

---

# **AC 2012-4356: BUILDING INFORMATION MODELING: DESIGN INSTRUCTION BY INTEGRATION INTO AN UNDERGRADUATE CURRICULUM**

## **Major Kevin P. Arnett, U.S. Military Academy**

Kevin Arnett is a first-year instructor at the U.S. Military Academy in the Department of Civil and Mechanical Engineering. He teaches CE404, Design of Steel Structures; CE403, Structural Analysis; and assists with CE492, Civil Engineering Capstone course.

## **Mr. Craig E. Quadrato, U.S. Military Academy**

# **Building Information Modeling: Design Instruction by Integration into an Undergraduate Curriculum**

## **Abstract**

Building Information Modeling (BIM) developed into a prominent field of knowledge and practice in the Architect/Engineering/Construction (AEC) profession over the past decade. As this field emerged in both academia and industry, increasingly viewed as critical for significant practice, the state of the art became more clearly defined. As the field matures, the door opens for the effective integration of BIM at the undergraduate civil engineering program level.

Some universities have taken the approach of addressing this new body of knowledge via seminar sessions, in addition to the standard academic load, while others have addressed the need with the development of a specific course devoted solely to BIM. The seminar approach evolved early when the topic was new. This approach is not as comprehensive and consequently not as demanding a commitment for both students and faculty alike. The alternative of creating an additional course adds BIM to the list of compulsory or elective courses and offers the opportunity for in depth learning on the topic. This provides a significant focus on the topic and builds on prior knowledge, but requires an additional course load for both students and faculty; the new course results in treatment of BIM as a separate specialty rather than a method to connect engineering disciplines.

A third approach is possible now that time allowed BIM concepts to become more standardized is to integrate BIM fundamentals throughout the complementary courses in an undergraduate civil engineering program. Integration creates the advantage of directly linking BIM to work in existing courses and highlights BIM in its normal state as a condition of the engineering environment rather than a separate subject. And while uniting coursework in a common BIM software platform offers significant advantages from a program perspective, simply using consistent BIM concepts in courses may also have a significantly positive effect on the undergraduate experience, specifically in capstone design courses. An initial implementation of this integrated approach is presented and evaluated in this paper based on the experiences in the civil engineering program at the United States Military Academy.

## **Introduction**

In many ways, Building Information Modeling (BIM) is both a cutting edge technology and a quickly evolving process within the field of civil engineering. As such, it is susceptible to potential exaggerated expectations, as well as to misunderstandings and even lack of definitions of its true scope and meaning. In many ways, it is being developed directly in industry, and a natural separation exists between practitioners and educators, which makes incorporating the practice into the educational system a lagging process. As the education process has lagged, the technology and process have proliferated (even now government GSA contracts require BIM<sup>(1)</sup>)

in industry while the educational community has worked to assimilate the new field into the curriculum.

The purpose of this paper is to discuss when BIM practices and concepts should be integrated into civil engineering education, to discuss how to best accomplish that integration, and to present the merits of an approach that has been substantially implemented to serve as an example within the undergraduate education community. Ideally, to evaluate the effectiveness of the BIM curriculum implementation, a cross-institutional study would be conducted, but this lies outside of the scope of the current paper. It is however, the authors' hope that this paper could lead to that end by starting a discussion. For covering the current scope of material, the starting point is to cover the current practice for BIM in both practice and education. Next, the merits of introducing BIM at the undergraduate level are set forth. This leads to the merits of implementation at the program level for undergraduates, and once discussed, the state of integration in the civil engineering program at the US Military Academy is presented with recommendations for institutions considering this course.

## **Background**

### What Is BIM and Why Does It Matter?

Building Information Modeling has been a developing field for quite some time, but in the grand scheme of things it is actually quite new. As such, there are typically misunderstandings about the key concepts for BIM and what they mean. This is true especially due to a fixation on a few of the more attention grabbing aspects of the process. The most definitive and accurate definition found for BIM, as defined by the National Building Modeling Standard Committee of the National Institute of Building Sciences, is:

“ . . . an improved planning, design, construction, operation, and maintenance process using a standardized machine-readable information model for each facility, new or old, which contains all appropriate information created or gathered about that facility in a format usable by all throughout its lifecycle.”<sup>(2)</sup>

Although there are some general terms in the above definition, it does a good job of specifying some of the key concepts of BIM. In its essence, a building information model is exactly as it is phrased: a model with information about the building. However, there are differences between BIM and preceding practice, which are important to highlight, as they support the pedagogical framework to extend BIM into the civil engineering undergraduate curriculum.

