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A Quasi-Experimental Study of the Effect of Computer Simulation and Animation (CSA) on Student Learning in Kinematics in a Foundational Undergraduate Engineering Course

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Abstract: A quasi-experimental quantitative study was performed to investigate the effect of computer simulation and animation (CSA) on student learning in kinematics in a foundational engineering dynamics course. The study involved 149 student participants in two recent semesters: 67 in a comparison semester and 82 in an intervention semester. This short paper describes two CSA modules we developed for students to learn curvilinear motion and relative motion, two critical topics in kinematics. The pretest-posttest results show that the students in the intervention semester achieved high learning gains of 62% and 59%, respectively, from two CSA modules. These two percentages represent, respectively, a 23% and 46% increase in learning gains as compared to those in the comparison semester.

Keywords: computer simulation and animation (CSA), quasi-experimental study, student learning, kinematics

1. Introduction and Literature Review

Engineering dynamics is a foundational course that all undergraduate students in mechanical, aerospace, civil, and environmental engineering programs are required to take. Covering numerous physics and engineering concepts and problem-solving procedures, this course requires students to have solid conceptual understanding and problem-solving skills. Therefore, many students regard engineering dynamics as one of the most difficult courses to learn and succeed in (Streveler, Litzinger, Miller, & Steif, 2008).

Computer simulation and animation (CSA) has received growing attention in recent years in engineering education and has been employed in teaching and learning a variety of engineering courses, such as engineering statics, engineering dynamics, and strength of materials (Budhu, 2009; Philpot, 2000; Stanley, 2008; Kraige, Akhtar, & Bisht, 2007). However, the assessment of student learning outcomes with CSA has been limited to single-group research designs, and heavily relies on students' self-reported surveys and interviews only (Stanley, 2008). Ha & Fang (2013) have conducted an extensive literature review on the use of CSA in engineering mechanics (particularly engineering dynamics) classes. They found that quantitative assessments involving pretests and posttests are lacking. To fill this research gap, the present study conducted quasi-experimental, quantitative research involving pretests and posttests on two groups of students: an intervention group and a comparison group.

The scope of the present study is limited to assessing if and to what extent CSA improves student learning, rather than investigating why and how CSA improves student learning. The organizational structure of this short paper is as follows. First, it describes two CSA modules that we developed for students to learn curvilinear motion and relative motion in engineering dynamics. Then, this paper presents a research question and describes the research method. Next, research findings are presented and analyzed. Finally, conclusions are made at the end of this paper.

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2. Computer Simulation and Animation (CSA) Modules

Engineering dynamics includes kinematics and kinetics. Curvilinear motion and relative motion are two important topics in kinematics. To improve student learning of these two topics, we developed two CSA modules, A and B. Figures 1 and 2 show two representative computer graphical user interfaces (GUIs) of these two CSA modules.

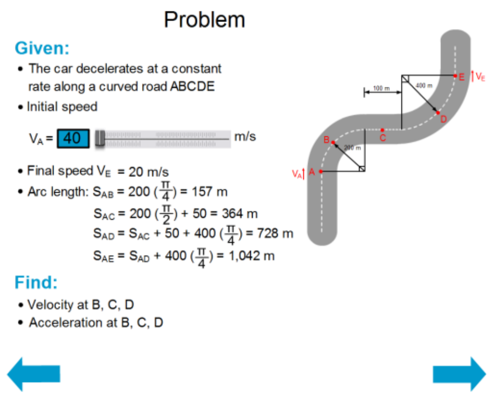

Figure 1. A representative computer graphical user interfaces of CSA Module A: curvilinear motion.

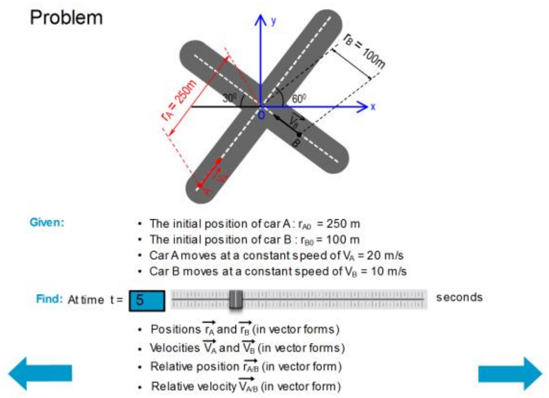

Figure 2. Two representative computer graphical user interfaces of CSA Module B: relative motion.

