Building Information Modeling - Necessary but not Sufficient: A Cross Functional Perspective

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Abstract
Building information modeling (BIM) has had a profound impact on the AECO industry. It has forced the industry to fundamentally reexamine the way it does business. Changes have occured at the organizational and contractual as well as the technological level. In order to respond to this change professional education programs must reexamine both the content and the methodology of its pedagogy.

This presentation will report on one such effort. It describes a multidisciplinary effort to use BIM as a common language to integrate programs in Architecture, Engineering, and Construction. It also suggests that BIM in conjunction with real world experience is required in order for students to fully grasp the inter-dependencies of the industry. This effort is particularly challenging as it requires organizational, personnel and technological change.

Keywords
BIM, Architecture, Engineering, Construction, Cross-Functional

1. INTRODUCTION

Building information modeling (BIM) has had a profound impact on the AECO industry. It has forced the industry to fundamentally reexamine the way it does business. In addition to the host of software products that have been developed, the advent of new contractual forms such as the ConsensusDocs and the AIA Integrated Project Delivery series is evidence of the widespread changes in the industry. The insurance industry is also changing and new products are being developed to address the innovative organizational forms that are emerging.

The changes that are occurring in industry demand a response from the academy. If we are to prepare our graduates for the challenges that they will face we will need to reexamine the way we do business. This presentation will report on one such effort. It describes a multidisciplinary effort to use BIM and experiential learning as vehicles to integrate programs in Architecture, Engineering, and Construction.

This effort is particularly challenging as it requires organizational, personnel and technological change. The organizational challenge examines the inherent difficulty in structuring a true a cross disciplinary program. Issues of academic and resource ownership are particularly important. The personnel challenge looks at the necessity of achieving buy in and developing champions in all the various disciplines. The development of a vehicle around which the various actors can achieve consensus is seen to be a key to success. Lastly the technological challenge involves the development of an information system that supports integration and collaboration.

While this effort is, and will remain, a work in process it presents an educational model that reflects the dynamics that are occurring in the industry.

2. CURRICULUM / ORGANIZATION

Norwich University is a small university with an enrollment of approximately 2,000 undergraduates. Unique to Norwich is that, despite its size, it contains programs in Architecture, Civil Engineering, and Construction Management. While these programs are all housed in separate Schools, the need for efficiencies, dictated by the size of the programs, has required that each School offer 'service' courses for the others. The combination of service courses coupled with relatively small number of faculty has moderated the silo effect that is so common in the industry and academia.

The initial movement towards a cross-functional curriculum involved the Construction Engineering Management program which was established in 2007. From its inception in 2005 the program was envisioned as an inter-disciplinary experience. The functional silos and litigious attitude that exist in industry were identified as major contributors to the well documented inefficiencies with which the industry struggles. The academic silos, in which most AEC professionals trained, were seen as a major contributor to the structure of the industry. By training the CEM students with architectural and engineering students it was believed that the 'separation by a common language' (Oscar Wilde or Bertrand Russell) syndrome might be overcome. At the same time CURT (Construction Users Round Table) was becoming a powerful voice of the owner in demanding change to our inefficient, litigious industry. Coincidentally, the use of BIM was at an inflection point and was poised to enter a phase of rapid growth.

The curriculum is still evolving but at the present time students interact with their AEC counterparts in the following courses.

Introduction to Engineering	CEM/ ENG
Fundamentals of Design	CEM/ ARCH
Surveying	CEM/ ENG
Site Development	CEM/ ENG
Passive Environmental Systems	CEM/ ARCH
Materials	CEM/ ARCH
Construction Practices	CEM/ ENG
Structures I and II	CEM/ ARCH
Active Environmental Systems I and II	CEM/ ARCH
Construction Accounting and Finance	CEM/ ARCH/ ENG
Capstones	CEM/ ARCH/ ENG

As can be seen from the list, while there is significant interdisciplinary activity involving CEM, the interaction between ARCH and ENG is minimal. In addition those courses where all three disciplines interact are limited.

In order to develop a common language to integrate all three disciplines we needed to introduce a common element. That element is building information modeling. BIM is introduced early in the curriculum and serves as a common platform that allows communications and handoffs between various courses and disciplines. However, the fact that we have the ability to conduct integrated projects does not guarantee that BIM will be implemented as more than 3D CAD. As described previously, this does not address the fundamental fragmentation of the industry. In order to accomplish this goal we needed to combine the language with tangible action. To borrow from the jargon of finance (Warren Buffet) we needed to develop a process that resulted in the students and professors having 'skin in the game'.