The first difference is in how BIM has advanced the state of design past pure 3D modeling. BIM models are more than just three dimensional drafting tools. A true BIM model accomplishes more than just a visualization purpose. Secondly, a BIM model

contains parametrically defined objects. This means that key features of an example object are defined and then scaled or related to other objects via key parameters. An example would be a steel I-beam. In 3D CAD, every single line would need to be generated individually to draw the model. In BIM, lists of possible cross sections exist and the beam is generated by connecting it to the other beams/girders/columns it physically connects to in the structure. Then in the course of design, moving a column line does not require redrawing every single member affected. And third, BIM software possesses the key ability for an object have linked or embedded information. This leads the fourth, fifth, and beyond dimensions of BIM, as the timeline for placing the beam and the associated cost are linked to the beam in the model. The “beyond” could be as varied as the intended capabilities. Items can be grouped, categorized, and aggregated. Aggregation being hierarchical way to denote that this beam is a part of this floor, etc.

The next difference between BIM and preceding practice is found in the end use of the model. It is different to note that different ends will be considered most important by different parties, and this key aspect highlights a Building Information Model’s paramount function as a communication tool. In the preconstruction phase, a BIM model is a tremendous vehicle to conduct a concept/feasibility assessment. A selected concept’s initial BIM model then facilitates the design process both in initial visualization, allowing simultaneous work and collaboration by multiple disciplines with faster integration, and the ability of clash and conflict detection. This benefits the construction phase first by significantly reducing the need to for change orders by up to 40% according to figures determined at Stanford University.<sup>(3)</sup> Additionally, the scheduling, cost, aggregation, and other data allow for a more efficient and accurate planning effort, resulting in better execution for construction. In the post construction phase, the building information model becomes a very valuable store of information for the operation and maintenance of the facility.

BIM is typically discussed in the architectural, engineering, and construction (AEC) fields with a big part of the engineering emphasis falling into the structural side, but there are further fields that benefit from these concepts. The visualization, parametric abilities, and embedded information lend themselves similar to hydrologic and runoff design,<sup>(4)</sup> transportation engineering<sup>(5)</sup>, and in aspects of geotechnical design.<sup>(6)</sup> This just adds to the need for knowledge in this area that has been established in other studies of the AEC field.<sup>(3)(7)(8)(9)</sup> Several emerging management and project delivery systems are directly supported by BIM processes. One example is Integrated Project Delivery (IPD). IPD as a process, demands the type of collaboration that BIM is optimal for producing.<sup>(10)</sup> Another example is lean construction concept where BIM also provides an enhanced capability and framework to apply lean construction principles.<sup>(11)(12)</sup> Additionally, BIM provides the platform that will allow emerging (in addition to existing) disciplines to effectively collaborate in the design of facilities, and the capabilities developed for

“green” design are a great example of how another emerging field can gain.<sup>(13)</sup> All of these reasons make quite clear how important knowledge the concepts and techniques of building information modeling are ever more critical in the AEC industry.

### When Should BIM Concepts and Skills be Learned?

The ever increasing importance of BIM begs the question of when should engineers learn these concepts and skills. When the field was quite new, it was initially presented to both graduate and undergraduate students through seminars or as small additions to an existing course. However, as the practice evolved and became better defined a more substantive education in the material became requisite. Engineers not fortunate enough cover the topic in their university studies were required to learn on the job. While this is not always optimal, it at least offered the advantage of being directly applicable and less abstract when applied to real situations. Increasingly though in depth options to learn the material became available in both the undergraduate and graduate school curriculums. These options varied with some approaches offering separate courses specifically addresses BIM and others attempt to integrate the information and learning across an engineering program of study. With an adequate review of the background information, the main question of this paper can be addressed and the merits of one approach can be discussed and illustrated.

### **When to Integrate: The Case for Undergraduate Integration**

#### Further Refinement of the Need

In evaluating the question of when BIM education should occur, it is important to anchor the evaluation in a common frame of reference. In order to attempt to build that frame of reference, the ASCE “*Civil Engineering Body of Knowledge for the 21st Century*” (BOK) is the most comprehensive framework set forth for civil engineering education.<sup>(14)</sup> Figure 1 below, presents ASCE’s vision for the required knowledge and capabilities for a civil engineer, along with the expected means for an engineer to acquire those skills in various degrees. As BIM is not explicitly called out in this vision, further judgment is required. Which of the outcomes indicated correspond with BIM and BIM concepts? The outcomes of design, sustainability, project management, breadth in civil engineering areas, communication, and teamwork are certainly among the foremost.

While on the job training was presented as an option above, it is not a particular leap of faith to accept that it is preferable for a new hire at a firm to already have the knowledge required. Prior knowledge places an applicant at an advantage to their peers, and this is borne out in the surveys of industry expectations concerning BIM.<sup>(3)(7)</sup> BIM skills and concepts are also still an emerging field in industry so the availability of in-house mentoring is not always guaranteed on the topic. Combining industry expectations, common sense, and an evaluation of the relevant BOK outcomes BIM clearly has a place in a university education.

