# Interactive 3D Visualization As A Tool For Construction Education

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*Abstract* - **Throughout the years, various teaching methods have been adopted to assist students to better understand building assemblies and construction details. Many current teaching techniques for explaining building assemblies use various mediums such as 2D drawings, isometric and perspective drawings, photographs of assemblies and also field trips to the construction jobsite. Such detail needs to be complemented with plans, elevations and sections. This is necessary because in any drawing only *2 dimensions* are visible. 3D CAD modeling addresses the third dimension that is not present in 2D CAD drawings, and allows better viewing, validating and understanding building components and their construction. This paper addresses the impact of using 3D in teaching and its advantages over current approaches. The paper describes a pilot study conducted with students from the Virginia Tech Architecture and Building Construction departments. The experiment investigated the advantages of 3D representation as compared to 2D drawings, in understanding construction assemblies and details. The paper also discusses the shortcomings of the traditional methods and compares the suitability of using 3D as a teaching aid. A new approach utilizing Pocket PCs and/or laptop computers via wireless connectivity, to allow students to access and view 3D models remotely, is briefly presented.**

*Index Terms* - Construction Education, 3D Modeling, Construction Details, Construction Assemblies, Handheld Computers, Wireless Technologies

## INTRODUCTION

Current teaching tools used in construction education are unable to sufficiently include complex details, realistic design and construction problems that could enhance learning. Many current teaching techniques rely on conventional instruments such as 2D CAD drawings (plan, isometric and perspective), photographs and site visits. These traditional teaching approaches have their own drawbacks that could lengthen students' learning curve. 2D drawings cannot address the issue of depth. Any assembly detail needs to be complemented with plans, elevations and sections. This is necessary because in any drawing only 2 dimensions are presented. Therefore, it is quite easy to miss out details. Components in a 2D drawing could be expressed as lines, but the depth of such components cannot be represented therefore the difficulty to understand the details increases. Almost all construction assemblies have many components interconnected and are of different types of materials. It is very difficult to represent and differentiate these details in 2D drawings.

Isometric, axonometric and perspective drawings address the issue of depth only to a degree. A few of the details are better represented but are limited to only 2 faces and the angles are fixed. Complicated assemblies still cannot be studied and fully understood using these representations. Color photographs and slides are limited to the view captured, which make them unsuitable as an effective approach. Site visits may not be readily accessible to students for various safety and regulation reasons. In addition, you may not be able to see what you need during the site visit because of progressing work schedule. The fact that once an assembly is completed, many of the key components are no longer visible hinders the learning experience. With this in mind, a study was initiated to identify and establish the shortcomings of existing techniques for teaching and exploring building construction components and assemblies. The depth aspect is the most serious drawback to the current techniques.

Interactive 3D modeling seems to be the next logical step in enhancing the current teaching techniques given that it addresses the third dimension that is missing in 2D views and drawings. Adding the third dimension to viewing an assembly gives it a unique position in space and clarifies many of the details associated with its components, including connectivity issues. Interactive 3D tools also allow manipulating the 3D view, which adds flexibility of viewing. Using these tools, the 3D model can be rotated around any axis, and panned or zoomed in any direction. Realistic rendering of the components representing the various materials is possible, which gives a "true depth" and "feel" of the model. Texture mapping and dynamic lighting can create a realistic simulation of the structure and enhance the 3D object. With 3D viewing tools, students are able to position and recognize the object with relation to others in the scene, enabling a better and more complete visualization and instigating an interactive learning process. It is even possible to mimic the sequence of construction. This enables better and complete visualization of the model, as compared to 2D drawings, since all 3dimensions

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are visible simultaneously allowing the students to make correlations between components.

Clayton et al (2002) pointed out the following issues:

• The often suggested idea that "students of architecture do not gain much practical knowledge in construction methods and management during their education."

• "Although students typically complete courses in construction methods, many studio projects lack any semblance of cost or project management and may indicate only a rudimentary attention to construction."

