Learning Fundamentals of Building Construction Using 3D Visualization

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Despite our current computing age, many students prior to college have limited experiences using technology in instructional settings or in academically productive ways. Compounded by varying academic standards, the computing ability of high school students entering construction management programs vary greatly. This study investigates the impact of computer assisted instruction on learning effectiveness in CAD courses which are integral to construction management curricula. These courses require learners to understand and know the basics of construction processes as well as use state-of-the-art software to explore building construction. Computer assisted instruction enables learners to grasp complex concepts using interactive video tutorials to reduce student frustrations resulting from minimal computing experiences and by assisting students beyond the limited hours of the classroom. To quantify the effect of computer assisted instruction, two student groups were exposed to 1) traditional classroom lecture and laboratory work in the classroom and 2) traditional classroom lectures using online video tutorials. After engaging these learning processes, the students were surveyed and evaluated regarding the students' understanding of building construction using computer visualization software. Data show normalization of the overall classroom performance with no negative effect on overall student performance when using video tutorials as compared to traditional laboratory methods. Most important, this modified teaching method provides high-quality foundational knowledge in building construction simulation which is applied throughout the academic experience of students.

Keywords: Construction; Visualization, Computer Assisted Learning

Introduction

Within academia visual tools in addition to written or spoken information are all required for comprehension. Thus, teachers now incorporate varying teaching styles within their traditional instructional methods to improve teaching effectiveness and overall student performance. From this stance, visual analysis of building data ensures comprehension of construction document information. When considering our current technological revolution, however, the computing ability of high school students entering construction management programs varies greatly as a result of varying academic standards (Abdulrasool, et al., 2007).

Specific computer visual analysis techniques include digital prototyping (*The Economist,* 1994) (Porter, 1994) and Virtual Reality Modeling Language (VRML) (Campbell, 2000). Digital prototyping has been proven successful in manufacturing of precise aircraft components and in creating and testing variations in engine design. VRML, a tool that provides interactive navigation of three-dimensional information, has been explored on an experimental basis to understand the built environment before construction. In all cases, three-dimensional models are requisite to computer aided processes and have revealed the ability to significantly aid the construction of buildings throughout the construction process (Coles & Reinschmidt, 1994) (Sylvester & Pilgrim, 2002) (Back, Maxwell & Isidore, 2000). Consequently, we now explore building construction using digital standards such as building information modeling (BIM). It is when competencies of visual analysis become routine that digital models will transform the construction industry (Holness, 2008) (McGraw Hill Construction, 2009).

Teaching Philosophy

Within the course analyzed in this study, teaching not only rewards exemplary students for their performance, but also helps others to excel and grow their fundamental understanding of building construction. This approach is achieved first by teaching increasingly complex visualization concepts and skills and secondly by applying these concepts to virtually construct an existing building. This virtual construction process stimulates new ideas that restructure the students' world view of fundamental constructs which occur in the built environment. Ultimately, students learn in multiple contexts, first as sequential learners, then as sensing and intuitive learners.

Teaching computer software is a synchronous activity of repetitive tasks. However, when conducting laboratory activities within limited classroom hours, students experience much difficulty, and consequently experience great frustration. Addressing this problem, video tutorials were developed to improve student performance using an asynchronous learning environment that allows them to synthesize classroom demonstrations at different times and at different locations. The targeted course teaches an introduction to construction and fundamentals of graphic expression using computers to beginning students and allows students to examine complex software demonstrations at their own pace, facilitating improved student learning. At the end of this course students are able to engage methods of construction and interpret construction documentation using state-of-the-art computing software.

Student Performance in Web- Based Education

Numerous studies have been conducted with results that show significant improvement, as well as no significant improvement in student learning within online courses. In the first case, Alavi (1994) found that overall student performance within collaborative environments were significantly higher than student performance within traditional in-class sessions. Likewise, Hartman, Dziuban, and Moskal (2000) found similar results when evaluating media enhanced courses. However, contrary to previous findings, numerous studies have been conducted with results that show no significant differences in student performance (Hiltz 1994) (Royse, 1999) (Borthick and Jones, 2000) (Piccoli et al, 2001). From this stance, this study uses an online course supplement and provides new insight into technology assisted learning.

