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Optimal Methods of Input for Pedagogic Engineering Software

James C. Squire[1*], Gerald A. Sullivan[1] and Thomas J. McCormick[1]

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ABSTRACT

Computer simulations are commonly employed to teach intuitive causal engineering relationships, yet there is little research regarding what aspects make such simulations maximally pedagogically effective. This paper investigates how the discrete vs. continuous nature of user input, such as moving a dial vs. typing a parameter, affects actual learning as well as the user-perceived learning. The $N = 91$ cohort size was not sufficient to establish statistical differences at the $\alpha = 0.05$ level, but at $\alpha = 0.1$ it was observed that simulations using continuous input caused students to learn more effectively, and that students who used continuous input methods believed, following their use, that continuous input learning methods were more effective than discrete input learning methods. Surprisingly, an inverse correlation was found between objectively-measured student understanding and subjectively-rated student belief of their own subject mastery. In other words, students who used continuous input simulations believed they were better teaching tools in general, even though they believed their specific learning was inadequate.

Keywords: Pedagogy; simulations; continuous; discrete.

1. BACKGROUND

Computer demonstrations and simulations are well-researched tools for teaching; resources such as The Guide to Simulation Games for Education and Training have existed for half a century [1] and numerous studies have investigated the value of interactive simulations in the engineering and mathematical academic setting, for example [2-5]. The ubiquity of mobile computing devices, the rise of Massive Open Online Courses (MOOC), and changes as textbook publishers embrace electronic media have further spurred the use of simulations as an important method to provide an intuitive, self-guided understanding of quantitative cause-and-effect relationships [6-8]. Such simulations may use discrete methods to interact with them, such as setting simulation parameters, pressing a calculate button and observing the results, or they may employ a continuous method of interaction, such as dragging a slider and observing in real-time how the results are affected. Although demonstrations using continuous input methods are considerably more difficult to program, no studies have attempted to quantify the pedagogical benefits, if any, of adopting one manner of user interaction over the other.

2. METHODS

This work describes a set of experiments to test the hypothesis that interactive software demonstrations using continuous input methods are more pedagogically effective than those using discrete input methods. Two different interactive computer demonstrations were created, available at [9], each of which develops student intuition connecting a phasor representation and its time-domain sinusoidal waveform. Both demonstration programs have identical output areas displaying the sinusoid, and identically-appearing input areas showing the phasor. The discrete version requires the user to input the magnitude and angle of the phasor and press a calculate button; the continuous version uses a similar input screen but allows the user to drag a point to establish the phasor

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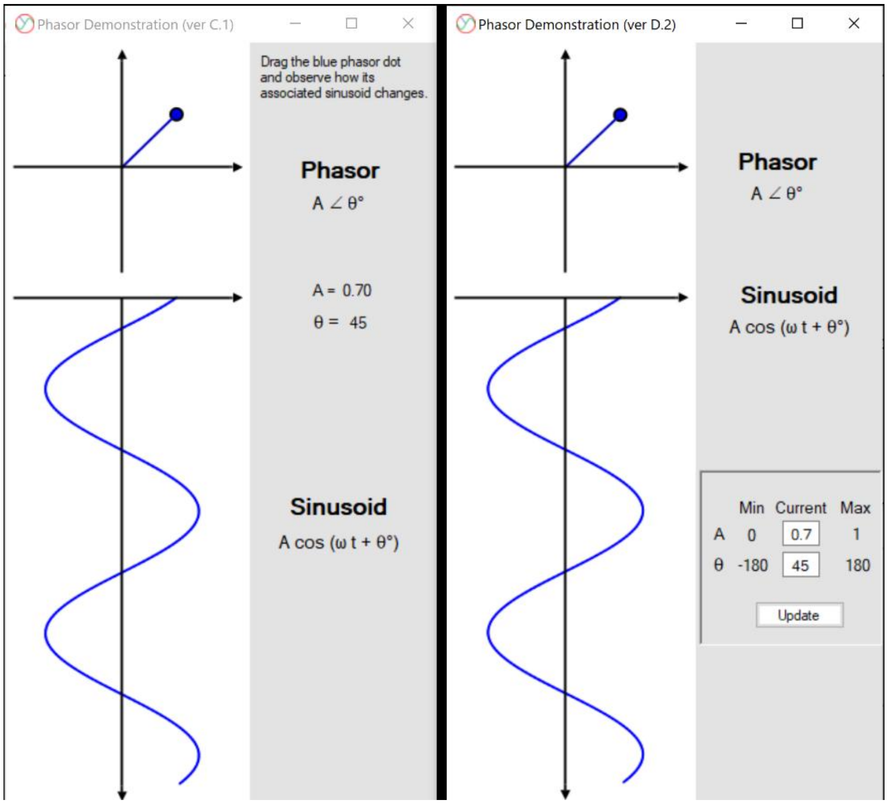
[1] *Virginia Military Institute, Lexington, VA, USA.*
**Corresponding author: E-mail: SquireJC@vmi.edu;*

magnitude and angle. Although this pilot study examines only a pair of tightly-coupled programs, further work is planned to determine if certain subjects inherently lend themselves better to discrete or continuous input methods.