• "Because faculty members tend to concentrate research and teaching upon aesthetics, theory and history, students may complete their education lacking know-how in building technology and construction. This has also led to frequent criticism that recent graduates lack knowledge of construction."

Considering these issues, Clayton et al (2002) undertook a research study with the goal of:

• "Integrating construction into design education through computer methods that help to isolate construction issues and provide experience through simulation."

• "Testing the viability of 3D computer modeling and 4D CAD as a way to enhance learning about construction among design students."

Their approach was to integrate construction into design education and using computers to help explain construction issues and provide experience through simulation. The simulation incorporated 3D graphics for visual modeling, rendering and animation. Their proposal was to institute a design-build studio in schools of architecture. The educational objective of this has been to cultivate teamwork and impart the knowledge of construction. Clayton et al (2002) concluded that:

• "Our experiments demonstrate the viability of 3D modeling and construction simulation as a method of incorporating construction issues into studio courses."

• "The discipline of creating 3D models that are precisely sized to match actual dimensions helps students obtain an awareness of construction materials. The creation of assembly and construction in a more powerful way than does conventional 2D drafting."

• "Teaching with 3D CAD can increase construction content in architectural education. Our use of virtual construction appears to be a viable way to respond to industry demands for increased knowledge of construction among architecture school graduates."

Elsewhere, Haque (2002) investigated the usage of 3D model information to enhance learning. He argued: "Traditional lecture format teaching methods sometimes fall short of conveying complex analysis and design principles that need to be mastered in reinforced concrete design course. One of the methods of reducing this shortfall is to use simple animated virtual models, which demonstrate basic structural design concepts that can be used to enhance the students understanding. The interactive computer aided learning allows students to proceed at their own pace, motivated by a curiosity about "what happens" interactivity and "the need to know" the design/analysis principles."

Haque demonstrated that some of the visualization techniques used are Image visualization / Animation, Digital Image Manipulation, Interactive Design Animation (Java) and Walk-through Virtual Navigation. The author's view is if 3D objects can be presented on the web and can be interactively changed / navigated, it will be beneficial for the students' conceptual understanding on the domain topics. According to Haque, nothing can be more convincing to a student than being able to walk-through a virtual model of a transparent concrete beam with all the reinforcement details. With a walk-through, things can be discovered, added or corrected before the actual construction begins. A walk-through is an excellent way to show students the reinforcement details. In conclusion, Haque stated that various visualization techniques can be valuable aids not only in teaching design principles of reinforced concrete structures in the class room, but also effective self directed tools for open learning via the web. It is evident that these new technologies can be used to enhance the quality of education as compared to the current teaching methods employed everywhere.

This paper continues to explore the impact of using 3D technologies and its advantages over current teaching approaches utilizing 2D representation. The paper describes a pilot study conducted with students from the Virginia Tech Architecture and Building Construction departments as subjects. The pilot study investigated the advantages of 3D representation as compared to 2D drawings, in understanding construction assemblies and details. The paper discusses the shortcomings of the traditional methods and compares the suitability of using 3D as a teaching aid. The paper also presents a proposed method of utilizing handheld devices, such as Pocket PCs, via wireless connectivity, where students can access and view 3D models stored at a remotely located web server. We believe this will further assist teaching and shorten the students' learning curve.

## METHODOLOGY

Four types of assemblies where chosen for the experiment. 2D drawings for each assembly (plan, and elevations) were developed using AutoCAD. An example 2D drawing for one of the assemblies is depicted in Figure 1. The 2D drawings were imported in 3D Studio Viz to generate the corresponding 3D models. Figure 2 depicts the corresponding 3D model developed. All 3D models were saved as 3DS file format and exported into the Deep Exploration™ (Right Hemisphere, 2003), a 3D visualization software that allows viewing and real-time manipulation. The viewing of the 3D models was conducted using a desktop PC running Windows XP. Two types of displays were used; (1) a SVGA desktop monitor and (2) the Elumen's VisionStation (Elumens, 2003). Figure 3 illustrates the overall setup of the experiment.