Outcome Number and Title	Level of Achievement					
	1	2	3	4	5	6
	Knowledge	Compre- hension	Application	Analysis	Synthesis	Evaluation
<i>Foundational</i>						
1. Mathematics	B	B	B			
2. Natural sciences	B	B	B			
3. Humanities	B	B	B			
4. Social sciences	B	B	B			
<i>Technical</i>						
5. Materials science	B	B	B			
6. Mechanics	B	B	B	B		
7. Experiments	B	B	B	B	M/30	
8. Problem recognition and solving	B	B	B	M/30		
9. Design	B	B	B	B	B	E
10. Sustainability	B	B	B	E		
11. Contemp. issues & hist. perspectives	B	B	B	E		
12. Risk and uncertainty	B	B	B	E		
13. Project management	B	B	B	E		
14. Breadth in civil engineering areas	B	B	B	B		
15. Technical specialization	B	M/30	M/30	M/30	M/30	E
<i>Professional</i>						
16. Communication	B	B	B	B	E	
17. Public policy	B	B	E			
18. Business and public administration	B	B	E			
19. Globalization	B	B	B	E		
20. Leadership	B	B	B	E		
21. Teamwork	B	B	B	E		
22. Attitudes	B	B	E			
23. Lifelong learning	B	B	B	E	E	
24. Professional and ethical responsibility	B	B	B	B	E	E

Key:

<b>B</b>	Portion of the BOK fulfilled through the bachelor's degree
<b>M/30</b>	Portion of the BOK fulfilled through the master's degree or equivalent (approximately 30 semester credits of acceptable graduate-level or upper-level undergraduate courses in a specialized technical area and/or professional practice area related to civil engineering)
<b>E</b>	Portion of the BOK fulfilled through the prelicensure experience

Figure 1: ASCE BOK 2008 Educational Outcomes<sup>(14)</sup>

But should that be reserved to the graduate level? In fact, holding this education until the graduate level would miss the mark intended by the BOK and not be an effective educational strategy. First, delaying BIM education would miss a large portion of the intended audience. Comparing the number of civil engineering bachelors degrees to civil engineering masters degrees in 2009-2010, the numbers suggest a rough disparity of about 6,000 students per year who do not extend their educations beyond the undergraduate level.<sup>(15)</sup> Secondly, if you consult the document outlining five potential civil engineering career paths published by ASCE, either

by implication or by explicit inclusion as alternate/alternate options, civil engineering graduate degrees are not necessary prior to initial entry into the workplace or even at later points in time. <sup>(16)</sup> And lastly, the outcomes linked to BIM above all have relatively high levels of achievement expected at the undergraduate level in the ASCE BOK. This leaves the undergraduate level as the best option to introduce BIM concepts.

### Outcomes Facilitated

Does BIM education really help at the undergraduate level? As an exciting new field, it certainly provides a good tool for faculty to market their programs to underclass students attempting to make a decision about their program of study, but it also addresses the BOK and other outcomes at a significant level as well. Through the vehicle of a multi-disciplinary capstone design project or by its very nature, BIM can provide substantive contributions to the advancement of each outcome. The benefits of BIM used these capstones is something with ever increasing acceptance. <sup>(8) (17) (18)</sup>

### *Design*

In the undergraduate civil engineering education, much effort is focused on the details of the design of select systems. Whether we are discussing a structural or other solution, as you build student knowledge, they are often started from a set of design decisions that are already assumed. This is due to the very technical nature of those sub-system designs. Learning about BIM has the advantage of providing an opportunity to engage early in a design process where needs are evaluated and systems/sub-systems are selected and compared. This can reinforce the sub-system design skills, while also educating students on the process one takes to get to what they may have viewed as the “given” information for other coursework.

### *Sustainability*

As noted above, BIM as a field of knowledge is often relied up in the field of sustainable design. <sup>(13)</sup> BIM tools and concepts produce significantly better information for use in sustainable design, and there is the benefit of compatible software that can further analyze the data provided from a BIM model. This field is the perfect piece of a multi-disciplinary capstone project, which may be the best and/or only time an undergraduate program can address the material.

### *Project Management*

In many ways you could argue that BIM is a preeminent project management tool. In addition to supporting project management specialties such as estimating, scheduling, and producing quantity take offs which inform management decisions (all mentioned above), BIM is also a tremendous vehicle for a project leader to actually *manage* the *whole* project by providing a

common platform for all the differing disciplines to communicate critical information in an interactive way.