Drag the blue phasor dot and observe how its associated sinusoid changes.

A = 0.70
θ = 45

	Min	Current	Max
A	0	0.7	1
θ	-180	45	180

Fig. 1. Two almost-identical interactive programs purporting to teach phasor concepts. The left panel shows the version designed for continuous-input and output; the learner drags the blue phasor and moves it around while observing the constantly-changing time-domain sinusoid that the phasor represents in the window below. The right panel displays the discrete-time version in which the learner enters values for the phasor magnitude and angle. In this version, the phasor is not changed until the user presses the “Update” button

The experiment was conducted in three stages. First, students were randomly selected to be in the A or B teams by alphabetically ordering students in each class and assigning even numbers to continuous and odd numbers to discrete cohorts. Both groups were given ten minutes to read identical tutorials, available at [10], that provide an introduction to the mathematics linking phasors with their time-domain sinusoids. Students were next given instructions to download the phasor application appropriate to their cohort, downloadable at [9], and given a set of identical exercises to complete requiring them to use the software application to determine relationships between various given phasors and their time-domain representations. Last, students were required to close their phasor applications and complete questionnaires [11] which probed their objective understanding of phasors as well as their subjective beliefs about the quality of their understanding of phasors, as well as their rating of the phasor demonstration app as a learning tool. The questionnaire began by requesting their self-assessment of subject mastery, and their subjective determination of the utility of applications such as these in learning causal relationships in engineering. For example, in question 6 of the questionnaire, students were asked “How well do you feel you understand the relationship between a phasor and its associated sinusoid?” Questions 8-14 were designed to measure students’ objective performance in recognizing the equivalence between a phasor and its corresponding time domain signal. The final question asked the students again to provide their subjective determination of the utility of applications such as these for learning causal engineering relationships as compared to traditional methods of instruction. The comparison of the results for the discrete vs. continuous phasor apps were evaluated using the two-tailed student T distribution.

3. RESULTS

A total of 91 students were involved in this Work-In-Progress study; 52 in the continuous group and 39 in the discrete group. The actual understanding of the student cohorts, based on scoring of the objective questions, are shown in Fig. 2.

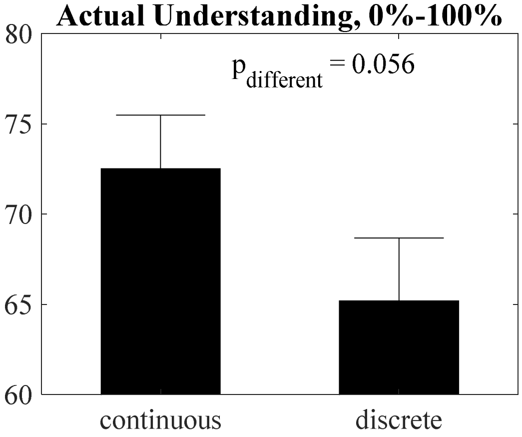


Fig. 2. Comparison of the objectively-scored questions from the two cohorts. The error bars represent the standard error of the mean. In the given sample size, statistical significance at the 0.05 level is not achieved, although it is clearly close. Larger planned studies may, or may not, bridge this gap, clarifying whether or not continuous-style inputs on pedagogical programs improve learning efficacy

Although the objective data do not quite reach significance with this N=91 sample, students' self-assessments of their learning show much stronger differences that reach statistical significance, and curiously they show the *opposite* of what appears to be the objective truth; the cohort that used the continuous applications believed they understood less than the students that used the discrete applications (Fig. 3). This may reflect the Dunner-Kruger paradox that explains the cognitive bias which occurs when low-ability people lack the framework to assess their abilities accurately, and high-ability people overestimate the abilities of others [12,13].