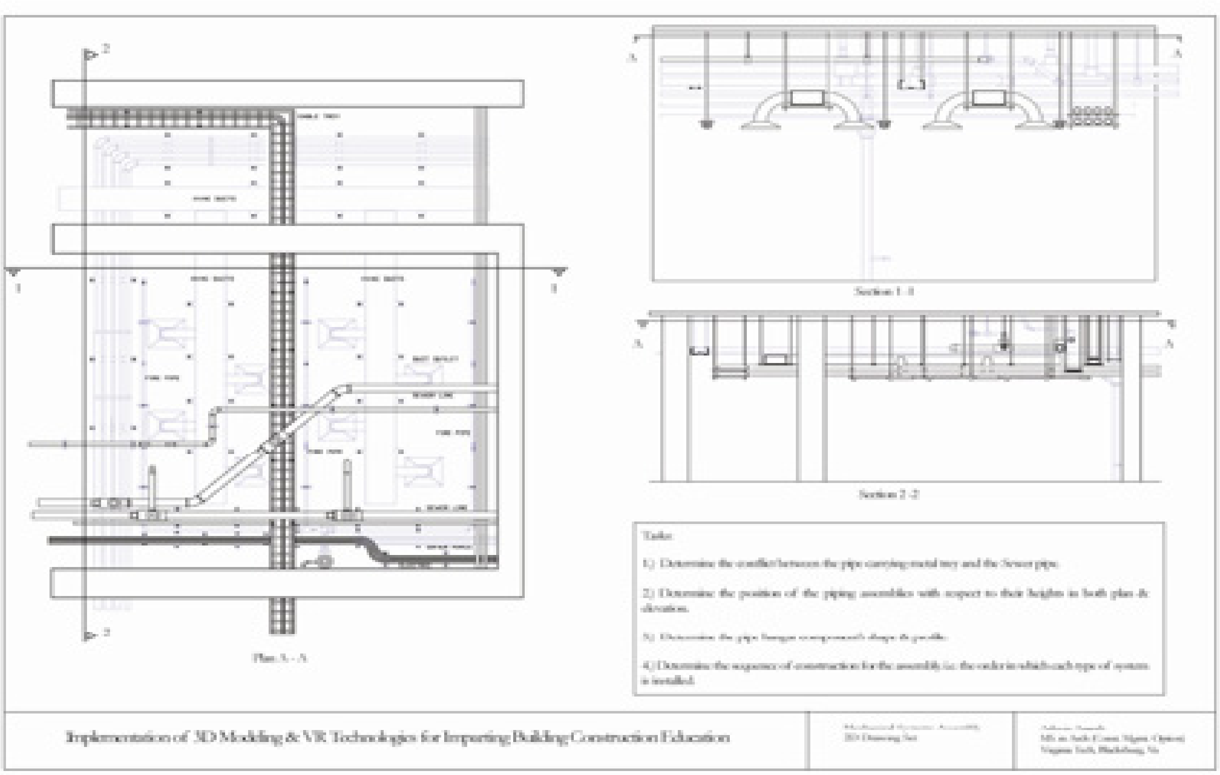


FIGURE 1: EXAMPLE 2D DRAWING (MECHANICAL ASSEMBLY DETAIL)

Each student was asked to review and analyze two different assemblies; one presented in 2D, and a different one in a 3D format. Students were also asked to perform specific tasks and identify specific details in each assembly. Students were then required to respond to a questionnaire to capture their comments and feedback. Varying the assemblies viewed in 2D versus 3D for each user allowed for unbiased results to be achieved.

