Effectiveness of Using Visualization in Construction Education

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Abstract

The need to integrate advanced education technology tools, such as interactive simulations and visualizations, into the curriculum has been recognized by accrediting bodies because these tools enhance student learning and improve the quality of an engineering education. In this paper, the authors describe a visualization-based teaching approach to construction education in which different visualization tools, including video clips, 3D models, drawings, and pictures/photos, together with complementary texts, are used to assist students in deeper understanding and effective mastering of materials. The proposed teaching method was used to teach a construction management course offered at California State University, Long Beach. An assessment rubric was developed to evaluate the effectiveness of the proposed teaching method and the evaluation results indicated that, overall, the visualization-based teaching approach helped students to effectively learn the materials. With continuous modification and improvement of the course materials and interactive functions, the proposed visualization-based teaching tool is expected to help students deeply understand and effectively master the subject materials.

Keywords

Learning Effectiveness, Learning Assessment, Visualization, Engineering Education, Learning Performance, Teaching Performance.

Introduction

Previous education-related research works have revealed that advanced technology tools such as interactive simulations and visualizations enhance student learning and improve quality of engineering education.[1, 2, 3, 5, 11] For example, interactive multimedia units provide motivation, increase learning rate, contribute to retention, and even help effectively manage large classes while supporting the teacher as facilitator. [1, 4, 9, 13] Visual simulations are particularly effective at deepening understanding of abstract and highly mathematical subjects such as electromagnetism.[8] Likewise, three-dimensional animation and walkthrough computer models demonstrate construction processes and complementary texts describe the various steps for dual coding of information.[7] In construction management curriculums, students learning about construction processes usually need additional tutorials with illustrative animations, simulations, or further explanations with visualizations. For instance, when learning construction technology, students need to visualize materials and sequences of construction process, i.e., how all components of a facility are assembled. This paper presents the development and implementation of a "learning with visualizations" method which is designed to assist students in more fully understanding and effectively mastering the materials. The proposed visualization-based learning method was used to teach a construction engineering management course at California State University, Long Beach. An evaluation of the effectiveness of the teaching method was conducted using an assessment rubric and the results of the evaluation are discussed.

Visualization-Based Learning Framework

In the proposed visualization-based learning framework, the content of the materials to be covered was organized in three main modules: Learn, Practice, and Assess. These three separate modules enable students to achieve a deeper understanding as they undergo a three-stage learning process:

(i) Learning: Students go through the dialogues and visualizations to enhance their knowledge and understanding. The lecture notes are prepared and organized in chapters, sections, and subsections including texts, dialogues, and illustrative visualizations (e.g. video clips, drawings, 3D models, images, and photos).
(ii) Practicing: At the end of each chapter, questions as "food for thought" are given as multiple-choice quizzes or tests, which are scored to assess the student's knowledge. Students are asked to solve practical problems using their acquired knowledge and apply what was learned to unfamiliar problems.
(iii) Assessing: Students' learning is assessed by means of questions as "food for thought." Their answers to these questions are scored and the scores are used to assess what they've learned against objectives of the course. For each chapter, based on the assessment outcomes (i.e. the student scores), the instructor provides students with recommendations for what topics in the chapter need to be reviewed before going further in subsequent chapters to be covered in the following lectures.

To make the three learning modules interactive, the proposed visualization-based learning framework was implemented in Macromedia Studio 8™ and used a computer teaching tool named VisualLearning. Macromedia Studio 8™ was selected for this implementation since it offers the broadest range of creative tools to create interactive dialogues and visualizations using advanced graphics, text, animation, video and audio tools.

Implementation

The proposed teaching tool, VisuaLearning, was used to teach a construction engineering management course, CEM 121 Construction Drawings, offered at the Department of Civil Engineering and Construction Engineering Management at California State University, Long Beach. Figure 1 shows a typical screen shot of VisuaLearning, in which texts, 3D images, video clips, and drawings are entered as illustrative visualizations for the foundations of a residential construction project to be covered in the course CEM 121. After going over the learning materials for a particular subject (e.g. Graphic Vocabulary), students are prompted to answer questions in a quiz or test about what has been learned. These quizzes and tests are scored to make sure students understand the materials before going further in the subsequent chapters.