Research Methods

To assess the effectiveness of each digital course supplements on student performance, a longitudinal study was conducted to examine student performance over a two year period using 1) a descriptive analysis to investigate overall course performance and 2) a univariate analysis of variance (ANOVA) to test for significant differences in student performance within select knowledge areas. Student performance during academic year 2007 – 2008 used traditional in-class teaching methods and is referred to as the control group. Student performance during academic year 2008 – 2009 used an online video course supplement and is referred to as the experimental group. In addition to the above analyses, a survey was used evaluate the impact of the online course augmentation on student satisfaction.

Specifically, the descriptive analysis investigated changes in the final course grade for the control and experimental populations comparing Fall 2007 and 2008, Spring 2008 and 2009, and the averaged total results for the Control and Experimental groups. The ANOVA tested for significantly different treatment means in three knowledge areas including 1) Homework, 3) Midterm and 3) Final Exam. The final project discussed in the appendix is not analyzed in this study due to its qualitative nature. Overall, this study hypothesizes that rigor and student accountability can be increase with no significance difference in student performance when using traditional in-class technology instruction or online assisted instruction using video tutorials.

Case Study

The select course is an introductory construction class that teaches design vocabulary, elements of visual organization and the fundamentals and systems of graphic expression. Students are introduced to operational procedures and usage of CAD programs that exist in construction and architecture. When completing this course,

students are able to 1) demonstrate their understanding construction documentation methods, 2) demonstrate their understanding of ethical construction practices, 3) engage principles of leadership within a team environment, and 4) utilize CAD software to analyze buildings and their systems.

Online and web conferencing programs are integral parts of this course and are used to supplement face-to-face class sessions to maintain continuity of instruction throughout the semester. The online blackboard supplement for this course includes prerecorded lectures, lab assignments, class notes, official grades, and other pertinent information. Centra conferencing software provides a virtual classroom that enables faculty and students to attend class from anywhere they have access to an Internet connection. Overall, three instruments are given to assess the course. They are 1) in-class blackboard exams, 2) homework, and a 3) final project. This study analyses student performance on two in-class exams and homework.
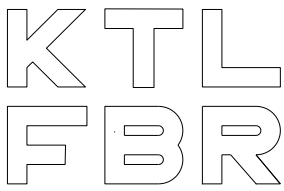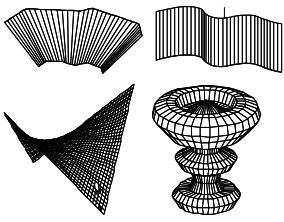
Online Video Course Supplement

Online video course supplements were implemented within the course Foundations of Construction which comprises plan reading, computer modeling, and systems analysis. Students experienced five (5) content modules each containing one interactive video tutorial created using Camtasia software (Table 1). Over a period of ten weeks, the video tutorials were sequentially accessed and required assessment of each concept module before students were allowed to advance within the course. For the remaining five weeks of the course, students executed a virtual construction using learned visualization concepts and skills.

To assess student satisfaction and aid in the development and implementation of the course supplement, a Likert scale survey was given at the end of each content module. In total, five surveys were administered. Students anonymously responded to questions using a multi-item scale that measured the extent to which students agree or disagree with a specific question. Each survey presented five answer fields with a scale of 1 to 5, whereas 1=strongly agree, 2=agree, 3=neither agree nor disagree, 4=disagree, 5=strongly disagree. The mean for each response was computed and averaged across subjects for all tutorials. This comparison examines student ratings regarding tutorial effectiveness and student understanding.

Table 1

Content Modules for Homework Assignments

| Activity	Outcome	Description
ABC Letters		This exercise teaches students the fundamentals of drafting using coordinate data entry, both absolute and relative. The objective of this exercise it to teach accurate data input using familiar elements.
Surfaces		This exercise teaches students to create primitive 3D elements such as spheres, boxes, wedge, etc. and special surfaces using Rulesurf, Edgesurf, Tabsurf, and Revsurf. The objective of this exercise is to familiarize the students with basic 3D commands and advance surface commands used to develop complex objects.

ABC Block
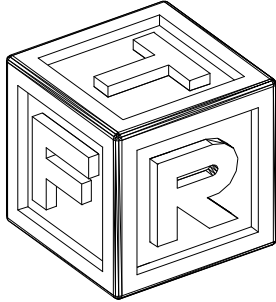
This exercise teaches students to define work planes, draw within work-plane, and assemble a 3D element. The objective of this exercise is to teach students to navigate, construct, and assemble elements within a 3D environment.