3. PROJECTS/ PEOPLE

Common among the AEC disciplines in higher education is the desire to inculcate students with the value of design, craftsmanship, problem-solving, work ethic, and the ability to adapt to change. A standard pedagogy adopted by many educators is to simulate real-world experiences through classroom-based vignettes that are designed to illustrate and abstractly replicate real-world situations. Although these exercises have value, the safety net of academia is omnipresent and it weakens the learning experience. Recognizing this limitation, many AEC programs try to further this by including design/build coursework that involves students in the hands-on reality of conceptualizing, designing, and ultimately fabricating a building, or large-scale object. While the value of this real-world experience is widely acknowledged, the student may come to under value it because the all-pervading academic safety-net limits the potential of their personal investment.

Despite the fact that BIM has been fundamental in increasing multidisciplinary practice, its role in how AEC related disciplines learn from each other in an academic environment remains missing. Although BIM can introduce students to the role that various disciplines play in the making of a building, it doesn't provide an actual sense or appreciation of the intellectual, physical, or emotional investments that each discipline makes toward the creation of the finished building or product. In order to achieve this, the intellectual safety-net must be removed and the reality of complex teamwork introduced.

A true multidisciplinary environment in higher education offers an opportunity for inter-collegiate dialogue. The value of this goes beyond that of the traditional designer/builder/owner relationship by bringing all three parties together in a loose, but genuine temporary corporation. Not unlike current AIA Integrated Project Delivery (IPD) documents that clarify owner/designer/builder relationships, the inter-collegiate multidisciplinary design/build approach takes advantage of the inherent interest by all departments in the successful outcome of the project. It's not surprising that mutual respect and mutual benefit are the two first essential principles listed as critical to success in AIA's IPD documents. These two characteristics also allow the intercollegiate multidisciplinary design/build pedagogy to work well in introducing AEC students to the greater contexts of their discipline.

The challenge we faced was the development of a project that was easily understandable and valuable to the university faculty, was capable of being accomplished by an integrated team of students, and also had the real world sense of urgency that moved it beyond the realm of an

academic exercise. Our first effort in this regard focused on the Associated Schools of Construction Design Build competition. We assembled a team of Architectural, Engineering and Construction students to participate in the competition. In reviewing the outcomes we felt that the completion functioned well in developing a sense of urgency and interdependency. BIM functioned well as a common language; however, there was still a lack of skin in the game.

During a meeting of interested faculty from Engineering, Architecture, Management, Political and Environmental Sciences the Energy Mobile Building Arts Research Center (EMBARC) emerged. The Project involved the conversion of a 20 foot shipping container to a solar powered laboratory that would act as a mobile education venue. The EMBARC will be deployed to schools across the state and by its intrinsic structure and experimental agenda introduce students to research in sustainability and environmental sciences. The project addressed the interests of all the participants and created champions and ownership across the University.

A team of professors along with 8 student interns from Architecture, Engineering, and Construction committed to working on the project during the summer. The university provided initial funding as the first part of a larger grant. Further funding would be dependent upon the success of the project. In addition a commitment was made that the project would be unveiled at convocation. The project had a ten week Design/ Build time frame. The students and the faculty had skin in the game.

With the tight schedule the team recognized that a common language would be critical for success. While BIM is currently used throughout the curriculum the degree of competency varied within the disciplines. Therefore the first week of the project was devoted to an intensive Revit workshop. For many of the faculty and the students this was their first intensive experience with the software. The time constraints required that the project be a condensed design/ build experience with design produced on a just in time basis. However, the productivity of the student interns had been over estimated and as a result the project proceeded on more of a simultaneous rather than JIT design/build. An interesting result of this condensed approach was that the students were required to translate design into construction in real time. They were also able to experience the interdependencies between the various 'trade' items. Most importantly they learned the interdependencies of the various disciplines. The project would not be successful unless they all worked together. At this point in time, while the project is substantially complete the BIM model is still a work in progress.

The emotional, intellectual, and physical rigor being offered by the design/build team as well as the owner/client is concretized for the students in projects like these because the client is integrated, not abstracted. The level of reality and consequence brings a tone of seriousness and professionalism to program, and allows students to see each other's roles and the contribution and significance that each discipline makes toward the project. A clear indicator that the safety net has been removed from under the students is when the lines drawn between disciplines get blurry; a construction management student designs a door, an architect lays out a business plan.

