2006-109: EMPLOYING 3-D SKETCHUP GRAPHIC MODELS FOR TEACHING CONSTRUCTION DRAWING LANGUAGE

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Employing 3-D *SketchUp* Graphic Models for Teaching Construction Drawing Language

Abstract

Students entering Construction Management have increasingly less experience in drafting or field construction. Historically students have taken high school courses in carpentry or mechanical drawing. From those experiences, they have acquired the beginning basic language of construction drawings through hands-on experience. However, today's students are not so prepared, and it is imperative that a new learning tool be employed to educate students to understand the language of construction and construction drawings.

This paper addresses the need for developing such a learning tool. Using the computer program *SketchUp*, a catalog of 3D manipulative computer models were created and incorporated into a variety of academic Construction Drawing and Analysis class exercises. This tool enabled students to manipulate, orbit, zoom in/out, and have selective viewing of construction components learning models. These activities allow students to dissect a building structure and develop an understanding how building components inter-relate. The analysis of comparative students using the models showed a positive direction in understanding construction and will be a basis for suggestions on how to implement, incorporate, and utilize *SketchUp* to develop basic language skills of Construction Management students.

Introduction

Students entering Construction Management have increasingly less experience in drafting or field construction. Historically students have taken high school courses in carpentry or mechanical drawing. From those experiences, they have acquired the beginning basic language of construction drawings through hands-on experience. However, today's students are not so prepared, and it is imperative that a new learning tool be employed to educate students to understand the language of construction and construction drawings.

When students are taught for the first time how to read and understand Construction Drawings, there is a noticeable lack of understanding three-dimensionality of the drawings. Working in a 2-D document, with its myriad of different line types and designations leaves many students lost in the adequate reading of the drawings. Students can be provided with static 3D drawings, isometric drawings, videos and photographs to assist in understanding building details. In addition, students may be allowed to visit construction sites to assist them in visualizing the construction components and systems. These processes, however, are minimal measures to assist in student learning. Because of this problem, the author has investigated different variations of representing the image to improve understanding of the construction process and details.

Previous applications of understanding construction drawings have used photographs and isometrics to help explain 3-dimensional applications.[1] Site visits and walk-throughs have also enabled students to visualize conditions in real-life instances. Both methods have been

successful in part, but were limited to specific buildings under construction which did not allow subsequent classes the same learning opportunities. Because of this shortcoming, another method of representing 3-dimensional environments was necessary.

A variety of web-based building environments have been created in the recent past to promote learning opportunities for students in architectural and construction educational settings. An example of historic buildings exists at the Great Buildings Collection which is billed as the "gateway to architecture around the world and across history documents a thousand buildings and hundreds of leading architects, with 3D models, photographic images and architectural drawings,".[6] This website allows students to view and manipulate massing models of historic extant and demolished buildings throughout the world. (See Fig. 1)

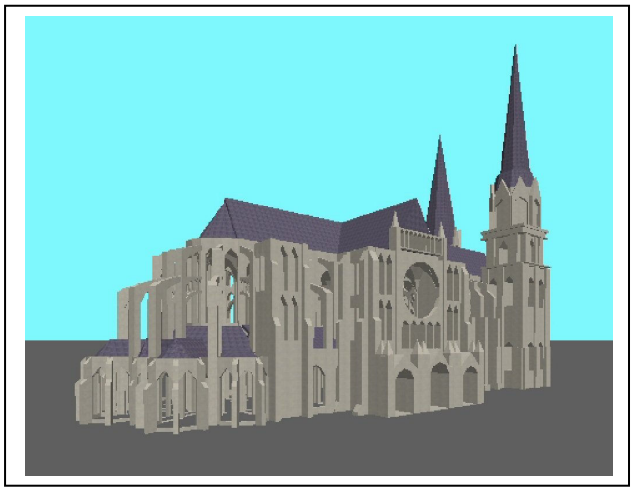

Figure 1 - Chartes Cathedral Massing Model
Great Buildings Collection

Other research in 3D modeling for architectural and construction management students has looked at a variety of modeling software are used in estimating, material takeoffs, and marketing visualizations,[3] while others have studied the shortcomings of 2D vs. 3D representations when evaluating construction document building assemblies.[5] In addition, virtual reality (VR) and 4D CAD modeling have been studied to allow students the opportunity of interactively generating a construction project process activity.[4]

Many of these projects required the learning of advanced CAD packages beyond those normally associated with current programs in construction management. Because of ACCE minimum requirements and university imposed minimum General Requirements at the author's university, advanced courses are not implemented, outside of independent study courses. Because of these limitations, it was determined that the author would investigate available design software that could be utilized initially by instructors, and then if applicable, be incorporated into future construction graphics CAD courses.

