your program offer an emphasis or minor in BIM?	Q36: Does your program offer a Master of Science or Engineering PhD in BIM or BIM research?	Q37.What level of BIM education is currently being expressed in other courses?		Q38: Please explain what 'other' level of BIM education is currently being expressed in your courses?	Q39 Areas where BIM is being taught/evaluated:	
NO: 100%	Yes: 23%	We do not mention BIM in our courses, materials, seminars or course concepts	0%	We use BIM in our senior-year capstone design course	4D Scheduling/Productivity	23%
	No: 77%	We mention BIM in our courses conceptually	46%	Students may pursue BIM related projects as part of their graduat project/thesis	Optimization	8%
		We bring in industry seminar speakers to discuss/show exampoles of BIM execution on projects	54%	BIM is communication tool not a subject	Cost Control/ Estimating	31%
		We are teaching BIM into courses	77%		Constructability/ Interference Checks	31%
		We are teaching BIM advancec courses	23%		Engineering Calculations (ductwork sizing, pipe sizing, structural members sizing..)	31%
		We have infused BIM projects into 1 or more traditiona	46%		Visualization / Renderings / Marketing Aspects	62%
		We have infused BIM projects into 1 or more design co	54%		Sustainability / Energy Modeling	54%
		We offere Topics or Project courses in BIM research pr	15%		Commissioning	0%
		Other	23%		Facility Management / Operation & Maintenance Scheduling	8%
					Site Planning	38%
					Risk Mitigation	8%
					Interoperability with other software packages	38%
					None of the above	8%
					N/R	15%

Q40.The lack of BIM course(s) in your program's instructional curriculum is due to:		Q42: Does your AE program require a AutoCAD introductory course for undergraduate graduation?	Q43: At which point in the undergraduate curriculum is a AutoCAD introductory course taught?	Q44: Are there additional courses that utilize (or extend) AutoCAD education in the classroom? If yes, please specify title(s) of courses.	Q45: To the best of your knowledge, what year did AutoCAD course(s) become part of your required course offering(s)?
Funding for training or procuring a faculty member to teach BIM course(s)	38%	Yes - 69%	Freshman - 31%		Before 1990 - 23%
Funding for computer laboratories with required hardware	15%	No- 31%	Sophomore - 31%	ArE 350 (advanced CAD)	1990-1995- 15%
Funding to purchase BIM software for campus compute laboratories	0%		Anytime during upperclassman career - 8%	Most courses with projects. Senior design projects course.	1996-2000- 15%
Deemed high importance by faculty. But lack of multiple faculty's experience/training on BIM and the ways best to incorporate BIM into the classroom stall efforts to properly implement BIM projects and assignments	31%		N/R - 31%	Markup and development of design drawings with Autocad o BIM is required in all our senior level design courses. Some use Autocad and some use BIM.	2001-2005 - 0%
Deemed low importance by faculty	15%				2005-2010 - 8%
Deemed low importance by advisory council and/or employers of your graduates	0%				Unsure date - 8%
None of the above	8%			ARE311-CAD in Engineering and Construction (2 cr hr.)	N/R - 31%
N/R	38%			Same as BIM....we are in a transition between AutoCad and REVIT structure	
				Not any more.	
				In upper division lab/studio courses students are given the option of using AutoCAD or Revit to complete their work. Most students use Revit since that is the software being used in the second of two building information type classes.	

Q46: Do you currently offer any of your AutoCAD course(s) thru distance education? If yes, please specif title(s) of course(s).	Q47: Does your AE program offer a AutoCAD introductory course as an elective for undergraduate graduate credit?	Q48: At which point in the undergraduate curriculum is a AutoCAD introductory elective course taught?	Q50: To the best of your knowledge, what year did AutoCAD course(s) become part of your elective course offering(s)?
	Yes - 0%	N/R 100%	N/R 100%
No.	No - 31%		
	N/R 69%		
No			
CNS544-Prb/Construction Science/Revit			
no			
No.			
No, we do not offer any AutoCAD courses thru distance education			

