Evolution of a construction graphics course for engineering education

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Abstract
The construction industry is being inundated with new technology utilized to help expedite all processes of construction. Visualization of the entire process and individual assemblies of materials has become a standard requirement for individuals in the construction industry. The traditional means of education needed for construction was gathered by hands on experience and could take several years for the individual to obtain. Many AEC firms do not have the time to train carpenters, subcontractors, or superintendents how the construction assembly processes come together. Today’s engineer or construction manager that goes through a higher educational system has the ability to utilize new technologies enabling her/him to obtain the visualization education quicker than traditional means. Technology is providing marketing alternatives such as three-dimensional models for visualization, simulation, and spatial analysis. This paper discusses the evolution of the construction graphics course taught to Engineering & Construction Management students at Purdue over the last 10 years. The course originally was introduced to get Engineering and Construction Management students visually cognizant of all traditional 2D graphics used in industry. Today’s course was designed and delivered to assist students in learning the creation, integration of every graphic type used in construction as well as examining 3D geometry, spatial relationships, geographic information, quantities of materials, and properties of building components. The paper will discuss the evolution of graphics education in the civil engineering and construction management course at Purdue University and how the curriculum came about which was influenced by new technology utilized by the AEC industry.

Keywords: BIM, BIM education, commercial construction, engineering education, visualization

1 History of course
From the earliest prehistoric drawings to current drafting standards, graphical illustrations are a natural means for communicating ideas, concepts, or actions. “For thousands of years, graphic representations have been one of the main forms of communication.” (Luzader and Duff, 1989) “An idea must exist in the mind of the artist, engineer, or designer before it can become a reality. The concept is developed on paper or a computer screen. It is then shared with others in the form of sketches, controlled line drawings, dimensioned drawings or computer generated images.”(Gill, 2004) Many of these ideas and concepts were how the creation of a computer graphics course was created at Purdue University 10 years ago.
Several years ago, the Building Construction Technology department at Purdue University decided it was important to introduce students to technical graphics into the curriculum. This was done in conjunction with introducing blueprint reading into the curriculum too. Graphical standards for 2D illustrations came into effect around the beginning of the 20th century. (Schantz, 1998) The course started off teaching students how to draw construction related problems using traditional T-square and triangles on drafting tables. The introduction of how to read blueprints was also included in the course mainly because reading blueprints and creating construction documents went hand in hand. The initial thought was if the students could create a set of construction documents, they could read any set. “The need to learn how to read a drawing is absolute, because all people related with the technical industry must be capable of reading or interpreting a drawing without hesitations.” (French, 1947). The introduction of projection drawings concluded the course content. Traditional projection drawings where introduced to the students from parallel projections to perspective projection drawings.

Pictorial isometric drawings were not utilized much in traditional construction documents other than for a plumbing schematic. Perspective drawings, the next most realistic projection drawing, were created only as a means to market the project and were usually created by artist. The introduction of each type of projection drawing was essentially needed to show the construction student every type of graphic they would encounter in the construction industry.

Over the years, the course evolved into a computer based course. All course content in the course was redesigned with the introduction of the computer and the deletion of the drafting equipment. Descriptive geometry once introduced and calculated with drafting equipment was essentially minimized due to the software accomplishing the same task easier. Current technology however has once again transformed the course into a multi-technology, multi-projection drawing, and spatial visualization curriculum.

2 New technology in construction

The AEC industry is going through several changes in the technological and process areas for creating construction documentation. CAD exploded into the construction world and brought a revolution of controversy on how to create construction documents into the Architectural, Engineering, and Construction industry. The AEC industry and more specifically individual companies must look at other parameters and aspects of the construction communication process other than technology. Production and profitability play a large factor in any construction project. Can the document be generated at a specific rate in order to sustain profit within the project guidelines? Can the incorporation of technology make the production process less time consuming and without technological headaches? These are questions that most AEC professionals are asking before the technological switch will take place in their business. When all was said and done, CAD won over traditionally created construction documents. The benefits of CAD created documents far outmatched traditionally created construction documents. Today’s construction technology & software has evolved beyond the wildest expectations of most AEC professionals.

Building Information Modelling is taking over for traditional 2D CAD. Like most new technology, controversy has plagued the AEC industry about the utilization of Building Information Modelling (BIM). “Building Information Modelling isn’t something you can order out of a box... it is a process.” (LaFevre, 2007) “Building information modeling 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. 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.” (Autodesk, 2008) With
Building Information Modeling, students can see how visualization can be an important part of the construction process. Most clients have a hard time interpreting 2D construction documents. With Building Information Modeling now, those same clients can clearly understand how the building will look as well as how it will be constructed. It is the combination of the years of traditional construction documentation creation and the integration of 3D modeling technology that the current course integrates currently.

3 Current construction graphic curriculum

It is that good course content comes from years of educational training as well as integration of industrial practices into current course curriculum. Today’s construction companies have to utilize both traditional documentation creation and utilization in order to construct current projects. 3D modeling however is being utilized to create the 2D construction document sets. The implementation and utilization of 3D models, especially architectural, had become significantly easier and more efficient to construct. (Giambruno, 1997) It has only been recently that software companies are creating the 3D Model in the form an Architect or Engineer understands the traditional 2D way of drafting. Most software packages to date are drawing Architectural documentation by creating the documents in a traditional 2D fashion but adding material and height to create a 3D model. Most designers creating the 3D models have had to increase their knowledge of how the structure is built in order to draw or model the building in the computer. With this increased knowledge, the curriculum has evolved into a combination of 2D construction document understanding & creation, 3D modeling creation as well as construction document extraction, and spatial visualization.

