Comparing the Use of Multimedia Animations and Written Solutions in Facilitating Problem Solving

Neelam Khan*, Dong-Hai Nguyen†, Zhongzhou Chen‡, and N. Sanjay Rebello¶

*School of Science and Technology, Georgia Gwinnett College, Lawrenceville, GA, 30043, USA
†Department of Physics, Ho Chi Minh City University of Pedagogy, Ho Chi Minh City, Vietnam
‡Department of Physics, University of Illinois Urbana-Champaign, Urbana, Illinois, 61801, USA
¶ Department of Physics, Kansas State University, Manhattan, KS, 66506, USA

Abstract. We compared the use of solutions to a problem in the form of multimedia animations and static worksheets to help students learn how to solve physics problems that required the use of mathematical integration. We administered four tasks related to electricity and magnetism problems. In each task, students individually attempted a pre-test problem followed by a worksheet problem based on the same concept. Then, we provided students the solution to the worksheet problem either as a narrated multimedia animation or in a written format. Finally, all students solved a post-test problem. Results indicate that on all four tasks, there was a statistically significant improvement in problem solving scores for both the animation and written solution treatments. We found no significant differences between the treatments.

Keywords: multimedia, animation, worksheet solution, problem solving
PACS: 01.40.Fk

INTRODUCTION

Previous studies investigated students' difficulties in understanding processes that are involved in integration such as their inability to understand an integral as a representation of sum, distinguishing variables and constants, and limits of integration while setting up the integral in physics problems [1-4]. In this study we assess students' performance on solving a problem requiring integration by comparing the use of multimedia animations and static worksheet solutions. We investigated the extent to which students' abilities to set up and compute an integral in a physics problem can be improved after presenting them with the solution to a similar problem in the form of a multimedia animation or a static worksheet.

Previous research has shown the superiority of multimedia instruction in improving student learning as compared to listening to a verbal explanation or reading the text [5]. Stelzer et al. showed that the use of multimedia module pre-lecture presentations improved the performances of students significantly as compared to text-based presentations [6, 7]. Chen et al. introduced the multimedia learning modules (MLM's) as a pre-lecture assignment and found that students' performance on pre-lecture questions that they answer prior to lecture improved significantly as compared to semesters when MLM's were not introduced [8]. However, to date there have been no studies specifically comparing the use of multimedia animations and static worksheet solutions to facilitate students' understanding of integration problems. We address the following research questions:

1) Does viewing the multimedia animations improve students' ability to set up an integral?
2) Does viewing the multimedia animations improve students' ability to compute an integral?
3) How do solutions provided via multimedia animations versus static write-ups compare?

METHODOLOGY

One hundred and sixty eight engineering students taking second semester calculus-based physics participated in this study. Half of the participants completed animated tasks and other half completed worksheet tasks. Four of the tasks were completed, each by a different cohort of these participants. Figure 1 shows the research design for each task.

Students first attempted a pre-test problem. The worksheet problem was different, but based on the same concept as the pre-test problem. To determine whether students knew how to work out this problem before being administered one of the solution treatments, we asked them to attempt it. Next, in providing a solution to the worksheet problem we assigned students to one of two groups. Each student in the 'animated' group viewed a narrated multimedia

2012 Physics Education Research Conference
AIP Conf. Proc. 1513, 214-217 (2013); doi: 10.1063/1.4789690

animated solution to the worksheet problem. They could pause, rewind, and review the animation. Each student in the 'written' group received a complete written solution to the worksheet problem. Both of the solutions were identical except one was animated and other was static. The audio and visual explanation in the animated version was written in words and drawn pictures respectively for the static version. Both groups took about 15 minutes to view the animation or read the written solution. Finally, all students completed a post-test problem similar to the pre-test problem, but with changed surface features. The entire task took about 75 minutes to complete.

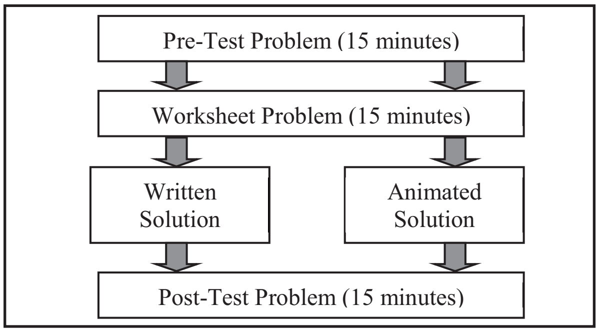


FIGURE 1. Research design for each task used in the study.