Terrain
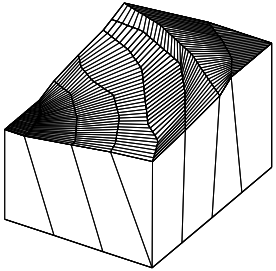
This project teaches students to interpret topographical drawings and to develop a three dimensional drawing of the resultant terrain. The objective of this exercise is to teach students spatial dimensions of 2D contour drawings and how buildings interact with the site.

Pergola
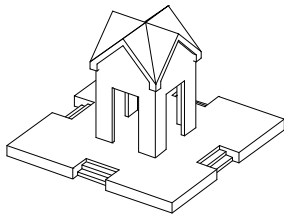
This project teaches students to plan and construct a 3D model of a pergola. The objective of this exercise it to introduce students to modeling techniques directly related to building elements.

Analysis of Results

Added to the curriculum in 2004, this course was created in response to the integration of technology within the construction industry and to help students understand the fundamentals of construction. In the traditional course, instruction was dependent upon in-class demonstrations of software which lead to more training than pedagogical inquiry. That is, more time was being spent on the demonstration of the software, rather than as a medium as a form of inquiry into building construction. Likewise, prior to the course modification, student learning of the software was the responsibility of the professor. After implementation of the video tutorials, students became accountable for learning the technology and software functionality both in class and independently.

Online Video Course Supplements

Using Camtasia software, video tutorials were recorded using Windows Media Video 7 Codec and Windows Media Audio 9 audio codec, encoded at a bitrate of 291Kbps with a frame rate of 10 frames per second. The video resolution was set to 1024 x 768 for all recordings. When necessary, files were segmented to ensure download and playback efficiency. The average file size for all supplements is 8.762 megabits with a total file memory of 166.483 megabits; the total playback time was 1.5 hours.

When analyzing survey data on student satisfaction to the course argumentation, the results show a positive overall student satisfaction when using online video course supplements. Specifically, over 70% of all students agree or strongly agreed that the video supplements had clear grading criteria and objectives that help them learn and understand course material beyond the classroom (Table 2).

Table 2

Summary of survey results for CAD assessments

Category	Clear Grading Criteria	Tested on Objectives	Help to Learn	Contributed to Understanding	Emphasized Material	Aided Beyond Classroom
Strongly Agree	31%	33%	56%	54%	35%	55%
Agree	42%	55%	28%	31%	53%	32%
Neutral	13%	9%	10%	10%	11%	8%
Disagree	9%	1%	1%	1%	1%	1%
Strongly Disagree	0%	1%	0%	0%	0%	0%
Not Applicable	5%	0%	4%	4%	0%	4%
Unanswered	1%	1%	1%	0%	0%	0%

Descriptive Analysis of Overall Course Performance

Figure 1 shows the overall course performance (course grade) by common semester and by year. The dashed line represent the performance of the control group and the solid line represents the experimental group. Excellent, above average, average, below average and poor refer to grades "A", "B", "C", "D", and "F" respectively.

(a)