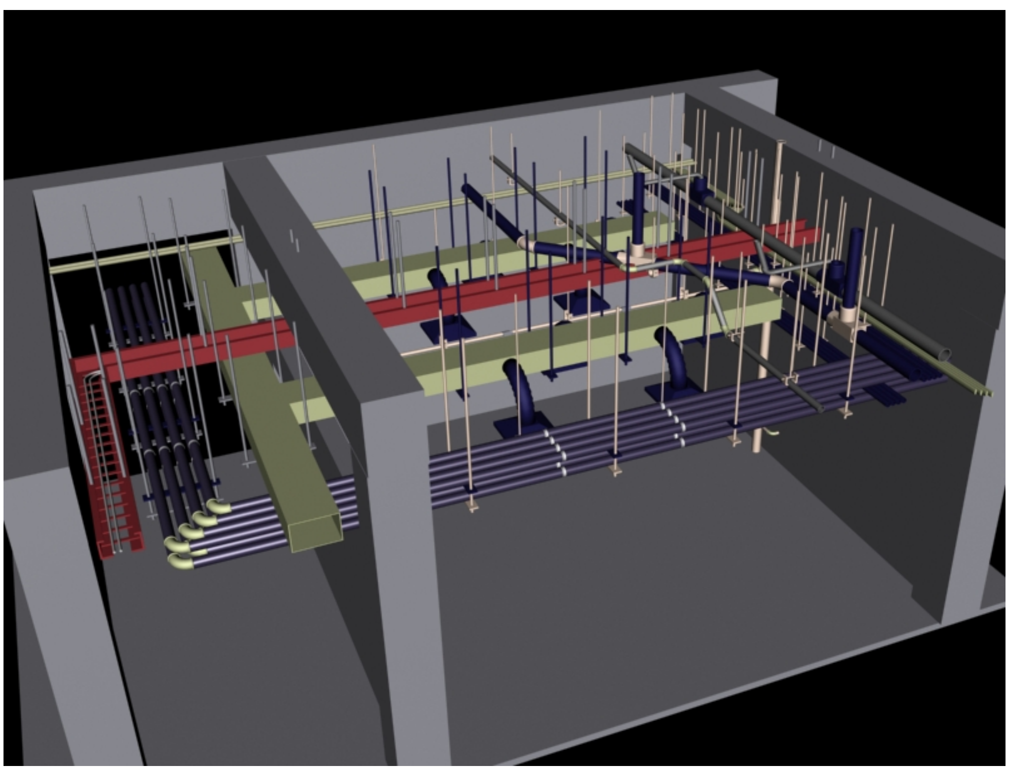

Figure 2: Example 3D Model Developed

Questionnaires

The main points considered in preparing the questionnaires were:

- The ease with which components can be identified in both 2D and 3D models.
- The ease with which components' shapes, profiles & general dimensions can be determined in both the 2D drawing sets and the 3D models.
- The ease with which connection details such as steel-to-steel, steel-to-concrete & masonry details can be determined in both 2D and 3D.
- The ease with which solutions for the tasks could be determined as listed in each of the construction assemblies in both 2D and 3D.
- The ease with which the sequence of construction can be determined in both 2D and 3D

A sample population of 25 students was selected from the Architecture and Building Construction programs.

The sample varied; there were undergraduate, masters and PhD students with background in architecture, arts & design, civil, and construction. Also more than 50% of the population was comprised of international students from Asia and Europe.