### *Breadth in Civil Engineering Areas*

BIM is the ideal integration vehicle for the different disciplines that are required to produce a new facility, and as such, can contribute to a breadth of knowledge.

### *Communication*

Simply put, this is essentially the main purpose of BIM; to communicate information in a usable way. Whether via visual means or by compilation of key data types from various objects or by the comparison of information from different disciplines, communication is at the heart of BIM.

### *Teamwork*

With the collaborative objectives that BIM serves, and when used in the capstone/project group manner, BIM will allow the conduct of group learning that cannot be paralleled with any comparable level of realism in a purely academic setting.

### Pedagogical Considerations

In addition to fitting best in the undergraduate arena and contributing to the BOK outcomes, BIM education at the undergraduate level provides further benefits, when considered in light of learning theories. BIM facilitates learning using a wider variety of learning styles. It also aids in the implementation of several different learning principles, and lastly, in properly working through the learning required to understand BIM concepts, students will reach higher levels of cognitive achievement.

Richard Felder and Linda Silverman's article "*Learning and Teaching Styles in Engineering Education*," published in 1987 outlined a strong set of learning styles that have become a widely accepted standard in the engineering education community.<sup>(19)</sup> In that article Felder and Silverman identified a tendency for teaching styles to be disconnected from predominant student visual, sensing, inductive, and active learning styles. Instruction in BIM and using capabilities provided by BIM technologies directly address many parts of this disconnect. The overarching example is in the ability address learners with a visual preference.<sup>(8)</sup> Beyond BIM instruction, the software can simply be used to produce better graphical representations for problems, which can be used to assist students in developing visualization skills. The other major learning style that BIM provides capability to address generating active learning, brought about by the nature of the BIM process in a group capstone.



Several educators have compiled lists of learning principles, but using the list presented by Phillip Wankat and Frank Oreovicz, several cases where BIM adds to the educational experience are highlight. The compendium of learning principles presented was:

1. Guide the learner
2. Develop a structured hierarchy of content
3. Use images and visual learning
4. Ensure the student is active
5. Require practice
6. Provide feedback
7. Have positive expectations of students
8. Provide means for students to be challenged yet successful
9. Individualize the teaching style
10. Make the class more cooperative
11. Ask thought provoking questions
12. Be enthusiastic and demonstrate the joy of learning
13. Encourage students to teach other students
14. Care about what you are doing
15. If possible, separate teaching from evaluation

**Figure 2 Compendium of Learning Principles<sup>(20)</sup>**

BIM, either alone or as part of a capstone, directly addresses items 3, 4, 5, 8, 10, 11, & 13. The visual capabilities have been noted, and the collaborative aspects of a BIM project and the way it builds on prior learning make the link to the other principles.

The ASCE BOK actually frames its outcomes on another very significant aspect of learning theory, Bloom's Taxonomy for the cognitive domain.<sup>(14)</sup> This hierarchical categorization of learning levels/outcomes ranges from the building blocks to the advanced level that could be categorized as the expert/evaluation level. The BOK appendix F breaks this down, but it is helpful to identify the levels of Bloom's taxonomy that can be reached. One of the strongest benefits of a multi-disciplinary capstone project using BIM is that it reaches levels 5 & 6 of the taxonomy (Synthesis and Evaluation) for a great variety of outcomes, both from the ASCE Outcome list and subordinate outcomes/objectives.

### **Where to Integrate**

Having presented the case for incorporating BIM concepts and tools in the undergraduate education, the question becomes how best to integrate BIM concepts at the undergraduate level. First, the option of a seminar style approach should be removed from consideration. In the authors' opinion, such an option does not constitute a level of integration substantial enough to meet the objectives previously discussed. The next option often discussed is developing a BIM course. This approach has been taken at several universities.<sup>(9) (17) (21) (22)</sup> The course proposed and demonstrated in this case is to incorporate BIM across the course of a civil engineering program, culminating with a multi-disciplinary capstone that also uses the same BIM tools and concepts.

## Program Level Integration

In many ways, a civil engineering undergraduate program follows the progress used in BIM. Often students are taught different civil engineering disciplines separately, and in order to facilitate higher order goals, often end with capstone course where they combine those various disciplines in a final interdisciplinary exercise. As a student progresses through the program, instruction in BIM tools along the way not only provides the explicit links to the rest of the process for the global learner, but also builds their skills for use in their final capstone. The fact that you will be using an integrated software suite helps students by keeping many user interfaces quite similar as they move through the program amplifying the incremental gains in each course. The benefits of this incremental learning has been noted in several other instances, as it breaks down the amount of BIM learning a student has to do solely in the course of a BIM conducted capstone.<sup>(5) (8)</sup> This further eliminates the challenge of finding room in a student's schedule for a whole new course, which is something cited by many educators as a reason for omitting BIM from a curriculum.<sup>(9)</sup> The culminating capstone then pulls all of their learning together and the application of the BIM *concepts* can become the focus rather than the use of the software tools or the learning of the foundational discipline specific knowledge. The high amount of technical knowledge (both discipline and software) required to teach BIM is also a big challenge in its instruction, as noted by the American Institute of Architects.<sup>(8)</sup> This deficit corrected allows students to use BIM as intended, as an *information model* and tool for project communication. The integration of BIM into the entire program is clearly a method with great merit.