The program chosen for use in creating new 3D graphic images was the *SketchUp* computer program, developed by @Last Software.[1] *SketchUp* allows simple, yet dimensionally accurate,

graphic representations of a variety of forms and shapes for quick and easy 3D form creation and supports a creative exploration of 3D form, material and light.

SketchUp Image Development

During the Summer 2005, the author received a university sponsored Teaching Fellowship to create a collection of 3D construction plans, images and details of the building project utilized in the Architectural Plans and Analysis class taught in the author's Construction Management program. The *SketchUp* program was investigated and determined to be user friendly 3D imaging software that was ultimately employed to create the images.

The author met with all instructors of the class to determine the most relevant detail drawings that students would need to better understand the basic 3D aspect of construction. From that list, emphasis was placed on understanding 1) civil grading and utility placement, 2) building foundation placement and reinforcement, and 3) wall and roof construction.

In addition, mechanical & electrical details were developed for the program's MEP Systems class, since the same building documents were employed in both classes. Details in mechanical ductwork, HVAC units, and rooftop exhaust fans were created. These details allowed students to understand the 3D interrelationship of building systems in the construction process. Ultimately twelve (12) *SketchUp* models were created from the Architect's original building CAD drawings for use in the Architectural Plans and Analysis and MEP classes.

The *SketchUp* program enables students to manipulate, orbit around, zoom in/out, and turn layers off/on of the learning models. This ability allowed students to manipulate the construction of the building design from the excavated foundation to the completed roof system. By turning on layers, the details are electronically constructed. (See Fig. 2) The tools allowed students to manipulate the *SketchUp* model view by zooming in, orbiting about the particular component, and gain a better understanding of how the components interrelated.

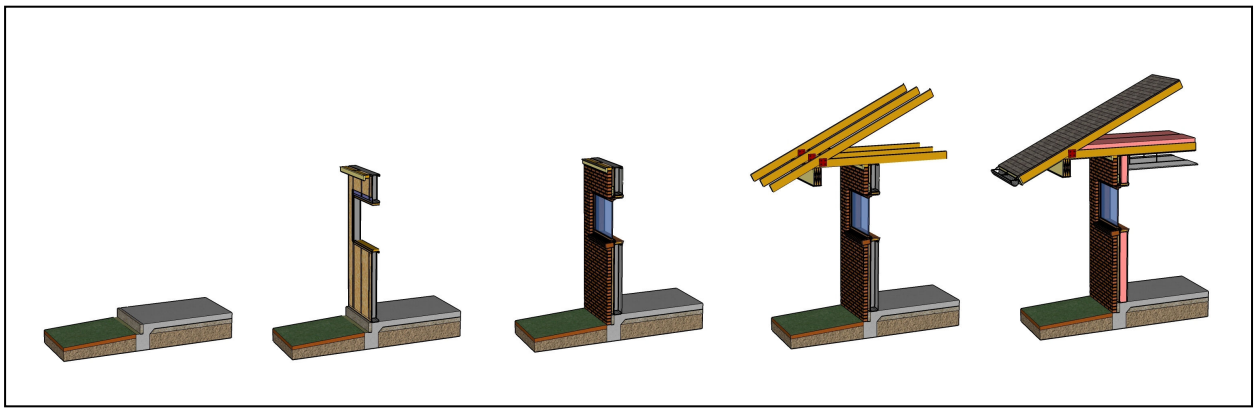

Figure 2 - *SketchUp* Models Layers

During the semester, students were encouraged to access all *SketchUp* images through the class *Blackboard*© site, and all college computer laboratories were provided with *SketchUp Viewer* software for student use. The *SketchUp Viewer* software is also available from @Last Software,

website free of cost. This program allowed students to view the construction of each building detail from the excavated foundation up to the finished roofing system. During the semester, specific homework assignments were given to students to employ these details in understanding the interrelationship of building components. The exercises allowed students to manipulate, orbit around, zoom in/out, and turn layers off/on on the models. In conjunction with the 2D details, students were questioned on how the building details are constructed. The exercises provided opportunities for the Instructor to determine if the students are able to 1) understand the functions available in *SketchUp Viewer*, 2) manipulate the models to determine the correct response, and 3) understand the construction interrelationship of building components and systems. Students were directed to employ both the 2D construction drawings as well as the *SketchUp* models to answer the questions. These exercises were created to formally impose the use of the *SketchUp* models.

During class presentations and exercises, the author utilized the images to reinforce the 2D drawings and to emphasize the inter-relationship of the building systems. In addition, alternative methods of construction were shown in the same format to show how other systems could have been employed by the designer. Based on 20+ years of design and construction experience, the author was able to draw on his knowledge of building systems to explain design differences that students have not had the opportunities to experience. Through the use of an electronic whiteboard, the author, an architect, drew revisions over the 3D models to represent possible alternatives.