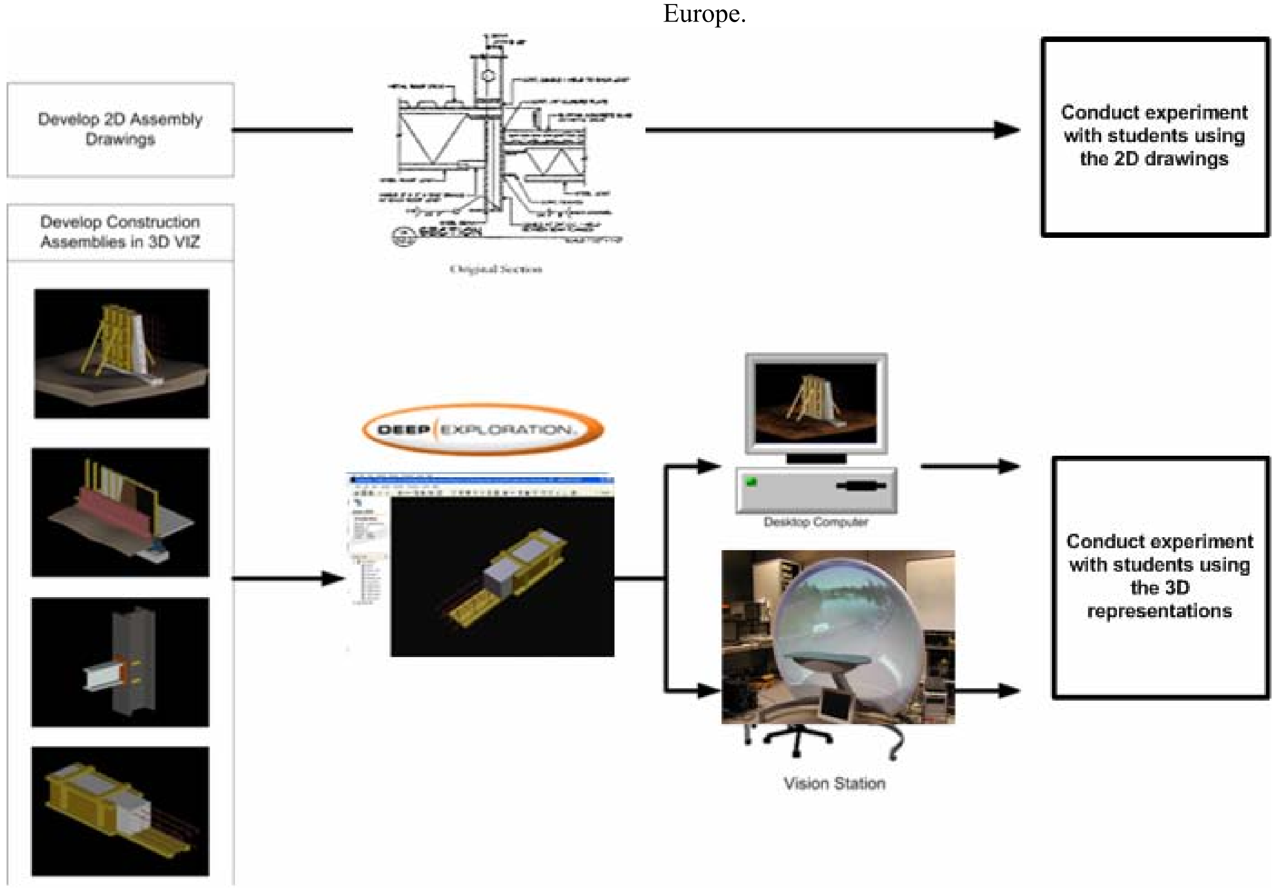


FIGURE 3: THE EXPERIMENT OVERALL SETUP

Such cultural and geographical variations in the population sample allowed for a diverse response, which may have added value to the results obtained.

Experiment

The time allocated for the experiment was approximately 20 minutes for each student. The experiment was divided into 2 sessions with 10 minutes allocated for each session. First, a student was given a set of 2D drawings and asked to perform the given tasks. At the end of the first session, the student was asked to complete a questionnaire. Next, a 3D model of a different assembly was displayed either on the desktop computer or the VisionStation. Instructions were given prior to the experiment to familiarize each student with the experiment setup. All the controls and functions were briefly explained to help students navigate around the model and perform the given set of tasks.

## RESULTS AND DISCUSSION

Each question was weighted on the lines of the Likert Scale from 1 to 5, with "Very Helpful" carrying 5 points and "Very Unhelpful" carrying 1 point. In the students' ability to identify the assemblies, the results indicate that it was easier for the students to identify the assemblies using the 3D models than the 2D drawing sets.