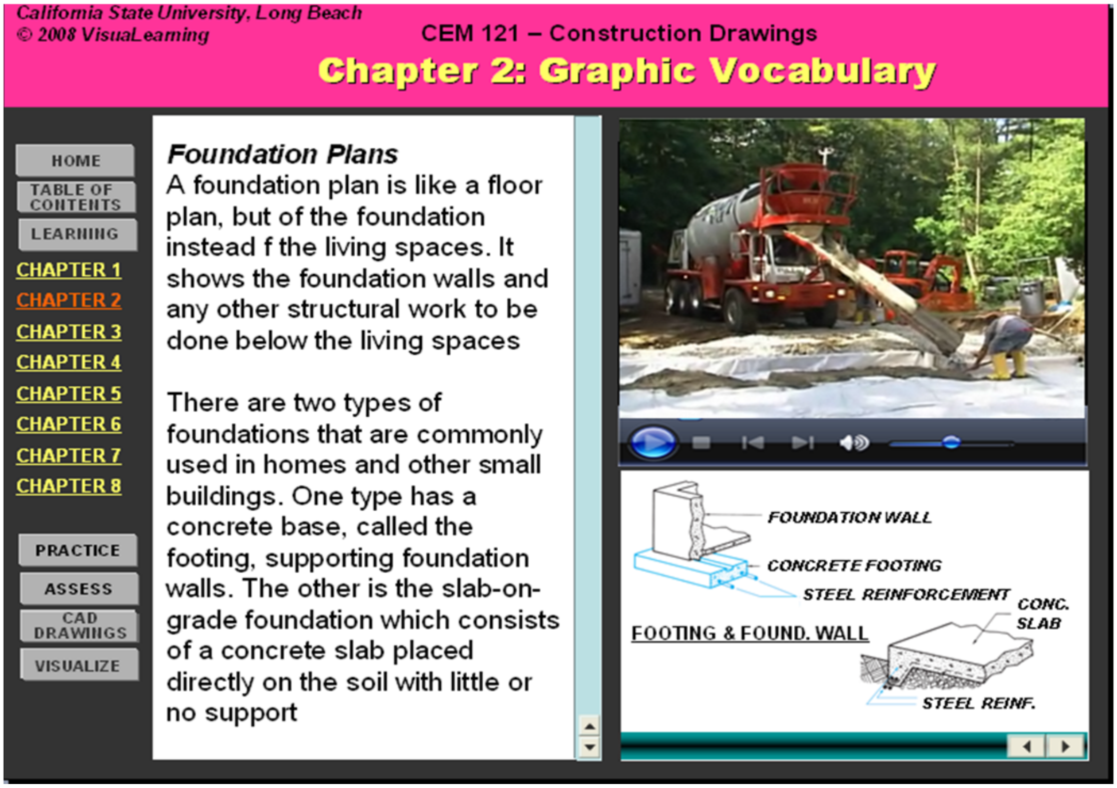


Figure 1. A Typical Lecture Note: Concrete Foundations

Assessment of Effectiveness

The effectiveness of proposed teaching methods was evaluated by means of different assessment tools. In addition to the traditional assessment tools such as homework, quizzes, tests, exams, lab reports, oral presentations, and projects, a rubric assessment tool was developed. This tool is used to evaluate the overall student achievements with respect to the learning objectives of the course. Once the course of study has been established, the overall expectations are determined through reviewing course-learned objectives, lecture notes, handouts, and materials collected on assessment strategies. To ensure that the overall expectations are being met, the performance criteria and evaluation methods should be established for assessment. Table 1 shows the performance criteria and evaluation methods for the course CEM 121, where the proposed visualization-based teaching method was implemented.

Table 1. Performance Criteria and Evaluation Methods.