## Benefits to the Individual Course in the Program

BIM instruction ought not be viewed as a drag on the individual courses that build towards the capstone. BIM and the differing software that corresponds with each discipline provide great vehicles for the learning in each individual course. They provide that link to the final set of plans resulting in a design culmination; provide the capability for advanced analysis; and provide an ability to better communicate design results. The fact that the software generates a 3D model replicates a physical model, but without requiring the same overhead (storage space, movement to classroom, etc.), means it is a tremendous vehicle to aid students in visualizing what they are doing, linking 3D to normal 2D drawings used in construction documents.<sup>(22)</sup> Additionally, the use of extensive models lends itself to distance learning which is a growing field in the civil engineering educational community.

## **West Point Civil Engineering Experience**

### Current Incorporation of BIM

As with every civil engineering program, the program at the US Military Academy at West Point constantly works to adapt to changes in the body of knowledge within its constraints. Figure 3

below depicts the current program for civil engineering majors in its current state. The courses where BIM concepts and tools are covered are shown below with stars.

Term 12-2	Term 13-1	Term 13-2	Term 14-1	Term 14-2
<b>MC 300 (L)</b> Mechanics and Design	<b>MC 364 (L)</b> Mechanics of Materials	<b>CE 403</b> ☆ Structural Analysis	<b>CE 404 (L)</b> ☆ Design of Steel Structures	<b>CE 492</b> ☆ Design of CE Systems
<b>MA 206</b> Probability and Statistics	<b>MC 311 (L)</b> Thermal Fluid Systems I	<b>CE 371 (R)</b> Soil Mechanics	<b>CE 483 (R)</b> Design of Concrete Structures	<b>CE 400</b> CE Professional Practice
<b>PH 202</b> Physics II	<b>CE 350</b> Introduction to the CE Infrastructure	<b>CE 380 (R)</b> Hydrology and Hydraulic Design	<b>Elective 1<sup>2</sup></b>	<b>Elective 2<sup>2</sup></b>
<b>LX 20__</b> Foreign Language	<b>CE 390 (R)</b> Site Civil ☆	<b>CE 450</b> Construction Management	<b>LW 403 (L)</b> Const. & Military Law	<b>Elective 3<sup>2</sup></b>
<b>SS 201 or</b> <b>SS 202</b>	<b>Math and Basic Science Elective<sup>1</sup></b>	<b>EN 302</b> Advanced Composition	<b>HI 301</b> History of the Military Art I	<b>EE 301 (R)</b> Fundamentals of Electrical Engr.
<b>EV 203 or</b> <b>PY 201</b>	<b>PL 300</b> Military Leadership	<b>SS 307</b> International Relations		<b>HI 302</b> History of the Military Art II

Figure 3 USMA CE Program (Shaded = CE required or core course)

One of the previously documented changes in the program was the introduction of the CE 390 Site Civil course for students graduating in 2007. <sup>(23)</sup> Since the initial inception, the focus on BIM technologies has deepened, with the use of Bentley PowerCivil. This software, with its ability to integrate with the Bentley suite of software also makes use of parametric modeling for purposes of site design. Progressing into CE403Structural Analysis used Bentley’s STAAD Pro structural analysis engine where students learned the critical skill to use commercial analysis software alongside of their progress in the fundamental knowledge of structural analysis.

In CE404Design of Steel Structures, the next layer of BIM technology was added to the repertoire of the student. Structural Modeler, which is the structural engineer’s link to BIM, not only allows the students to generate plans depicting the results of their designs, but does so within BIM processes. They can conduct their design’s using STAAD Pro and have the link to Structural Modeler illustrated, highlight the benefits for design iteration. They further gain use of a tremendous visualization tool, while learning how to generate 2D plans/construction documents from their 3D models. This process is the perfect lead in to the challenges BIM addresses for creating consistent documents and linking to the collaborative Bentley building suite. In CE404, students complete an engineering design project conducting steel building design, accomplishing course objectives for low-rise steel building design, while simultaneously supporting the program objective to function effectively on multi-disciplinary teams. This is the type of synergies the process is designed to bring about.