A similar comparison for identification of the assemblies' shapes and profiles was conducted. Students were able to identify the assemblies' shape and profile more easily using the 3D models than the 2D drawing sets. In the 3D models, the existence of the 3rd dimension helped students to understand better. Although all the supporting drawings were provided in terms of plans, sections and elevations, students were not able to correlate and position one drawing with the other.

In the determination of connection details (e.g. steel-to-steel; steel-to-concrete etc.), students have a clearer understanding when using the 3D models. This is because the 3D models were able to provide all the required details in one single representation.

A simple animation feature in the 3D viewing application helped students to trace the sequence of construction by clicking ‘on’ and ‘off’ on the graphical components of the 3D model in the order of their construction. This task was much harder to achieve for assemblies viewed in 2D format. Most students agreed that the 3D models were superior to 2D drawings in understanding the construction sequence of the components.

## PROPOSED FRAMEWORK FOR 3D VISUALIZATION IN THE CLASSROOM

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The ability to acquire and visualize construction assemblies and components as they are needed can increase the students’ level of and improve their learning curve as compared to current teaching techniques.

Previous research effort at Virginia Tech by Shiratuddin et al (2002) has investigated the suitability of the Pocket PC platform to visualize 3D models of construction assemblies and components.

The study explored several applications running on the Pocket PC and laptop computers that allow viewing 3D model files saved in the Virtual Reality Modeling Language (VRML) format. The proposed framework to view 3D models in the classroom builds on this research work utilizes wireless technology to view construction assemblies, stored on a remote server, using a mobile device, such as a Pocket PC or a laptop.

Figure 4 shows the proposed framework with two connectivity options. The 3D models used in the study and created using Autodesk 3DViz were exported to a VRML file format. The VRML model file was then transferred and stored on a PC based server that can either be a File Transfer Protocol (FTP) or web server. An FTP server is a protocol that allows sharing files with other computers on the network or making files available to people on the Internet. A FTP software client (e.g. WS_FTP, CuteFTP) is usually used to establish the connection to the FTP server.

Alternatively, a web server could be used to transfer files to any client locality using the Transfer Control Protocol/Internet Protocol (TCP/IP). This protocol allows for routing information packets and device to device communications. A web page is usually setup with the information to be shared. An internet browser (e.g. Microsoft Internet Explorer, Netscape Communicator) is required to access the pages and view the information.

In this experiment, two methods were tested for data transfer, using a wireless network connection, to acquire and view the VRML model on the PocketPC and laptop computer.

Option 1: A Stand-Alone FTP Server

An FTP server was set up on a desktop PC using the Serv-U software. The VRML models created were stored on the stand alone FTP server. An anonymous account was created to allow students to access the FTP server.