Outcome 1: Understand the language of construction drawings.
The student will be able to identify lines, symbols, and standards commonly used in construction drawings.
The student will be able to accurately interpret information.(e.g. dimensions, symbols, graphs, texts, etc.) in construction drawings for both residential and commercial construction.
The student will be able to interpret and relate written specifications of a construction project to drawing plans of that project.
tion methods: examinations, assignments and in-class exercises)
ne 2: Understand and read the different construction drawings in a set of plans for a building
The student will be able to identify, define, and relate the different construction drawings.
The student will be able to read site plans, foundation plan, floor plans, elevations, sections, details, door and window schedules in an architectural prints.
tion methods: examinations, assignments, and in-class work)
Outcome 3: Conduct quantity takeoff practices for construction drawings
The student will be able to compute mathematical values (e.g. material quantity, measurements) as part of interpreting construction drawings using the architect's and civil engineer's scales.
tion methods: examinations, assignments and in-class exercises)
Outcome 4: Apply visualization skills to understand the construction drawings
The student will be able to use 2D and 3D visualization skills to sketch and draw construction details using pictorial drawing or orthographical projection.
The student will able to use CAD applications including 2D and 3D modeling software (e.g. AutoCAD, Revit Architecture, ArchiCAD) to create basic construction details.
tion methods: examinations, assignments and in-class exercises)

A rubric is a powerful and useful scoring tool for both teaching and assessment[6]. The performance criteria listed above are used to develop the rubric assessment tool and Table 2 presents the elements of the assessment tool. The assessment rubric consists of two performance metrics, which include (1) ability to develop appropriate levels of detail for construction projects and (2) ability to develop appropriate levels of quantity-take off for construction projects. Student performance on each metric has four possible levels and is assessed on a scale of 1 to 4 with novice performance having a score of 1, apprentice performance having a score of 2, proficient performance having a score of 3, and exemplary performance having a score of 4.

Table 2. Assessment Rubric for Performance Criteria

Performance Criteria	Score (1-4)	Novice (1)	Apprentice (2)	Proficient (3)	Exemplary (4)
Ability to develop appropriate levels of **detail for construction** projects		Rarely use the proper method to develop construction details for construction projects	Use the proper method , some of the time, to develop construction details for construction projects	Use the proper method , most of the time, to develop construction details for construction projects	Always use the proper method to develop construction details for construction projects
Ability to develop appropriate levels of **quantity-take off** for construction projects		Rarely use the proper method to develop quantity-take off for construction projects	Use the proper method , some of the time, to develop quantity take off for construction projects	Use the proper method , most of the time, to develop quantity take off for construction projects	Always use the proper method to develop quantity take off for construction projects

Assessment Results and Discussions

This section describes assessment results based on student works and said assessment is made using the assessment rubric developed in this paper. The assessment results consist of two factors: (1) overall student achievement which evaluates the effectiveness of the learning objectives and (2) the potential for continuous utilization of the proposed visualization-based teaching tool by showing no significant difference in student performance for two consecutive years, 2009 and 2010. In order to analyze the assessment results, we collected and evaluated students' works using the assessment rubrics tabulated in Table 2. The CEM 121 Construction Drawings course, where this outcome is covered and achieved, is analyzed using the rubric for this outcome. We graded the students' works not only for the purpose of grading against answer keys but also to assess the achievement of course outcomes. The rubric was used to collect direct assessment data of 23 and 24 students for Fall 2009 and Fall 2010 respectively. Table 3 shows descriptive statistics by performance criteria. Figure 2 shows the difference in performance criteria between the two student groups with regard to construction details and quantity takeoff.

Table 3. Descriptive Statistics by Performance Criteria

Class Group	Fall 2009		Fall 2010	
Performance Criteria	Construction Details	Quantity Takeoff	Construction Details	Quantity Takeoff
No. of Students	23	23	24	24
Student average score achieved	36.43	41.00	34.77	39.00
Perfect score	41.00	54.00	41.00	54.00
Percentage (%)	88.87	75.93	84.81	72.22