The two CSA modules have the following common features. 1) They integrate visualization with the mathematical modeling to help students directly connect engineering dynamics with mathematics. 2) They have interactive computer graphical user interfaces that allow students to vary inputs and see how the numbers in mathematical equations change, simultaneously and dynamically. 3) They are web-based and stand-alone computer software programs, so anyone who has access to the Internet can use them anytime, anywhere, and at his or her own pace.

3. Research Question and Method

The research question is: to what extent did the CSA modules developed in the present study improve student learning in kinematics? To answer this question, a quasi-experimental research method was employed involving a total of 149 student participants in two recent semesters: 67 in a comparison semester and 82 in an intervention semester. These students were second-year undergraduate students in the College of Engineering at the authors' institution, a public research university in the United States. The majority of students were from mechanical and aerospace engineering (MAE) majors and civil and environmental engineering (CEE) majors. Before taking dynamics, they have taken physics and engineering statics courses. Ten percent of student participants were female, and 90% were males.

All students were taught by the same instructor using the same course syllabus. Students in the comparison semester learned from regular lectures only. Students in the intervention semester learned from regular lectures as well as the CSA modules. Pretests and posttests were conducted each semester. Because not every student who agreed to participate in the present study completed both pretests and posttests, slight differences existed between the number of students who completed pretests and those who completed posttests, as shown in Table 1.

Five assessment questions were developed for use in pretests and posttests for CSA Module A, dealing with curvilinear motion. Students needed to do calculations and generate a numerical solution in order to answer these five assessment questions. Therefore, these questions are also called calculation questions in this paper. Six assessment questions were developed for use in pretests and posttests for CSA Module B, dealing with relative motion. Among these six questions, the first two are conceptual questions to assess student conceptual understanding, and the remaining four are calculation questions to assess student procedural skills.

Table 1. Student participants.

Student group	Number of student participants who participated in pretests and posttests that were built upon	
	CSA Module A	CSA Module B
Comparison (not using CSA modules)	66	67
Intervention (using CSA modules)	82	78

An example assessment question for CSA Module B is: "The velocity of Car A relative to the velocity of Car B changes over time. A) True. B) False." This example question assesses student understanding of relative velocity. Students completed the pretests and posttests. Then, normalized learning gain was calculated for each module for each student based on his/her scores on the pretests and posttests. The following formula was used (Hake, 1998):

$$\text{Normalized learning gain} = \frac{\text{Posttest score (\%) - Pretest score (\%)}}{\text{100 (\%) - pretest score (\%)}}$$

Students who completed only one test (either a pretest or a posttest) were eliminated in the calculation of learning gains. The class-average learning gain was calculated based on the learning gain of each individual student. Statistical analysis using an independent means t-test was further conducted to investigate if there was a statistically significant difference in overall learning gains between students in the comparison group and the intervention group.

4. Results and Analysis

Figures 3 and 4 show normalized class-average learning gains for each assessment question for CSA Module A and B, respectively. As seen from these figures, students in the intervention group achieved much higher learning gains than those in the comparison group, for each assessment question and for both modules. For example, for assessment question No. 4 in Fig. 4, the comparison group even had a negative learning gain (-7%); whilst the intervention group achieved a much higher, positive learning gain of 63%.

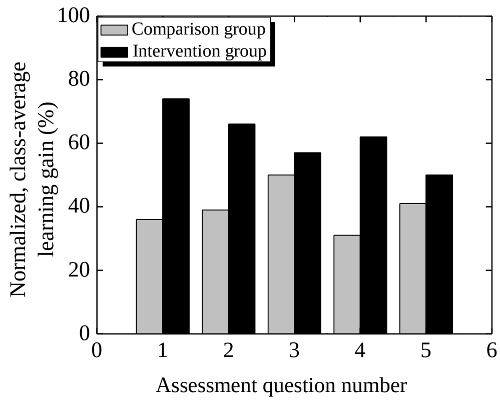

Figure 3. Normalized class-average learning gains for CSA Module A.