We administered four such tasks during the semester. One of the co-authors (ZC), who had prior experience creating multimedia modules, created the animations. Table 1 provides a description of each task and Figs. 2 and 3 show the pre/post-test and worksheet problems respectively on Task 1.

TABLE 1. Brief description of problems in each task

Task	Task Description
1	Electric field at the center of a semicircular arch with constant linear charge density
2	Resistance of rectangular shaped resistor with non-uniform resistivity
3	Magnetic field at a point due to a wire carrying non-uniform current density
4	Magnetic flux through a rectangular loop due to a current in an infinite wire outside the loop

A semi-circular arch of radius R_1 and charge density λ_1 (+ive constant) is placed concentrically with another semi-circular arch of radius R_2 and charge density λ_2 (+ive constant). Find the magnitude and direction of the electric field due to these two arches at point O.

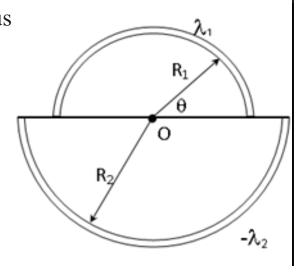
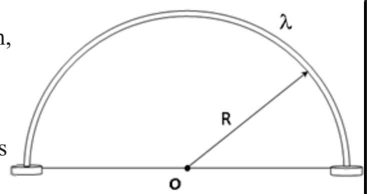


FIGURE 2. Pre–test problem on Task 1. The post-test problem was similar, with changed surface features.

You are standing at point O under an arch, radius R, electrically insulated from the ground, as shown in the figure. The arch is charged with a constant positive charge density λ.



Find the magnitude and direction of the electric field at point O.

FIGURE 3. Worksheet problem on Task 1.

On both the pre- and post-test problems, students had to first recognize the need for an integral and then set up an integral in the context of the physics scenario described in the problem statement. We scored the pre- and post-test problems according to a rubric. Firstly, points were awarded for setting up the integral, which included recognizing the variable of integration, setting up the integrant in terms of the variable, and the limits of integration; and secondly, computing the integral. While one may typically weigh setting up the integral to be more important than computation of it, we normalized both scores to a maximum of 10 points and report each normalized mean score separately.

RESULTS

In Task 1 (Fig. 2), students needed first to recognize (using symmetry) that the net electric field would be in the y-direction. They would need to start with the formula for the electric field due to point charge dq and then find the component of the electric field in the y-direction due to it. The charge element $dq = \lambda_1 ds$, where $ds = Rd\theta$, is an infinitesimally small element of the charge distribution. Then, they needed to recognize the limits of the integral from 0 to π to get the value of the electric field for the upper arch. They had to repeat the process for the lower arc and then find the resultant field.

Students in both groups demonstrated difficulty in setting up the integral on the pre-test problem. The main reasons were that students had difficulty determining dq, or they were unable to recognize the y-component of the electric field. Students had similar difficulties with the worksheet problem shown in Fig. 3. We previously documented these difficulties in detail [4].

Figure 4 shows that both groups improved their scores for both setting up and computing the integral. The students who were able to set up the integral correctly did not have any difficulty in computing the integral. Some of the students did not show the steps needed to compute an integral for the lower arc and wrote the answer for it directly. Points were taken off if they didn't show the steps for how to compute it.

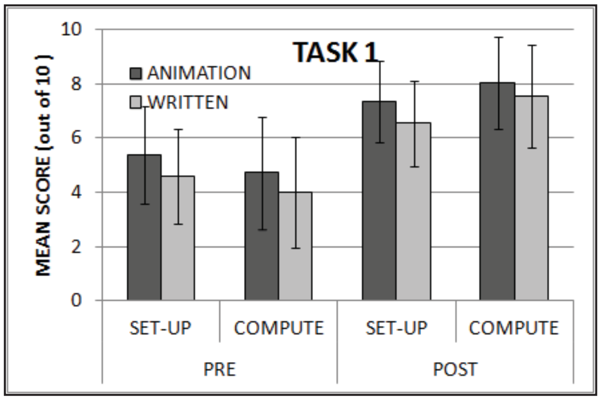


FIGURE 4. Results for Task 1. Error bars are standard error.

On Task 2, the pre-test and post-test problems required students to find the resistance of a cubic resistor, when resistivity was changing along the y-axis. The worksheet problem was to find the resistance of a cylindrical resistor, when it was oriented along x-axis and resistivity changed along the x-axis.