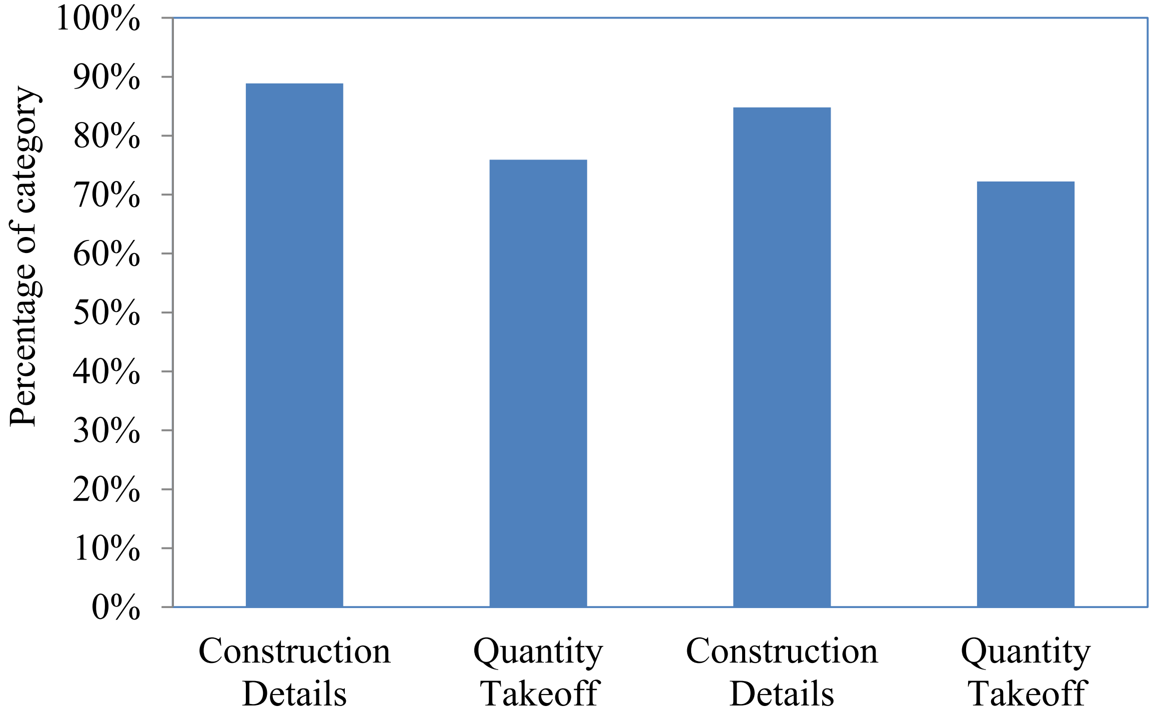
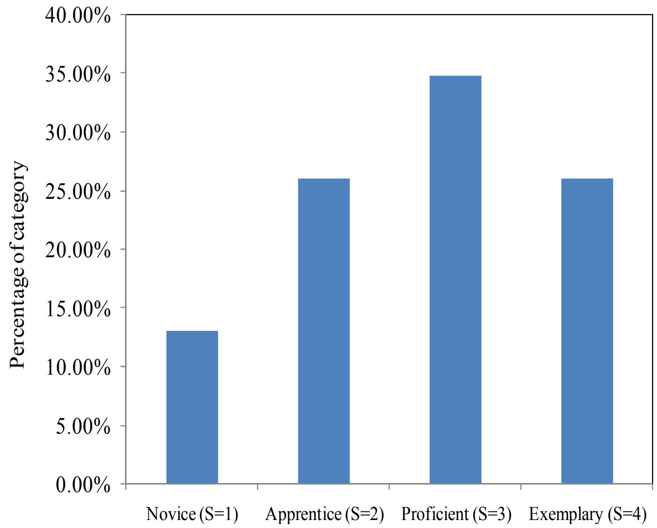


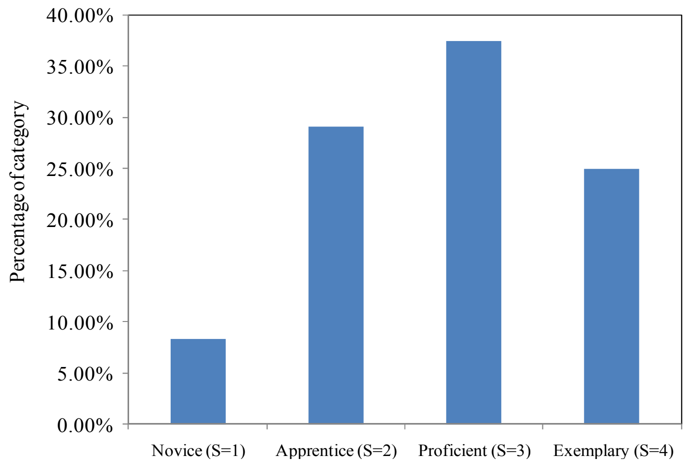
Figure 2. Comparison of performance criteria between the two student groups