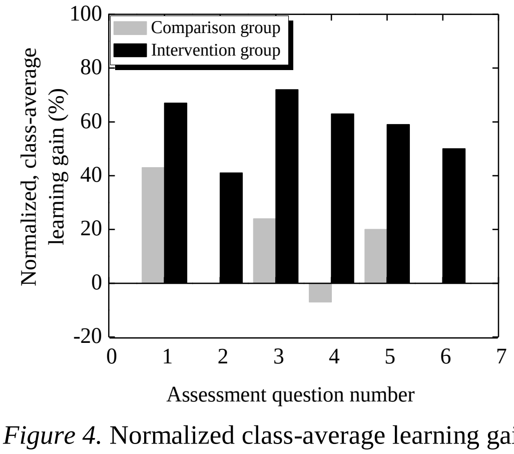

Figure 4. Normalized class-average learning gains for CSA Module B.

Table 2 further shows learning gains in terms of three categories: conceptual understanding (measured from conceptual questions in pretests and posttests), procedural skills (measured from calculation questions), and overall combined achievement (measured from all questions). As can be seen clearly from Table 2, the intervention group achieved higher learning gains than did the comparison group in all three categories. The overall learning gains are 62% and 59%, respectively, for CSA Modules A and B. These two percentages represent, respectively, a 23% and 46% increase in overall learning gains as compared to those in the comparison semester.

Table 2. Student learning gains (LGs)

Module	Student Group	Conceptual LG	Procedural LG	Overall LG
Module A	Comparison	N/A	39%	39%
Module A	Intervention	N/A	62%	62%
Module B	Comparison	21%	9%	13%
Module B	Intervention	54%	61%	59%

The results from an independent means t-test show that a statistically significant difference in overall learning gains exists between students in the comparison group and the intervention group for CSA Module B ($t = 4.13$, $p = 0.0001$).

5. Limitations of the Present Study

All data presented in this paper was collected from the authors' institution only. As students in other institutions have different backgrounds and experiences, the effect of CSA modules on student learning would vary from institution to institution. In addition, the present study does not address why and how CSA modules improve student learning.

6. Conclusions

Based on the results of the quasi-experimental study involving 149 student participants in a comparison semester and an intervention semester, the two CSA modules developed in the present study increased student learning gains by 23% and 46%, respectively. The difference in overall learning gains between the two student groups is statistically significant for CSA Module B. These findings suggest that properly-designed CSA modules can be employed to improve student learning in engineering dynamics, a difficult yet critical foundational undergraduate course.

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References

Budhu, M. (2009). Enhancing instructions using interactive multimedia simulations. *Simulation*, *76*(4), 222-231.

Ha, A., & Fang, N. (2013). Computer simulation and animation in engineering dynamics: A critical review and analysis. *Proceedings of the 2013 American Society for Engineering Education (ASEE) Annual Conference & Exposition*, Atlanta, GA, June 23-26, 2013.

Hake, R. R. (1998). Interactive-engagement vs. traditional methods: a six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, *66*(1), 64-74.

Kraige, L. G., Akhtar, I., & Bisht, S. (2007). Animation software for upper-level dynamics and vibrations courses. *Proceedings of the 2007 American Society for Engineering Education (ASEE)*, Honolulu, HI, June 24-27, 2007.

Stanley, R. (2008). An efficient way to increase the engineering student's fundamental understanding of particle kinematics and kinetics by using interactive web based animation software. *Computers in Education*, *18*, 23-41.

Streveler, R. A., Litzinger, T. A., Miller, R. L., & Steif, P. S. (2008). Learning conceptual knowledge in the engineering sciences: overview and future research directions. *Journal of Engineering Education*, *97*(3), 279-294.

Philpot, T. A. (2000). MDSolids: Software to bridge the gap between lectures and homework in mechanics of materials. *International Journal of Engineering Education*, *16*(5), 401-407.