Students had difficulty setting up the integral. The main reasons were incorrect substitution of integral variables as well as not recognizing the whole resistor as a parallel combination of thin slices of a resistor. This could be because the worksheet problem solving required the whole resistor to be divided in a series combination of thin slices. Thus, on Task 2 students had difficulty both setting up the integral as well as understanding the context of problem which is manifested from the lower mean score shown in Fig. 5. Both the pre- and post-test scores were substantially lower for Task 2 as compared to Task 1, indicating that much work still needs to be completed in analyzing students' difficulties with this problem and how we can address these difficulties.

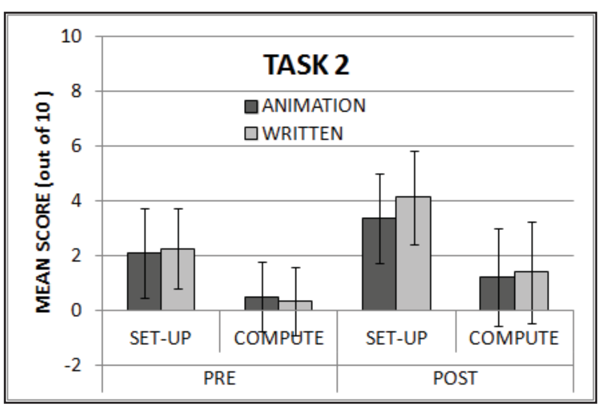


FIGURE 5. Results for Task 2. Error bars are standard error.

The difficulties with Tasks 3 and 4 were with setting up the integral, specifically with recognizing the variable of integration and constructing the integrant. Figures 6 and 7 show improvement from the pre- to post-test for Tasks 3 and 4 respectively, in setting up and computing the integral for both the animation and written solution groups.

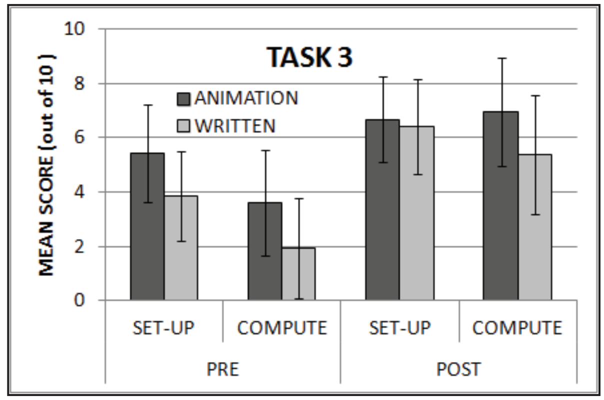


FIGURE 6. Results for Task 3. Error bars are standard error.

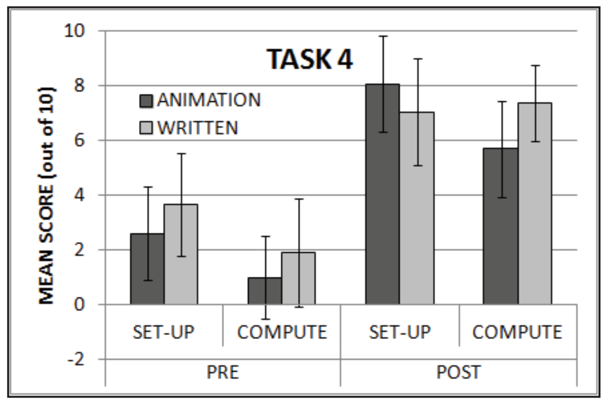


FIGURE 7. Results for Task 4. Error bars are standard error.

ANALYSIS

Repeated measures ANOVA (analysis of variance) was used to determine if there was a statistically significant difference between pre-test and post-test scores, as well as to see if there was an interaction between treatment (animation or written solutions) for both setting up and computing the integral. Table 2 shows repeated measures ANOVA results for all four tasks.

Our analysis shows a statistically significant ($p < \alpha = 0.05$) main effect for setting up mean scores on all four tasks and computing on three of four of the tasks. There was no significant interaction with treatment for any of the tasks for either setting up or computing. Examining the η^2 effect size shows a low to moderate effect size (maximum value = 0.682., minimum value = 0.326) for the main effect. This indicates that although the improvement from pre- to post-test was statistically significant, there was no statistically significant difference between the two treatments with regard to the improvement in the scores.

TABLE 2. Repeated measures ANOVA.