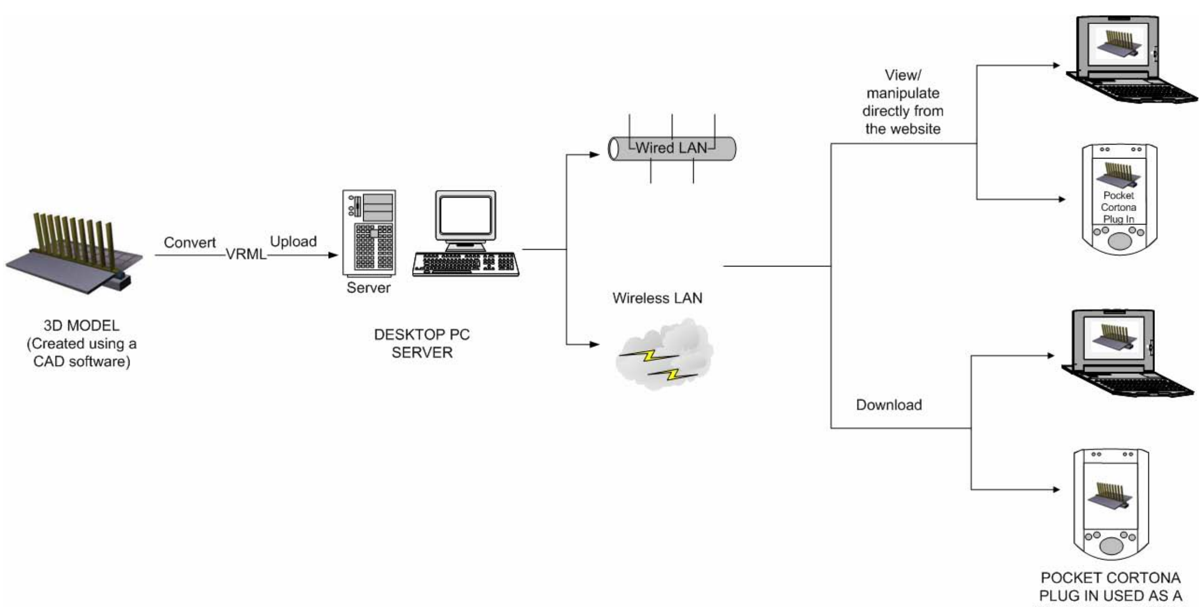


FIGURE 4: PROPOSED FRAMEWORK FOR WIRELESS 3D VISUALIZATION IN THE CLASSROOM USING THE POCKET PC

The Ruksun Scotty FTP client software (Ruksun, 2004) was used on the PocketPC to access the FTP server. Once a connection was established between the two devices, the VRML model files were then transferred across the wireless connection on to the PocketPC. At the time of writing Pocket Cortona (Parallel Graphics, 2004) is the only 3D VRML file viewer software available for the Pocket PC. It allows viewing and manipulating VRML files. We loaded the 3D models into Pocket Cortona and tested its functionality. For smaller to medium sized models the loading process was somewhat faster than larger models. The navigation through the 3D model however was still slow and cumbersome. It is seen that the computing power of the Pocket PC can be improved to support a smoother movement to view the 3D models using Pocket Cortona.

Option 2: A web-server

The models reside on a desktop PC web server. The web server used in this experiment came with Windows XP. A web site was setup to accommodate the VRML models. A hyperlink to the VRML models was created within the web page hence allowing students to click on it to view them in Pocket Cortona. The web page can be accessed wirelessly through the WWW. Once connected to the web site, students will be able to download and view the models on the Pocket PC using Pocket Cortona. Many academic institutions have started to offer wireless connection. With such offering, a wireless LAN could easily be setup using a wireless access point that will allow students to connect their laptop or Pocket PC to any websites.

## CONCLUSIONS

With positive results obtained from the study, it can be concluded and recommended that the 3D technologies can be adopted and used to enhance building construction education without significant investment in manpower or even computer systems, and yet able to achieve a more interactive learning environment. This approach may not only be useful for institutional teaching and learning but also to various agencies involved in any construction project.

A minor setback (that will diminish as more construction assemblies and components are modeled in 3D) is the initial time required to develop these assemblies in 3D and tailor them to a course curriculum. Once an established database of 3D models is developed, less effort will be needed to adapt and utilize them for various purposes.

Some of the important considerations in this study were not to develop high technology, complex and expensive computer intensive solutions, but rather to select and use any widely available off-the-shelf software (with little or no modifications required) that is capable of running on any standard PCs. The central idea is this method can be adopted without any difficulties by the academic institutions and use it as a tool to create a value added education for the students.

Although it is accepted that 3D can provide better visualization than 2D, the specific advantages need to be identified. The methodology to use these tools needs to be developed and evaluated to see the level of effectiveness and usefulness rather than just proclaiming that 3D is better than 2D.

Obviously, one of the most important aspects of the study is the students' review & feedback. As they will be the end-users of 3D technology, it is important to review their suggestions and feedback for development and improvement for future study. Many students gave a positive attitude and displayed interest to use the 3D technologies in learning. A few of them mentioned that it could be an interactive education tool in classroom sessions.

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