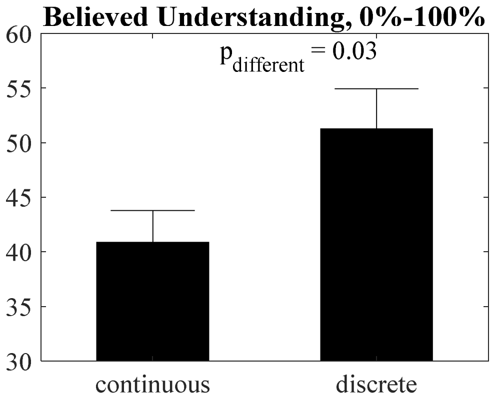


Fig. 3. Comparison of the students' self-assessment of their subject mastery before they completed the objectively-scored portion. It is noticeably below the objective scores, and surprisingly show a generally opposite trend from their actual understanding in Fig. 2

This relationship is graphically shown in Fig. 4, which shows individual students' actual understanding plotted against their subjective self-assessment. Because the underlying data are strongly gridded (there are only a limited number of objective questions, and the self-assessment is a Likert-graded scale with options), the data are shown with numbers representing the count of students with identical scores. Red scores represent those from the discrete group; green from the continuous group. The data points are displayed 1 percentage point higher and lower for red and green, respectively, so their numbers do not collide on the graph. The regression line is plotted for their aggregate and the R^2 value calculated, showing a slight negative correlation as previously discussed.

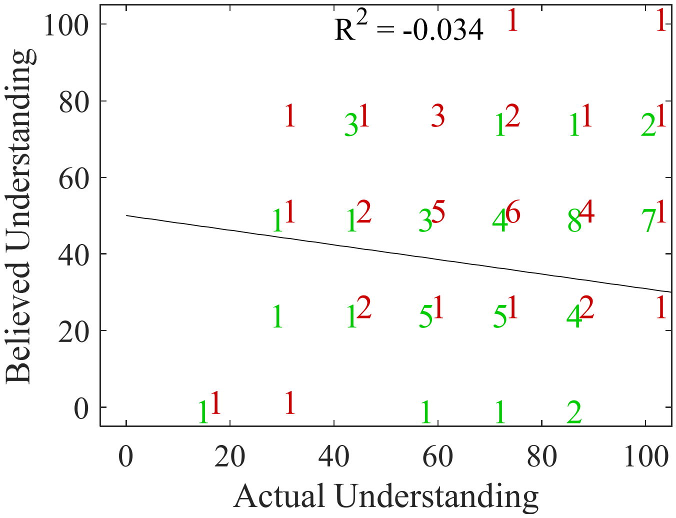


Fig. 4. Student self-assessed understanding compared with their objectively-determined understanding shows a negative correlation. Values from the continuous cohort are shown in green; the discrete cohort data are shown in red

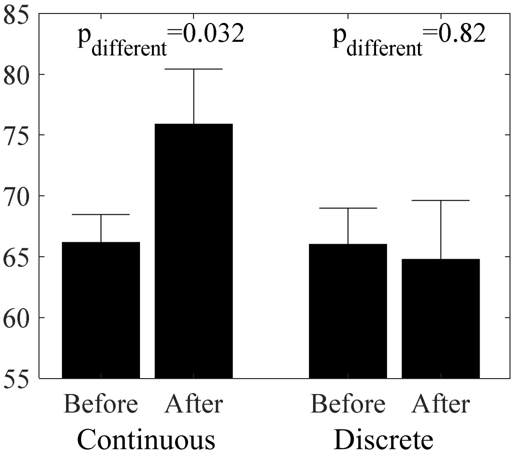


Fig. 5. Cohorts were asked to rate the pedagogic utility of interactive learning applications to understand causal engineering relationships such as they examined. The question was asked both before and after they completed the objectively-scored mastery test. Surprisingly, the continuous cohort who were asked the question after they completed the objectively-scored portion showed a statistically-significant difference from the other three categories

Students were asked to rate their perceived utility of interactive applications for teaching causal engineering relationships both before and after the students completed the objective assessment part of the test. Unsurprisingly, among most of these categories there were no significant differences observed, but the continuous cohort showed a significant ($p = 0.032$) increase in their ratings of the utility of these types of teaching tools when asked after they completed their objective testing. Larger cohort sizes with specific follow-up questions will be needed to understand what are causing these differences, since with the current cohort sizes we cannot yet determine if there is a difference between objective learning in the two cohorts (Fig. 2).