At the end of the semester in the fall of 2011, students were asked to answer questions evaluating the effectiveness of the course in helping them to learn BIM concepts and skills.

### Term 12-1 Course Feedback - CE404 Questions

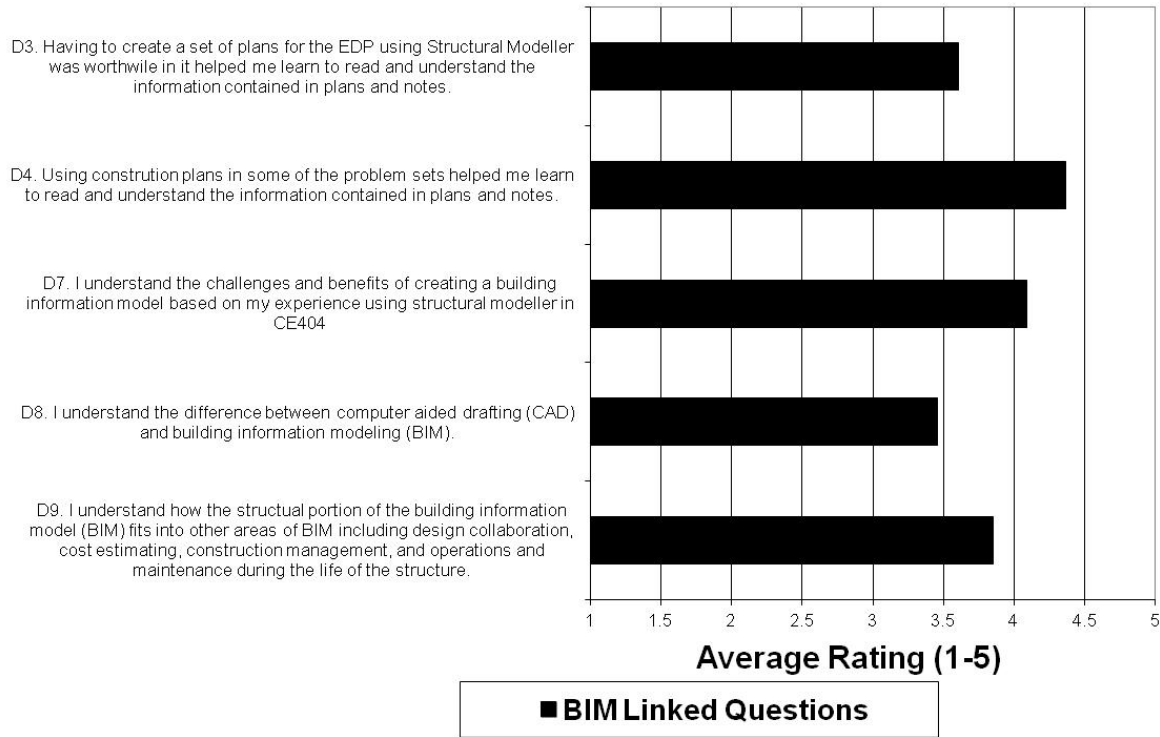
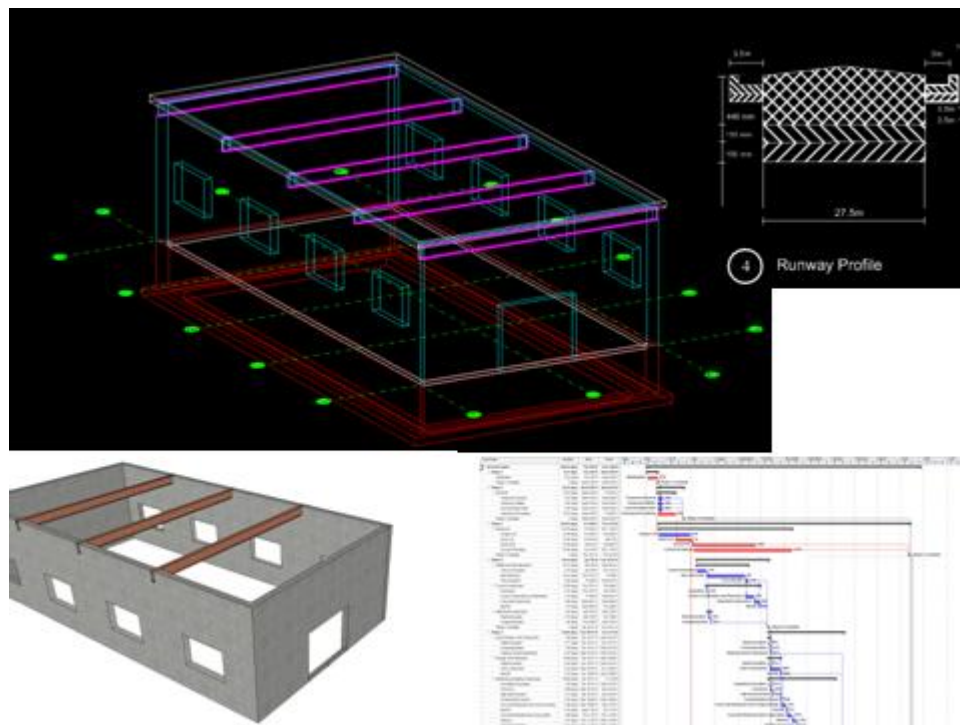