(b)
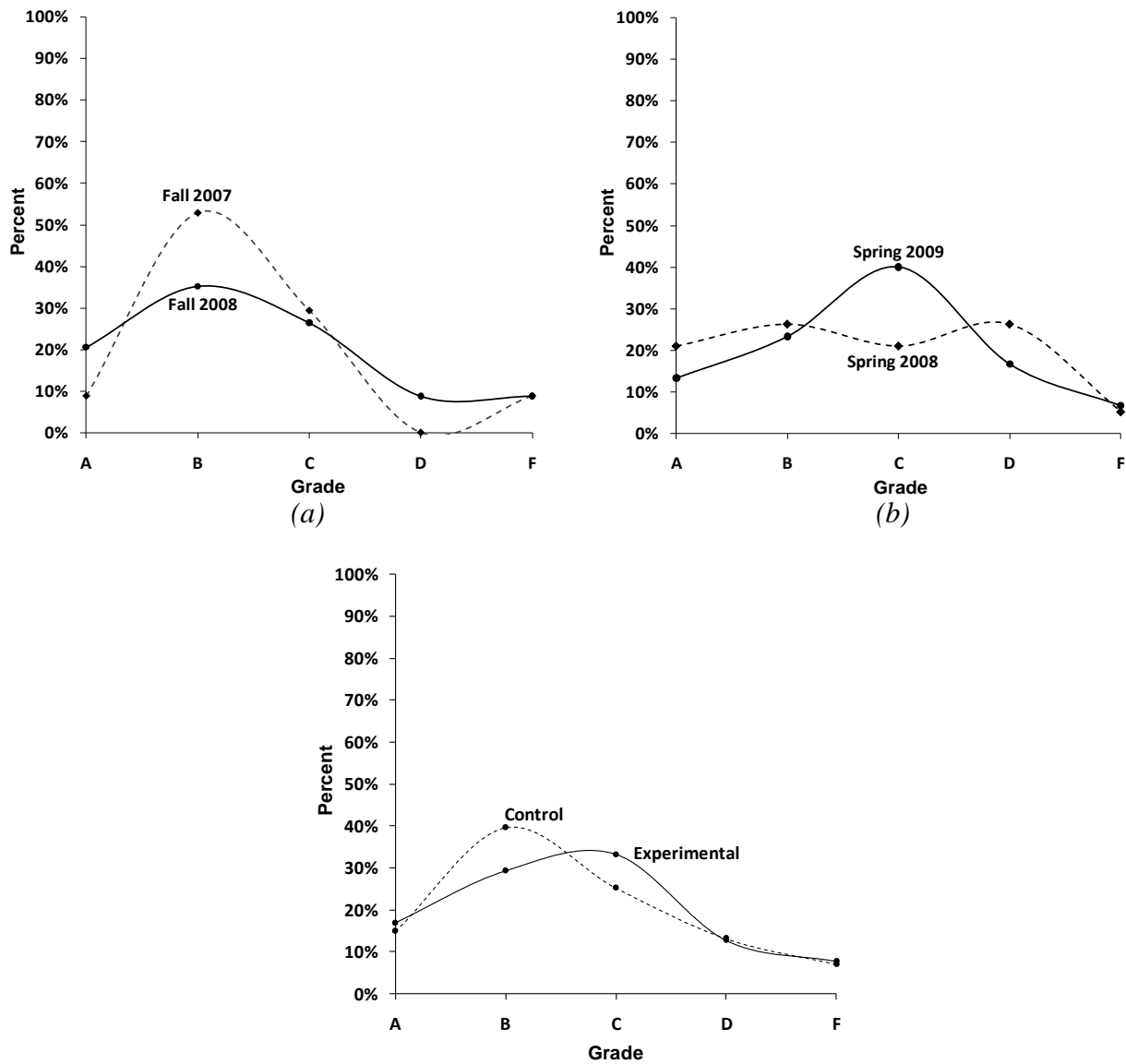
(c)

Figure 1. Analysis of student performance by overall course grade

For Fall semesters, Figure 1a shows that the experimental population of above average students reduced significantly. It is noted that the grade distribution remained skewed at the above average level. When comparing Spring semesters, Figure 1b shows that below average students were able to improve their overall course performance, while the population of above average and excellent students reduced accordingly. This comparison of Spring semesters show that the course augmentation normalized student performance. When comparing the total control population to the total experimental population, the number of above average students reduced while the number of average performing students increased. These changes are attributed to increased rigor of the course and increased individual accountability for homework activities.

Univariate Analysis of Variance

When analyzing the select knowledge areas, the ANOVA shows no significant difference in student performance for homework, midterm, or final grades. A linear correlation exists in student performance for similar semesters while high levels of interaction exist between Fall and Spring semesters (Table 3, Table 4, and Table 5). As hypothesized, the course augmentation was proven to have no negative effect on student performance.

Table 3

Tests of Between-Subjects Effects (Homework)

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	95.657[a]	3	31.886	1.001	.395
Intercept	70297.486	1	70297.486	2206.267	.000
Semester	38.736	1	38.736	1.216	.272
Group	23.505	1	23.505	.738	.392
Semester * Group	5.415	1	5.415	.170	.681
Error	4365.181	137	31.863		
Total	88070.703	141			
Corrected Total	4460.838	140			

[a] R Squared = .021 (Adjusted R Squared = .000)

Table 4

Tests of Between-Subjects Effects (Midterm)

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	68.439[a]	3	22.813	4.369	.006
Intercept	21517.188	1	21517.188	4120.783	.000
Semester	6.475	1	6.475	1.240	.267
Group	4.332	1	4.332	.830	.364
Semester * Group	32.229	1	32.229	6.172	.014
Error	715.363	137	5.222		
Total	28057.000	141			
Corrected Total	783.801	140			

Table 5

Tests of Between-Subjects Effects (Final)