4. CONCLUSION

The data show a larger student cohort than 91 is needed to determine if the central hypothesis can be proven: That application programs whose inputs are continuously-variable and have constantly-updated outputs provide a more effective learning tool than applications that provide discrete inputs and push-to-update outputs. Specifically, greater numbers of students will need to be tested using the applications reported in this paper to determine if statistically-significant differences can be reached. Further, several different applications will need to be designed to determine if the results reported in this study can be generalized, since it is possible that certain topics are inherently better suited to continuous vs. discrete simulation. Initial data suggest that differences in student learning between these modalities do indeed exist, and that although student self-assessment is a poor tool, it may be helpful to include subjective assessments both before and after the objective assessment.

If larger subsequent studies show significant and generalizable difference occur between pedagogical applications that use continuous graphical inputs and constantly-updated outputs rather than text-box inputs and push-to-update output methods, it may have an impact on future pedagogical engineering simulation designs.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Zuckerman DW, Horn RE. The guide to simulation games for education and training. Waltham, MA: Information Resources; 1970.
2. Aldrich C. Learning by doing: A comprehensive guide to simulations, computer games, and pedagogy in e-learning and other educational experiences. San Francisco, CA: Jossey-Bass; 2005.
3. Laurillard D. Technology enhanced learning as a tool for pedagogical innovation. J. of Philosophy of Education. 2009;521-533.
4. Adams AM. Pedagogical Underpinnings of Computer-Based Learning. 2004;5-12.
5. Huffman D, Goldberg F, Michlin M. Using computers to create constructivist learning environments: Impact on pedagogy and achievement. J. Computers in Mathematics and Science Teaching. 2003;22(2):151-168.
6. Salzmann C, Gillet D, Piguet Y. Massive online laboratories for MOOCs: A first edX scalable implementation. IEEE Proceedings of the 13th International Conference on Remote Engineering and Virtual Instrumentation, Madrid, Spain. 2016;246-251.
7. Gadanidis G. Designing a mathematics-for-All MOOC. E-Learn: World conference on E-learning in corporate, government, healthcare, and higher education, Las Vegas, NV, USA, Association for the Advancement of Computing in Education (AACE). 2013;704-710.
8. Dabbagh N, Benson AD, Denham A, Joseph R, Al-Freih M, Zgheib G. Massive open online courses. Learning Technologies and Globalizations, Springer Briefs in Educational Communications and Technology. Springer. 2015;9-13.
9. Squire J. Phasor Research.
Available:https://www.jimsquire.com/research/phasors/phasors.htm
[Accessed 1 Jan 2020]

10. Squire J. Phasor Tutorials.
Available:https://www.jimsquire.com/research/phasors/tutorial1.pdf
[Accessed 1 Jan 2020]
11. Squire J. Phasor Questionnaire.
Available:https://www.jimsquire.com/research/phasors/ questionnaire1.pdf
[Accessed 1 Jan 2020]
12. Kruger J, Dunning D. Unskilled and Unaware of It: How Difficulties in Recognizing One's Own Incompetence Lead to Inflated Self-Assessments. J. of Personality and Social Psychology. 1999;77(6):1121–1134.
13. Dunning D. The dunning–kruger effect: On being ignorant of one's own ignorance. Advances in Experimental Social Psychology. 2011;44:247–296.

Biography of author(s)

Dr. James C. Squire
Virginia Military Institute, Lexington, VA, USA.

He is the Jamison-Payne Professor of Electrical Engineering at the Virginia Military Institute, USA. He received B.S. degree from the United States Military Academy and Ph.D. degree from the Massachusetts Institute of Technology. He was awarded a Bronze Star in the Army during Desert Storm and was selected as Virginia's Rising Star professor in 2004. He is a licensed Professional Engineer in Massachusetts and Virginia and maintains an active consulting practice.

Dr. Gerald A. Sullivan
Virginia Military Institute, Lexington, VA, USA.

He is a Professor of Mechanical Engineering and holder of the Hardaway Chair at the Virginia Military Institute,USA. He received his Ph.D. from Rensselaer Polytechnic Institute in 1991. Prior to joining the faculty at the Virginia Military Institute in 2004, he held teaching positions at the University of Michigan-Dearborn and the University of Vermont, then took on a research position in the semi-conductor industry where he was involved in the development of precision alignment systems for X-ray Lithography applications. His research interests include electromechanical design, materials, and control systems, with research applications ranging from seismic communication systems for rescue operations in coal mines, robotic tick eradication, and most recently space structures.

Dr. Thomas J. McCormick
Virginia Military Institute, Lexington, VA, USA.

He is a professor of Electrical Engineering and Physics at the Virginia Military Institute. He has also served as a professor at the George Washington University teaching graduate level engineering. He severed a 30 year career in the US Army and a total of 37 years in the Federal Government retiring as a Senior Executive. He has published in National and International journals as well as IEEE and ASEE publications.

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