Figure 4 CE404 BIM Questions

The questions were posed on a 1-5 Likert scale, and though not overwhelming, the results support that the efforts accomplished the objective of BIM education to a measurable degree. This also makes sense as the full benefit of the work is expected to be gained in the final course of the progression.

This progression of BIM concept and tool learning is culminated in CE492 Design of CE Systems. This is a capstone course for the civil engineering program, incorporating the work of various civil engineering disciplines into one semester long group project. Structural design, site civil and hydrologic design, geotechnical design, as well as construction management skills are combined as students work through the complete design effort for a facility. This course makes each hour that meets a design “firm” and different members of the hour are appointed to serve in different roles for the project. This is where the work that is put in all of the feeding courses is really integrated in the type of collaborative environment where BIM flourishes. With links to the US Army Corps of Engineers, the projects provided are enhanced and provide a great degree of credibility and realism for students.



**Figure 5** Representative work from student capstone course

### Remaining Areas for Integration

The program still has room for further integration of BIM concepts and tools. Specifically, incorporation into CE450 Construction Management is an area where we could introduce many of the techniques and procedures for BIM that would further enrich our CE492 experience. This would specifically be in the areas of estimating, scheduling, and conducting quantity take-offs. Additionally, we can continue to look for appropriate ways to integrate the software into both our earlier courses, as well as the hydro and geotechnical courses.

## Triumphs

The design problem for CE404, as well as the capstone in CE492, are both great design problems, reinforcing design skills for the different types of structural elements that students are taught to design. This accomplishes the objective of students being able to make the jump from 2D plans to an understanding of the actual structure. This link used to be accomplished using plans from other facilities and with the use of K'NEX. While this was a very solid means, the use of BIM 3D models has brought the visualization capability to a new level, especially for structural systems other than beam-column construction. The ability to create a network based file storage capability that additionally allowed the course director to generate “firm” standard drawing rules provided a capability to customize student drawings creating a professional product that could be considered quite consistent across all student submissions. Instructors were also able to generate custom menus for students that contained the tools they needed at their particular phase of work, in order to make the use of the software a little less onerous. Finally, even with only two years of integration, the instructors have built a bench of 3D models and assemblies that have been useful in creating new design and homework problems as well as in class demonstrations.

## Challenges

The efforts were not without challenges. First off, implementing this in the course generated a steep learning curve and time requirement as faculty learned not only the use of the software, but the administrative portions of the software required to set the environment for student projects. This placed a demand on the department IT personnel, and both department IT personnel and the faculty were at the mercy of the academy network policies and priorities. Despite the uniformity at USMA, it was still a challenge to get the required software working perfectly on student and computer lab computers. This was especially true for student computers, which for the senior classes had started to show the maintenance issues common with aging computers. The faculty was also faced with a disconnect between software that is generated to create a single project architecture, rather than an architecture to be replicated for several student project groups.

## **Conclusion and Recommendations**

The implementation of this approach for integrating an education in BIM concepts, techniques, and technologies, although not perfected, is evolving into a great process. BIM education has found its optimal location in the timing of engineer education and the integration across the course of an engineering program yields a significant amount of pedagogical benefits. In addition to breaking down the learning required for BIM tools into more manageable and topic specific chunks, it provides additional and very useful capabilities to instructors along the way, letting them better accomplish their original course objectives. The course of the development of BIM concepts and techniques along the course of the program, as noted in the West Point experience and as anticipated in other universities, provides students in a capstone course the

opportunity to see BIM in its best possible light in an academic setting. This better prepares students to participate in industry and to help it with the ongoing transition to the technology. Consequently, it is the author's recommended approach for education on BIM.