Task	Setting Up		Computing	
	Main Effect	Interaction	Main Effect	Interaction
1	F(1, 66)=39.074, p<.001, $\eta^2 = 0.372$	F(1,66)=0.003, p=0.959 $\eta^2 = 0.000$	F(1,66)=49.886, p<.001, $\eta^2 = 0.430$	F(1,66)=.059, p=0.809 $\eta^2 = 0.001$
2	F(1,35) =26.213, p<.001, $\eta^2 = 0.428$	F(1,35)=.708, p=0.406 $\eta^2 = 0.020$	F(1,35)=3.714, p=0.062 $\eta^2 = 0.096$	F(1,35)=.040, p=0.740 $\eta^2 = 0.003$
3	F(1,34)=45.125, p<.001, $\eta^2 = 0.326$	F(1,34)=6.125, p=0.144 $\eta^2 = 0.062$	F(1,34)=19.934, p<.001, $\eta^2 = 0.370$	F(1,34)=.032, p=0.859 $\eta^2 = 0.001$
4	F(1,29)=146.641, p<.001, $\eta^2 = 0.498$	F(1,29)=1.619, p=0.213 $\eta^2 = 0.053$	F(1,29)=35.818, p<.001, $\eta^2 = 0.682$	F(1,29)=.357, p=0.555 $\eta^2 = 0.012$

CONCLUSIONS

We find that in all four of the tasks, there was a statistically significant improvement from pre- to post-test score in setting up the integral and a similar improvement in computing scores on three of four tasks. However, the effect sizes for the improvements were small to moderate. Our results also indicate no significant interaction between scores and treatment. Thus, both the 'animation' and 'written' solution were equally effective in improving students' scores in setting up and computing an integral.

LIMITATIONS & FUTURE WORK

Our results seem to indicate that written solutions and narrated multimedia animated solutions are equally effective in improving students' abilities to set up and compute the integral in physics problems. In spite of this statistically significant result, we caution against using this study to support the broad claim that both these treatments will always be equally effective in improving students' problem solving skills. We urge caution, due to limitations of the current study.

First, students were exposed to both treatments for about 15 minutes each. This condition contrasts unfavorably with previous studies in which students were exposed to animations over a longer period, for example in the form of pre-lectures as compared to textbook reading for the whole semester [8]. Second, the study focused on a rather specific subset of problems in the context of electricity and magnetism. Research has shown that students have several difficulties with these problems [4]. Thus, they may not be the most appropriate for testing efficacy of multimedia vis-à-vis written solutions. Third, the post-test problems might be too similar to the worksheet example, so even students with low conceptual understanding solved the problem resulting in a ceiling effect for post-scores on three of four problems. Research has shown the superiority of multimedia animations on written solutions for far transfer problems, much more than near transfer problems [9]. Lastly, our rubric for assessing the problems may have been too coarse to detect differences between the two groups, which might have been revealed by a deeper qualitative assessment such as think-aloud interviews.

Addressing the limitations opens up an interesting venue for future work. It would be interesting to carry out such a study over a longer period, spanning several topics. It would also be interesting to interview students using either the animations or written solutions to further explore the differences in learning while using these two treatments.

ACKNOWLEDGMENTS

This work is supported in part by the U.S. National Science Foundation under grant 0816207. Opinions expressed are of the authors and not of the Foundation. We are also grateful to Adrian Madsen and Amy Rouinfar for assistance with the statistical analysis.

REFERENCES

1. N. S. Rebello, L. Cui, A. G. Bennett, D. A. Zollman and D. J. Ozimek, "Transfer of Learning in Problem Solving in the Context of Mathematics and Physics" in *Learning to Solve Complex Scientific Problems*, edited by D. H. Jonassen, Mahwah, NJ: Lawrence Erlbaum Associates, 2007.
2. C. Manogue, K. Browne, T. Dray, & B. Edwards, Am . J. Phys. **74**(4) (2006).
3. C. Wallace & S. Chasteen, *Phys. Rev. ST Phys. Educ. Res.* **6**, 020115 (2010).
4. D.H. Nguyen and N. S. Rebello, *Phys. Rev. ST Phys. Educ. Res*. **7**, 010113 (2011).
5. R. Mayer, *The Cambridge Handbook of Multimedia Learning,* Cambridge University Press, New York, 2001.
6. T. Stelzer, D. T. Brookes, G. Gladding and J.P. Mestre, *Am. J. Phys*. **78**, 755, (2010).
7. T. Stelzer, G. Gladding, J.P. Mestre, and D. T. Brookes, *Am. J. Phys*. **77**, 184, (2009).
8. Z. Chen, T. Stelzer and G. Gladding, *Phys. Rev. ST Phys. Educ. Res*. **6**, 010108, (2010).

9 Z.Chen, Ph.D. Thesis, University of Illinois at Urbana-Champaign, 2012.