Using Stereoscopic Visualization to Support and Facilitate Student Spatial Skills in Construction Education

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To perform a detailed quantity takeoff for a building project, experience and judgment are required. Hence, it may be difficult for students to learn quantity takeoffs because of this. Typically in performing quantity takeoff, a keen understanding of geometry along with a plan reading ability and fundamental mathematics knowledge is required. Without well-developed spatial skills, construction drawings become abstract, not tangible. The importance of using visualization tools is well recognized by both academia and industry today. In many construction projects, 3D tools are used to effectively communicate with project participants. This paper reports an exploratory effort to measure the potential effect of stereoscopic visualization on student's educational experience in an entry-level core class. The main objective of this study is to investigate if this type of visualization can be used to support and facilitate student spatial skills in construction engineering and management education. For this, the potential impact of stereoscopic images is gauged in terms of students' understanding level of course materials. The findings of this exploratory study can be used to direct future research on a visual approach to construction engineering and management education.

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Background

Quantity takeoff is one of the most critical subjects in construction engineering and management (CEM) education. The quantity of material in a building project can be determined from two-dimensional (2D) drawings. To perform a detailed quantity takeoff, students in a CEM program must review a set of drawings, create three-dimensional (3D) mental images of the building, and calculate the quantity of material. Therefore, construction drawings are a fundamental instrument to perform quantity takeoff. However, students have difficulty in building 3D mental models of object configuration from 2D design information on several sheets representing different perspectives such as plan, elevation, and section views [1].

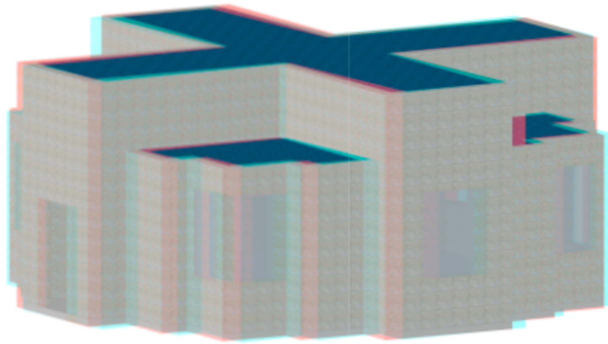
With no or little field experience, students struggle in interpreting 2D drawings, which results in difficulty learning core course contents. To cope with this issue, CEM programs have at least one course to teach students how to systematically relate multiple orthographic 2D views to a corresponding 3D model. Nevertheless, students without a proper level of spatial skills face challenges and spend a large amount of time in understanding 2D drawing information. In this study, spatial skills can be best defined as "the ability to present the spatial world internally in your mind" [2]. The National Science Board, in 2010, described spatial skills as one of the most important elements of science, technology, engineering, and mathematics (STEM) education [3]. Critical features of spatial skills in CEM education include the ability to build mental models of building components and materials from drawings [4].

Strong spatial ability is required to understand details of the finished structure and perform construction work. Visualization tools have served as instructional scaffolding in learning and instruction [5]. Students easily understand complex details of building elements through visual information process, in which they perceive, assimilate, interpret, store, and retrieve information [6]. Thus, it is extremely important to use visualization in order to support and facilitate student spatial skills in CEM education.

Spatial skills directly affect students' perceptions and performance on CM core courses. Several studies [7, 8] show that students with a high level of spatial ability can interpret drawings much faster and more accurately than those with a low level of spatial ability. This indicates that a student's level of spatial skills relates to how well the student can create and manipulate 3D mental models from 2D drawings. Fortunately, these skills can be enhanced by practice or some types of interventions [9, 10, 11, 12]. This paper reports an exploratory effort to examine the potential effect of stereoscopic visualization on student's educational experience in an entry-level core class.

Method

For this study, stereoscopic images were created to develop and facilitate student spatial skills in a CEM core course. Figure 1 shows a stereoscopic image of the building model used for this study.



Note: This image works well with a cyan-red stereo glass.

Figure 1. Stereoscopic Image

In this study, students' performance was measured during two phases, alternating between phases with an intervention. This measure was collected several times during each phase of the study to ensure its stability and consistency. It was used to represent the level of students' spatial skills.

Figure 2. Pilot Study Design

As shown in Figure 2, phase A indicates the baseline phase where no intervention was applied, and phase B is the intervention phase. The students were tested before the introduction of the intervention and then again during the first week after the withdrawal of the intervention.