Source	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	36.993[a]	3	12.331	2.076	.106
Intercept	28130.466	1	28130.466	4735.669	.000
Semester	7.186	1	7.186	1.210	.273
Group	3.954	1	3.954	.666	.416
Semester * Group	20.755	1	20.755	3.494	.064
Error	813.797	137	5.940		
Total	35787.609	141			
Corrected Total	850.790	140			

Conclusions

While the students' overall performance in the class was expected to increased, student performance instead normalized with no significant difference in student performance and increased student satisfaction. While developmental laboratory experiences were replaced with video tutorials regarding program's functionality, the course rigor was increased and overall quality of the classroom environment and student work was improved. The instructor now administers an in-class CAD exam for each video tutorial to verify independent student learning, eliminating external bias. New data indicate a significant increase in student performance on homework activities. Most importantly, the distribution of student performance remains normal with fluctuations in the number of excellent and failing student.

Future Work

To complete the course discussed in this study, students use learned visualization concepts acquired in the homework to investigate building construction through a virtual construction process. This approach facilitates a fundamental understanding of building systems and how computing technology can simulate real world conditions prior to actual construction. Future work will assess visualization, illustrated in the appendix, as an effective tool to improve students' understanding of complex processes involved in building construction.

Acknowledgements

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Appendix: Final Project (Sample Work)

Final projects are the combine effort of students groups divided into typical areas of site work, structural steel, concrete, metal stud framing, mechanical, roofing, glazing, and masonry. Final projects are graded based on completeness, accuracy, planning, and implementation of learned concepts executed in the online video course supplement. Within traditional in-class and technology assisted courses, students share accountability and engage in leadership and conflict resolution methods while performing the virtual construction of select buildings (Figure 2 and Figure 3).
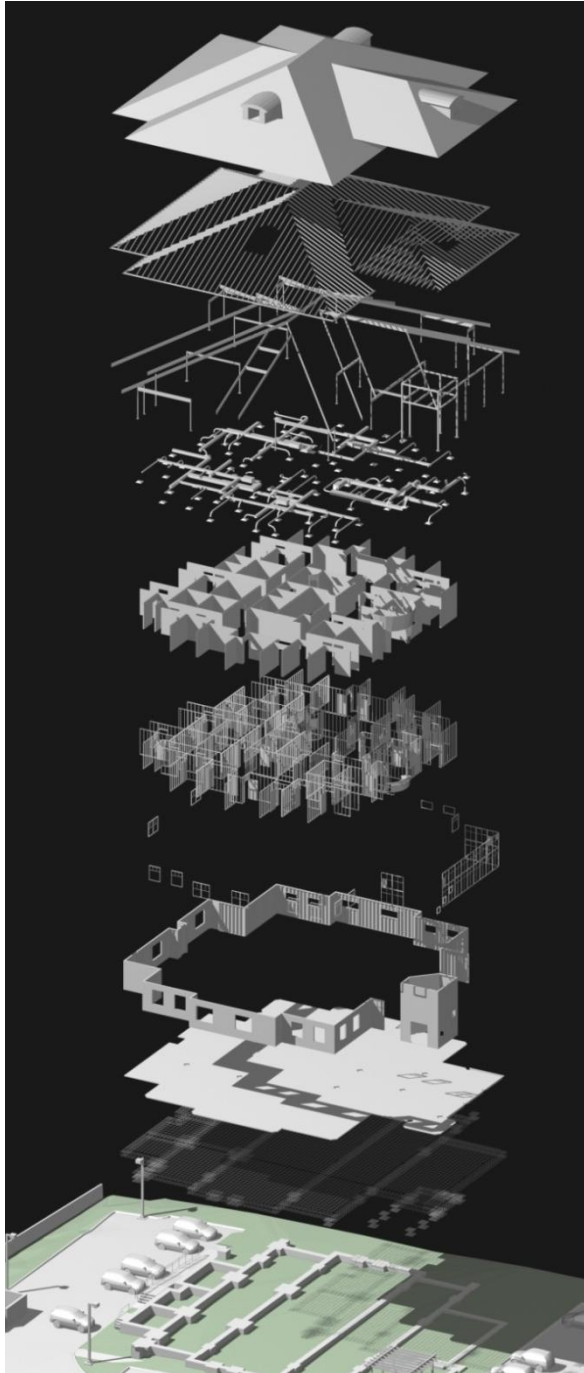
Figure 2. Small Office Building

Figure 3. University Library