4. TECHNOLOGY

The successful development of an inter-disciplinary program can only be accomplished when the IT infrastructure supports the efforts. An infrastructure that only supports 'lonely BIM' will

result in lonely professionals. They will be separated by that common language. Despite technical proficiency they will not have learned to function in the cross functional environment so critical to the industry. Isolated computer labs reinforce academic silos. As we proceeded with the development of an integrated curriculum we concurrently worked on the development of an integrated IT architecture, based on a virtual computing environment. Placing an architecture that supports the BIM in a virtual environment exploits the data sharing benefits of cloud computing, which is defined by Gartner as "...a style of computing where massively scalable IP-related capabilities are provided as a service across the Internet to multiple external customers." (Miller, C., 2009) Placing shared elements of BIM architecture in the cloud facilitates modeling, enhances process, encourages and supports collaboration, increases scalability, reduces costs and improves data sharing.

There are two components to establishing a virtual BIM environment that may be supported separately. The first component is the research and development activity, including customization of the OGC architecture, leading to a pilot BIM in the cloud project using virtual systems to create the cloud and various departments within the organization (engineering, architecture, building management, etc.) to simulate a user community. The deliverable of this component is a roadmap for creating a BIM in the cloud service provider.

The second component is software testing and virtualization. In this component software applications that could be appropriate for a BIM in the Cloud implementation are tested for compatibility with cloud computing and, if so, are virtualized for use in a virtualized environment such as VMWare ESX or vSphere. The deliverables for this component are final architecture designs for each product and an ISO image of the application and a virtualization/cloud computing guide if appropriate. Because of the size and complexity of most BIM-related applications, compatibility certification is a necessary step to virtualization.
The virtual environment is extremely flexible and cost-effective. However, it can have limitations. For example, the amount of memory available for video RAM may be limited beyond that which is optimal for high resolution graphics. In this case it may be preferable to use a high resolution monitor and desktop computer with considerably more video RAM than is available for the virtual system. When using this approach the virtual computer created within the virtual system (called a virtual machine or "VM") cannot be addressed using the usual method of connecting to it as a remote desktop. It simply is used to distribute application software instances and to provide sharable storage facilities.

For high-compute applications it is preferable to use a high performance computing (HPC) cluster. HPC systems combine the computing power of multiple servers running a special operating environment. For organizations using Microsoft applications it may be useful to deploy Microsoft's HPC server operating system.

One does not interact directly with the HPC cluster. Rather, one delivers instructions to it and it computes the result and returns the final product to the user's computer. So, if a user wanted to design a 3D model of a building, the user would design the building on his or her desktop or VM computer. Once the user has completed the design, he or she would send it to the HPC cluster, which would compute the solid model. Upon completion of the compute process the HPC would

deliver the finished model to the user's computer where the finished solid model would be displayed.

At present the optimal BIM implementation is a combination of virtual systems and HPC clusters. Most work is done on the VMs. This may include estimating, wire frame design and other collaborative tasks. When it comes time to perform a high compute function, such as solid modeling, the project is sent to the HPC cluster. The HPC cluster performs its work and sends the finished product back to the user. This may be an iterative process until the project is complete.

All elements of the project, from project management through design and rendering, may be completed in the VM/HPC environment. Further, the entire process may be collaborative. Engineers, architects, constructors and owners can have access to their parts of the process as well as to those group pieces that must be shared. This adds to efficiency, reduces costs and improves time to completion of the project through collaboration and data sharing.

5. CONCLUSION

Building Information Modeling has had and will continue to have a profound effect on the AECO industry. Educational institutions need to review their curriculum and pedagogy to reflect the demands that will be placed on their students. The inclusion of BIM in the curriculum is a necessary but not sufficient action. BIM has affected both the technological and the organizational aspects of the industry. Lonely BIM while providing a skill set will not prepare students for the new challenges that will face them. Projects that build on the common language are necessary. An approach that results in 'skin in the game' is necessary. Lastly the IT infrasrtructure needs to support the language and the projects. Implementing the software without an appropriate architecture will limit the potential of both.

The appropriate pedagogy is an evolving target. The importance of the project as a translation tool from the virtual to the real world was only understood as a result of the miscalcultion of student productivity. However, it was a fortutios miscalculation. As the industry evolves we need to be open to the learning that occurs. We need to develop the abiity to change and adapt. We have institionalized techniques that are 50 and sometimes 100 years old. We need to guard against the same tendency with technology. While the value of Virtual Design and Construction is unquestioned it is still evolving as is the translation to actual design and construction.

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