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Q52: Please include any further information on where your program stands regarding BIM education. Feel free to include hyperlinks to websites, syllabuses,white papers, etc...	Q53: Please include your own perspective of administrative support and advancement of BIM education at your university/program over the next 1, 5 and 10 year periods?
We are implementing several experimental courses at this time to encourage collaboration with BIM as an enabling platform. One is a BIM Design Studio course which is offered across AE, Architecture and Landscape Architecture. Another is a team senior design project course where we team a structural, construction, lighting/electrical, and mechanical student together to analyze a building and make recommend improvements based on analysis through BIM applications and workflows.	We have strong support for BIM initiatives. Having research sponsors and strong industry advocates has been valuable in gainin this support. The largest challenge is the training of faculty in interoperability issues. Most faculty are experts in their defined analytical tools, but the integration of the tools is where we encounter the challenges. We did start a BIM Wiki at bim.wikispaces.com to aim to capture relevant knowledge for our students, but this is challenging to upkeep.
We are developing graduate BIM courses based on scripting.	I believe that our administration recognizes the potential benefits of BIM, and sees it as a potential integrative element in undergraduate and graduate ArE curricula. Unfortunately, the current economic situation and decreasing availability of funds fo universities in general make it likely that significant new funding will not be invested in revamping undergraduate curricula arou BIM.
We have incorporated BIM as a major part of our Senior level architectural design/studio courses and encourage its use in our design engineering courses. Most students use BIM, at least in part, during their design capstone. We are not using BIM with structural design a it is rarely used with energy modeling but we would like to update our courses. Students have the opportunity to take additional Autocad and BIM courses offered by the College of Architecture as technical electives. Graduate students do this more than the undergrads.	Our university has an Autodesk comprehensive licenses so we have access to all the Revit products, but many computer labs are not capable of really running it. We need to get faster computers with more memory to make it more available. We do not ha any faculty with BIM training as regular faculty. Some of our adjunct professors are more proficient and they are the ones who a doing the training. We are planning on starting to incorporate it in our CEM courses with a new faculty hire.
I believe I already sent you this, but am repeating it here. I addressed related subjects in my sabbatical survey: http://aedesigndu.blogspot.com/search/label/results Here's a blog that responds to student assignments in my 'Intelligent Buildings' clas The first half of the course is BIM-focused. http://intelligentbuilding092.blogspot.com/search/label/BIM My approach to getting student started in the actual practice of learning BIM is 1/2 hour of class time plus an assignment. The following link shows what they are required do. It has been very helpful in getting them up and running, with many if not most of them rapidly adopting it for projects in other classes. http://intelligentbuilding092.blogspot.com/2010/01/getting-started-with-revit-architecture.html I also make it clear that this is only the l needle on a big tree http://intelligentbuilding092.blogspot.com/2010/01/learning-revit-in-detail.html In that course students have a term project. You'll see from the following student-generated choice of topics that BIM ranks high in their choices (link in post). http://intelligentbuilding092.blogspot.com/2010/01/paper-topics-full-list.html	The biggest issue for me/us is the faculty, not the students. We have site licenses for the necessary software and adequate lab facilities. Most facutly, however, do not see the relevance to their research interests and are reluctant/unwilling to spend the ti to learn BIM in order to incorporate it into their courses.
We offer an elective interdisciplinary (arch, larch, ae) BIM design studio.	There is high support for BIM education in AE. The biggest hurdle is with true interdisciplinary efforts due to conflicting student faculty schedules and lack of compensation for more than one faculty member involved in a course.
Just started the class a year ago and it is moving in the right direction	I believe our industry advisory council will recommend that BIM be a required class and we will likely need to have a faculty dedicated to teaching CAD/Revit/BIM on a full time basis.
Our Department has two programs, Civil Engineering and Architectural Engineering. I am an environmental engineer and since becoming Head 2-1/2 years ago, I have been learning much about our ARE program and BIM. However, to get a fuller understanding of BIM in our program, you should contact Dr. Tony Denzer at tdenzer@uwyo.edu.	Administrative support will remain strong and we will continue to advance BIM education in our program. We are currently searching for a lecturer who can continue and expand our expertise in BIM and our ability to more fully integrate it into the program.
Most faculty agree that 3D modelling is the wave of the future. As instructors, the goal is to determine the best way to use BIM tools as an educational tool in addition to being used as a production and coordination tool.	
	BIM is the pencil of the future. It is the communication tool that will be used. We should not teach BIM but require the student use it.

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Q54: Please include any additional comments/concerns regarding BIM technology in AE educational curriculum that you might wish to share.
I am quite interested in receiving a copy of the results of this survey if possible. Please send them to jmessner@engr.psu.edu. you would like further information on our BIM initiatives, please let me know.
My comments here are related to my comments in Question 34 regarding funding. Right now, funding efforts are coming from the private sector (AutoDesk, Bentley), which are understandably interested in seeing their BIM packages introduced at the undergraduate level. The problem with this is that the power of BIM is not related to one particular package versus another -- i the interoperability that BIM promises and sometimes comes close to delivering. This is independent of the package, so it's no likely to be supported by software developers. In our own undergraduate curriculum, we are trying to emphasize the software-independent aspects of BIM. In our graduate curriculum, we are just beginning to develop courses and projects intended to ma our current BIM software come closer to fulfilling its promise.
When there is an easier way to interface BIM to standard energy modeling programs like eQuest or EnergyPlus we will try to incorporate it in our modeling classes. I don't see the older faculty who teach structures looking to incorporate BIM into those classes.
While the industry advisory council is pushing for more BIM technology, they strongly recommend that students be able to communicate with hand drawing/sketches.

Figure 9:2 Raw AE Educator Survey Data