Twenty-three undergraduate students in an entry-level CEM core class participated in this pilot study. Twenty participants were males and three participants were females. They were freshmen (N=5), sophomore (N=10), juniors (N=6), and seniors (N=2). This study began by collecting several measures of students' performance to establish the baseline (phase A). Then, the pretest was given to the students before the intervention was introduced. During the intervention (phase B), performance was measured several times from the same group of students. The intervention lasted three weeks and involved various activities in class and at home. The intervention was later withdrawn and students' performance was assessed again from the posttest.

As aforementioned, the pretest and the posttest were conducted from one group of students. All participants in the group were required to take both the pretest and posttest. Scores on each test ranged from 0 to 10 points. The two tests were different but dealt with the same content of interpreting construction drawings and determining material quantities. The results of the pretest (without the intervention) and the posttest (with the intervention) were compared to determine if the intervention was effective.

A *t*-test for paired samples was used to measure the effect of the stereoscopic images by comparing the posttest and the pretest scores. The *t*-value was used to assess whether there was a significant difference in the mean scores of the pretest and the posttest.

For this pilot study, the null hypothesis (H_0) is:

> *Hypothesis* (H_0): Δ *Mean =0* $\rightarrow$ *Mean* $_{POST}$ - *Mean* $_{PRE}$ *= 0*, which indicates the means of the pretest and posttest are statistically equal regardless of the intervention.

This null hypothesis can be rejected if there is a statistically significant difference between the two means. Therefore, the alternative hypothesis (H_A) is:

> *Hypothesis* (H_A): *Mean* $_{POST}$ > *Mean* $_{PRE}$, which indicates there is a significant difference between the means of the pretest and the posttest.

If students' performance improved from the pre-test to the post-test, then the null hypothesis can be rejected and it can be speculated that this was caused by the intervention.

Results

The students' scores of the pretest and the posttest were collected and analyzed to identify the effect of the independent variable (i.e., stereoscopic visual images) using a *t*-test. Table 1 shows the results of the t-test with the students' scores of the pretest and the posttest. From this data, it appears that the use of stereoscopic visual images is effective. As shown in Table 1, the mean of the posttest (6.00) is greater than the one of the pretest (3.30).

The obtained *t* value of 6.16 exceeds the critical values under p=.01, which is 2.51 (refer to Table 1). Therefore, the null hypothesis (H_0) described above was rejected at the $p<.01$ in favor of the alternative hypothesis (H_A). The chance that these results were obtained purely by chance is less than 1%.

According to this data analysis, the stereoscopic visual images were effective in improving the students' capability of interpreting construction drawings and determining material quantities.

Table 1. *t*-Test: Paired Two Sample for Means

	Variable 1	*Variable 2*
Mean	6.00	3.30
Variance	2.82	7.86
df	22	
t Stat	6.16	
P(T<=*t*) one-tail	0.00	
t Critical one-tail	2.51	

Note: 'Variable 1' and 'Variable 2' refer to the posttest and the pretest, respectively.

Conclusions/Implications

Spatial ability is a unique type of intelligence for mentally organizing, understanding, and visualizing spatial relations among objects. This ability has been recognized as a critical skill in the STEM fields of study, including CEM education. Of course, the level of spatial skills varies from individual to individual. However, this skills can be enhanced by practice or training. With the advance of computer technology, computer graphics definitely helps to illustrate complex details of building elements in CEM education. In this exploratory study, the potential impact of stereoscopic visualization is gauged in terms of students' understanding level of course materials. The findings of this study may be a stepping stone to future research on a visual approach to learning and instruction in CEM education.

There is a common belief that people learn best if information is presented visually in the most concrete and realistic manner. A realistic 3D image, without a doubt, is better than 2D drawings at conveying information. Over the last decade, there has been a large momentum for visual communication in the construction industry. Building Information Modeling (BIM) is widely used to visualize building components of the project and facilitate effective communications between project participants. However, it is not possible to use 3D models for all construction activities. Construction professionals must possess a proper level of spatial skills to perform construction works. Therefore, to create learning environments conducive to CEM education, it is necessary to use visualization tools such as stereoscopic images or 3D models in order to support and facilitate student spatial skills.

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