The percentages shown in Table 3 was obtained for each semester and each metric by dividing the student average score achieved by the maximum score that students can obtain. It should be noted that the outcome of each performance criteria is achieved at a level that is greater than the acceptable level of 70.00%. A percentage greater than or equal to 70.00% in Table 3 implies that students demonstrated the achievement of outcome. The percentages for the assessment of construction details performance are 88.87% and 84.81% for Fall 2009 and Fall 2010, respectively, while those of quantity takeoff performance are 75.93% and 72.22%, respectively. The results indicate that students demonstrate competency at a proficient level. The effectiveness of using visualization was shown for both construction details and quantity takeoff.

An experiment was conducted to show the potential of the proposed teaching tool using visualization for continuous utilization in the CEM 121 course. In most cases, we do not know the actual variance or standard deviation of either of the two student groups, Fall 2009 and Fall 2010. The student samples are randomly and independently drawn from respective students that the samples are normally distributed and that the population variances are equal. Thus, the experiment method using a pooled-variance t-test is appropriate because it determines whether or not there is a statistically significant difference between the means of the two populations.[10, 12] Figures 3(a) and 3(b) show the distributions of overall student performance based on the rubrics for Fall 2009 and Fall 2010 respectively.



(a) Fall 2009



(b) Fall 2010

Figure 3. Comparison of Overall Assessment Results: (a) Fall 2009 and (b) Fall 2010

The experiment aims to compare the overall student performance between two groups for the proposed visualization-based teaching tool. The research hypothesis is to show that there is no significant difference in student performance for two consecutive years, 2009 and 2010, so that the teaching tool has a potential to continuously promote students' understanding and interest in construction. A T-test for the difference between the means of two independent student groups, Fall 2009 and Fall 2010, was conducted using Minitab 16®. The hypotheses to test whether the overall student performance ($\mu 1$) obtained from the class of Fall 2009 exceed those ($\mu 2$) obtained from the class of Fall 2010 are Ho: $\mu 1 - \mu 2 = 0$ and Ha: $\mu 1 - \mu 2 > 0$. Table 4 tabulates the statistical results for overall student performance.

Table 4. Statistical Analysis for Overall Student Performance

Class Group	Fall 2009	Fall 2010
No. of students	23	24
Mean	2.74	2.79
Standard Deviation	1.01	0.93
t-score (p-value)	-0.19 (0.573)	

At a 0.05 level of significance, the null hypothesis is not rejected because the p-value is not less than 0.05. We have sufficient evidence to show that the null hypothesis is true. From this we conclude that the interactive visualization-based teaching tool proposed here can be utilized as an effective teaching tool for any group of students that takes the CEM 121 Construction Drawing I course offered at the Department of Civil Engineering and Construction Engineering Management at California State University, Long Beach. With the continuous modification and improvement of the course materials and interactive functions, the proposed visualization tool is expected to help students achieve a deeper understanding, apply learning to unfamiliar problems, and optimize achievement of predefined learning outcomes through a diagnostic feedback loop.

Conclusion

The integration of interactive visualizations in teaching helps students deeply understand abstract subjects in construction courses. In an attempt to improve the quality of construction education, a visualization-based teaching tool was developed and implemented at the Department of Civil Engineering and Construction Engineering Management at California State University, Long Beach. In the proposed teaching tool, the student is provided with visual learning objects including graphics, animation, video, three-dimensional models, and illustrative images/photos, which are used as primary learning features. These learning objects consist of modules that help students achieve a deeper understanding (learn), apply learning to unfamiliar problems (practice), and optimize achievement of predefined learning outcomes through a diagnostic feedback loop (assess). The tool was used to teach a construction engineering management course and evaluated for its effectiveness. In addition to the traditional assessment mechanisms such as homework, exams, labs, etc., a rubric assessment tool was developed and used to evaluate the learning performance of students. The evaluation results indicated that, overall, the visualization-based teaching approach helped students to effectively learn materials. It was found that the visualizations provide dynamic representations of knowledge and increase classroom interaction and students' personalized learning experience. Overall, the visualization-based teaching method promotes students' understanding and interest in construction, which can lead to higher student retention rate.

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