The 2D construction documentation understanding and creation is still covered in the course. Today’s industry still utilizes the 2D construction document set to build the structures. Years of tradition has turned into habit and is not easily dissolved overnight. It is not known what percentage of AEC companies only create 2D construction documents; but from the consulting the authors have done with construction companies, the 3D model creation is taking over the industry. Construction management and Civil Engineering students require knowledge of traditional 2D construction documents in order to manage designers effectively as well as utilize those documents to build the structure. Currently there is no getting around still introducing students to traditional 2D construction documents creation. This is accomplished by a complete introduction to AutoCAD. AutoCAD is still a standard technology utilized in industry and therefore students should have a basic understanding of how to create, utilize, and manipulate documents.

Not all students in the course are interested in commercial construction. The class student composition is Civil Engineering, Construction Engineering Management, Building Construction Management, Industrial Designers, and a few undecided. Even then, not all students really want to
understand residential construction. Therefore, multiple types of CAD problems were created and are introduced to the students not particularly focusing on any one specialty. Initial lab problems focus on learning to draw in AutoCAD. Later problems get more specific by introducing a plot of land or a descriptive geometry problem of road construction in figure 1. Commercial floor plans are later introduced as well as detail drawing model of a steel bridge column detail. The variety of problems keeps most students interested for 9 weeks of class.

After AutoCAD is quickly introduced, the students transition to model creation. Revit is introduced to the Construction Management students. Over the next 5 weeks, the students start to learn the basics of the 3D Modeling technology as well as how to create the structural model which is covered in a demo lecture. There is only one 3D modeling lab introduced to get the students acquainted with the technology which is a simple lake cottage house due to the final project introduction shortly after the cottage lab. The final project is a combination of everything they have learned along with new information.

First, the students are told to get into a group of 5 individuals. Next, each group member is to select one of 5 different apartment units. They are to use their AutoCAD knowledge to draw a complete 2D representation of the apartment unit. The group is to decide specific information like layer naming, line types, and color of objects in the AutoCAD file. Once they get the apartment unit drawn, they are to give their .dwg file to each of the other 4 group members. At this point it becomes an independent project. Each student then assembles each apartment unit into a complex layout given by instructor. Once all units are assembled in AutoCAD, that complex is exported and imported into Revit to use as a guide. The entire first floor of the complex is completely modeled all the way down to the bathtub and kitchen cabinets. Once the first floor is complete, the entire first floor is arrayed upward to create a 4 story apartment building. A roof is added to the complex as well as a topographical landscape defined by each student. In some cases, this is where the project would end, but for this course a presentation document is created by the students to present their design to potential clients- being the teaching assistant for their lab section.

The students create a fictitious company and with their AutoCAD files and Revit files create a complete corporate presentation document in order to win construction of the proposed apartment complex. This project has been evolving over the last 3 years and the instructors have seen vast improvements in the presentation documents- see figure 2 for exterior rendering of final project. In construction, companies present proposals to clients all the time and the author discussed his proposed final project with industrial professionals with encouraging feedback. There is only 1 winner in industry and if the class was to mimic industry, only one student that receives the A or the bid to build the structure, but there is no way to justify that in education. So the grading of the final project is split

Figure 2, Exterior & Complex layout for BIM Final Project.
into 2 sections. First is for the construction document creation. This is where there is limited number of A’s, B’s and so on. The second part of grading is on actual CAD work of each student. Only the CAD files they created are graded and nobody gets penalized for group member’s inefficiencies. The ultimate goal is to get them working as a team and then create a construction proposal that closely resembles what industry currently does for clients. Team building is extremely important according to (LeFevre, 2007) as represented in figure 3, and his model of BIM common ground within the Construction Industry. It is this model that has helped create the final project in the Construction graphics course for Civil Engineering and Construction.

Through the entire semester, spatial visualization quizzes and sketches are given to the students to complete. The goal is to increase their visualization ability as well as think about complete orthographic, isometric, and perspective projection drawings- see figure 4. There are at least 4 different versions of spatial visualization problems during the semester. Each type of spatial visualization problem builds more and more visualization abilities within the student. Ultimately the goal of the class is a very thorough introduction to all the types of graphics they will encounter in industry while giving them a brief introduction to CAD, both 2D & BIM; all the while developing, testing, and improving their visualization skills.

Figure 3, Industrial Model of BIM

Figure 4, Spatial Visualization Examples

4 Conclusions

This course started out as a simple graphics introduction and blueprint reading course for Building Construction Technology students. The course has been evolving in a revolutionary area over several years. It is by no means perfect, but gives the students the most inclusive knowledge of projection drawings while increasing their spatial visualization skills. Traditionally created drawings using
drafting equipment was utilized initially, but with the introduction of computers and CAD; the course was modified quickly to incorporate technology. The CAD portion of the course has also been evolving over the last several years. Today’s current technologies as well as expert recommendations have quickly modified the course curriculum again. The final project was the result of a brainstorming session with multiple commercial construction companies and educational professionals.

The Construction Graphics for Civil Engineering and Construction course is giving the students a realistic view of what happens in the AEC industry. The course is usually for freshmen and sophomores, so the information they take from the course can be utilized in future courses they have in Civil Engineering or Construction Management. The AEC industry is in a constant mode of change and there is no one way to accomplish tasks. Each company the authors consult with agree that the way they do business and create graphics is changing and cannot be predicted as to what the future standards will entail. This course will strive to keep up with technology and give the students the knowledge they need to have a jump start for what industry has waiting for them.

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