## **Bibliography**

1. *Building Information Modeling in Construction: Current Practices and Their Implications for Construction Engineering Education*. **Mutai, Anthony and Guidera, Stan**. s.l. : American Society of Engineering Education: Annual Conference & Exposition, 2010.
2. **Eastman, Charles M.** *BIM Handbook: a Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors*. Hoboken, NJ : Wiley, 2011.
3. *Building Information Modeling (BIM): Benefits, Risks and Challenges*. **Azhar, Salman, Hein, Michael and Sketo, Blake**. Auburn, AL : Associated Schools of Construction: Proceedings of the 44th Annual Conference, 2008.
4. **Grigore, Irina, Cazanescu, Severin and Cazanescu, Raluca Alexandra**. AutoCAD Civil 3D 2010 with Hydraflow Extension. *Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Agriculture* . 2009, Vol. 66, 2.
5. *Work in Progress: How Building Information Modeling May Unify IT in the Civil Engineering Curriculum*. **Casey, Michael J.** Saratoga Springs, NY : IEEE: 38th ASEE/IEEE Frontiers in Education Conference, 2008.
6. *Integration of geotechnical design and analysis processes using*. **Obergrieber, M., et al.** Miami, FL : ASCE: Proceedings of the 2011 ASCE International Workshop on Computing in Civil Engineering, 2011.
7. *Industry's Expectations of Construction School Graduates' BIM Skills*. **Taiebat, Mojtaba and Ku, KiHong**. Boston, MA : Proceedings of the 46th ASC Annual International Conference, 2010.
8. *The Potential of BIM to Facilitate Collaborative AEC Education*. **Macdonald, Jennifer Anne and Mills, Julie E.** s.l. : American Society of Engineering Education: Annual Conference & Exposition, 2011.
9. *The Integration of BIM in the Undergraduate Curriculum: an analysis of undergraduate courses*. **Sabongi, Farid J.** Gainseville, FL : Proceedings of the 45th ASC Annual International Conference, 2009.
10. *Building Information Modeling in Architecture, Engineering, and Construction: Emerging Research Directions and Trends*. **Becerik-Gerber, Burcin and Kensek, Karen**. 3, s.l. : ASCE, 2010, Journal of Professional Issues in Engineering Education and Practice, Vol. 136.
11. *Interaction of Lean and Building Information Modeling in Construction*. **Sacks, Rafael, et al.** 9, s.l. : ASCE, 2010, Journal of Construction Engineering and Management, Vol. 136.
12. **Ningappa, Geetanjali.** *Use of Lean and Building Information Modeling (BIM) in the Construction Process; Does BIM make it Leaner?* s.l. : Georgia Institute of Technology, 2011.

13. **Krygiel, Eddy and Nies, Bradley.** *Green BIM: Successful Sustainable Design with Building Information Modeling.* Indianapolis, IN : Wiley, 2008.
14. *Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future.* Reston, VA : ASCE, 2008.
15. **Gibbons, Michael T.** *Engineering by the Numbers. Profiles of Engineering and Engineering Technology Colleges.* s.l. : ASEE, 2010.
16. Career Paths In Civil Engineering, Career Development. *American Society of Civil Engineers.* [Online] [Cited: January 5, 2012.] <http://www.asce.org/Content.aspx?id=15154>.
17. *BIM Undergraduate Capstone Thesis: Student Perceptions and Lessons Learned.* **Azhar, Salman, Sattineni, Anoop and Hein, Michael.** Boston, MA : Proceedings of the 46th ASC Annual International Conference, 2010.
18. *Simulating the Collaborative Design Process Through a Multidisciplinary Capstone Project.* **Setterfield, Charlie, Dunn, Eric and Marcks, Russell.** s.l. : American Society of Engineering Education: Annual Conference & Exposition, 2010.
19. *Learning and Teaching Styles In Engineering Education.* **Felder, Richard M. and Silverman, Linda K.** 7, s.l. : American Society of Engineering Education, 1988, *Journal of Engineering Education*, Vol. 78.
20. **Wankat, Phillip C. and Oreovicz, Frank S.** *Teaching Engineering.* New York : McGraw-Hill, Inc., 1993.
21. *Experiences Implementing an Undergraduate Civil Engineering Course in BIM.* **Dupuis, Matthew, et al.** s.l. : American Society of Engineering Education: Annual Conference & Exposition, 2008.
22. *Teaching Building Information Modeling as an Integral Part of Freshman Year Civil Engineering Education.* **Sacks, R. and Barak, R.** 1, Reston, VA : ASCE, January 2010, *Journal of Professional Issues in Engineering Education and Practice*, Vol. 136.
23. *Introducing Students to Civil Engineering.* **Evers, Jason, Conley, Chris and Klosky, James.** s.l. : American Society of Engineering Education: Annual Conference & Exposition, 2007.
24. *Building Information Modeling: Implications of Government and Industry BIM Initiatives for AEC Education.* **Guidera, Stan and Mutai, Anthony.** s.l. : American Society of Engineering Education: Annual Conference & Exposition, 2008.