An additional evaluative tool of the class was a "Class Team" model project. The project called for the "Class Team" to construct a physical model of a specific quadrant of the building, incorporating all building systems. Students were presented with an exercise that incorporated a variety of construction drawing plans and details and asked to compile the information so as to understand the building construction. Individual two person teams were assigned specific building systems (i.e.: foundation, exterior wall, exterior veneers, interior partitions, roof structure, etc.) and a two person Project Management team was responsible to "manage the construction" of the building model. The author specifically incorporated into the building model quadrant, three of the building *SketchUp* models to ascertain if students would employ them to assist in constructing the model systems. The results were mixed in the final outcome of the two Class Team projects (See Figs. 3 and 4).

Figure 3 - Term Model Section 004

Figure 4 - Term Model Section 001

Outcome of Research

In conjunction with homework and the "Class Team" model, to determine the effectiveness of the *SketchUp* models in learning construction systems and understanding of the 2D construction drawings by students, the author conducted a Student *SketchUp* Models Questionnaire at the conclusion of the semester. Two CMGT 3100 Architectural Plans and Analysis class sections participated in the use of the *SketchUp* models. As anticipated, results varied from each specific class based on the dynamics of the individuals involved. Utilizing a five point Likert scale, the results of the questionnaire were:

Question		**Section 001 (Mean)**		**Section 004 (Mean)**	
Did the *SketchUp* models of the existing building site and the completed building site assist you in understanding the project site conditions?		3.89		4.35	
Did the *SketchUp* models provide a more concise understanding of the construction drawings 2D details and the constructability of the details?		4.05		4.42	
Based on the use of the *SketchUp* details, are you better able to understand other 2D building details and plans?		3.85		4.64	
Were you able to manipulate the *SketchUp* models in such a fashion so as to understand the process of construction?		3.41		4.35	
Did you use the *SketchUp* models to understand the components of construction when you were building your Team Term Model?		3.29		3.13	
Do you believe that more *SketchUp* details should be added to the detail list for future classes?		3.00		2.93	
Do you think that the *SketchUp* software would be a useful tool to learn in CMGT 2800 Construction Graphics?		3.35		4.35	
YES/NO Did you employ the *SketchUp* details outside of class?		(Y) 43.7%	(N) 56.3%	(Y) 35.7%	(N) 64.3%

It was anticipated by the author that motivated students would be more likely to use the *SketchUp* models outside of the classroom setting. The percentages of use correlate that assumption. Section 004 was judged by the author to be the more proactive in their desire for learning. It was anticipated that a greater percentage of student would use the models since specific assignments were given to encourage their use. Additionally, the models did provide for

increased learning of 2D drawings when incorporated, either during in-class presentations or by students. Students did perceive the greater understanding of the construction details when using the *SketchUp* models.

The "Class Team" Model had the potential for a more complete understanding of the 3D construction of the building. Students, however, did not use the *SketchUp* models to their fullest capability. This became evident as students began constructing the physical 3D model components. The inability to understand the interconnection between roof and wall structure and the correlation between the light well and the ceiling became apparent. (See Figs. 5 and 6) Through the use of the *SketchUp* models, these connections would have been more easily understood.

Figure 5 - Model Light Well / Ceiling

Figure 6 - Building Light Well / Ceiling
Curtis Group Architects©

However, it should be noted that none of the CMGT students had ever constructed a model prior to this class. Therefore their final projects were still a success. The models presented the students with the need to comprehend the 3D representation of construction. They became acutely aware of dimensions, accuracy of measuring, and the correlation between differing scale plans and details. Students were required to determine if the documentation provided them with all the pertinent information, and impressed on them the need to search out answers within the drawings, and not stop when the answers were not easily found. The ability to understand 3D dimensionality from 2D drawings was apparent, and thus the model project became the most valuable learning component in this class.

This finding has influenced the author to use the *SketchUp* program in future Construction Graphics classes. The current class teaches graphic expression of construction and architectural elements through use of CAD and drafting techniques that include lettering, orthographic and isometric projection, descriptive geometry, construction document organization and preparation. The author believes that by having students create 3D models, physical or digital, the students will assimilate a better understanding of the 3D language of construction drawings. Students will use their own laptop program of *SketchUp* and thus not be limited to university CAD labs. It is anticipated that through the use of *SketchUp* students will develop a more defined understanding of 2D objects, and thus be better able to read, disseminate, and synthesize

information from construction drawings. Future research on this proposed method of learning will determine the effectiveness of the *SketchUp* program in 3D awareness by construction management students.

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