Pedagogical Efficiency of Continuous vs. Discrete User Interaction with Computer Simulations

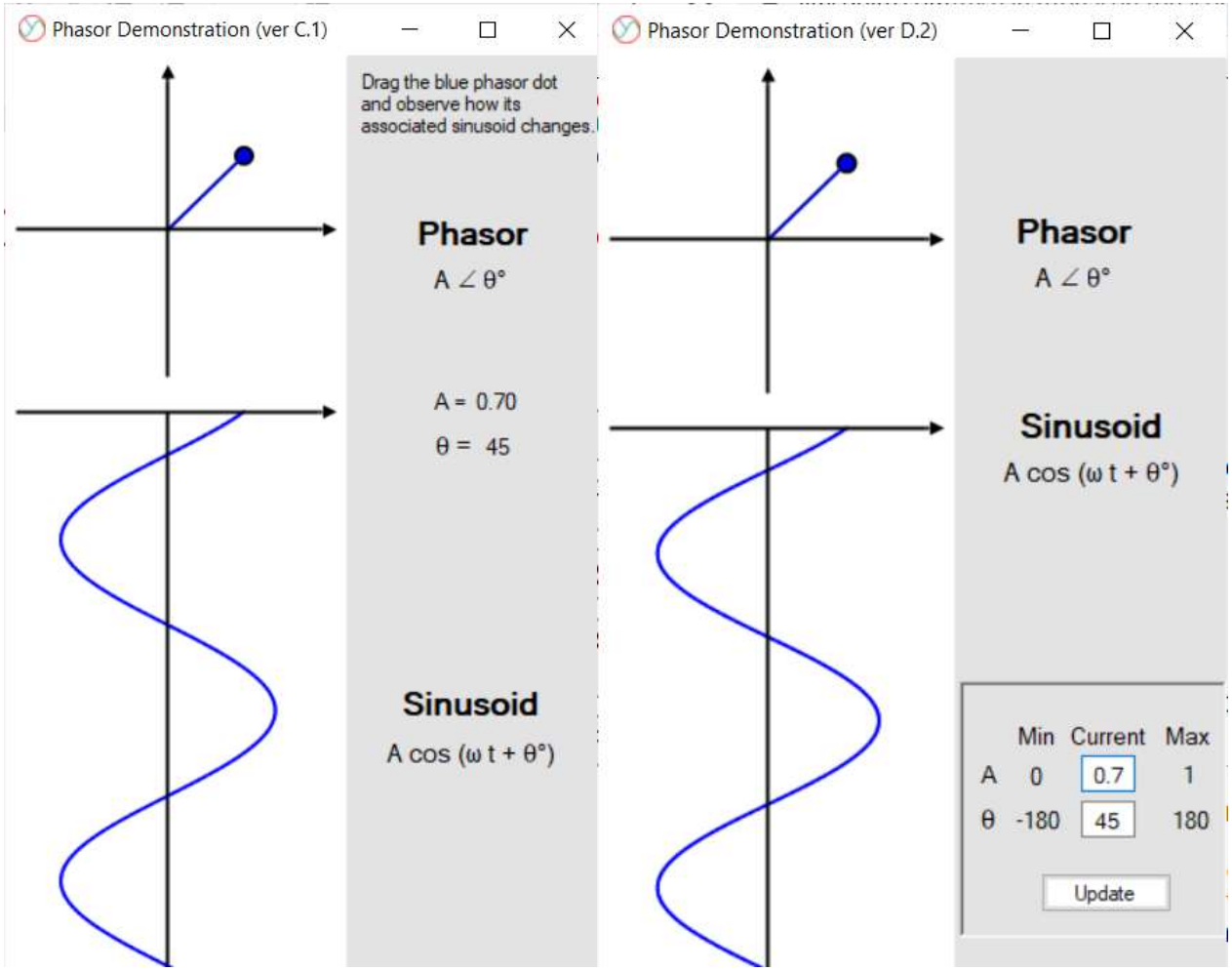
Dr. Gerald A. Sullivan
Mechanical Engineering Dept.
Virginia Military Institute
Lexington, VA, USA

Dr. David Feinauer
Electrical and Computer Engr. Dept.
Virginia Military Institute
Lexington, VA, USA

Dr. James C. Squire
Electrical and Computer Engr. Dept.
Virginia Military Institute
Lexington, VA, USA

Overview

Which is Better?



Background Context

- Computer simulations important part of modern STEM pedagogies
- Many simulations may be categorized by:
  - ***Discrete User Interfaces***--- simulation parameters set by text or numerical input
  - ***Continuous User Interfaces***----simulation parameters set by virtual knobs, sliders and/or mouse based selection from graphical operating curves
- Multiple interface modes identified as critical features for engaging students and boosting learning outcomes (Scalise)
- Simulations that include virtual knobs and sliders result in higher cognitive functioning than textbook-based courses, (Fang & Tjavadi)

Outline

- Purpose
  - Quantitative comparison of the pedagogical efficiency of simulations utilizing continuous user interfaces vs. discrete user interfaces
- Methods
- Results
- Conclusions

Methods

- Examine pedagogical efficacy of continuous and discrete user interfaces with a Phasor Simulator

- **Step I:** Distribute a 3 page tutorial
  - Covers basics of phasor analysis
  - https://www.jimsquire.com/research/phasors/

- **Step 2:** Randomly assign Continuous (C) or the Discrete user interface (D) simulation tool
  - 10-12 minutes learning with tutorial + sim

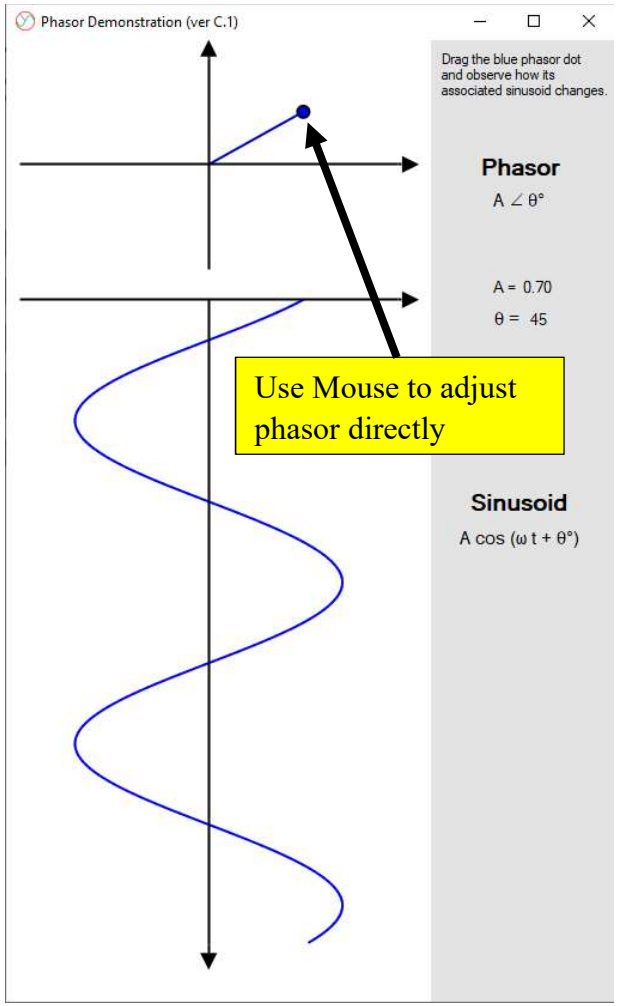


Figure 1: Phasor Simulation version C, with Continuous User Interface

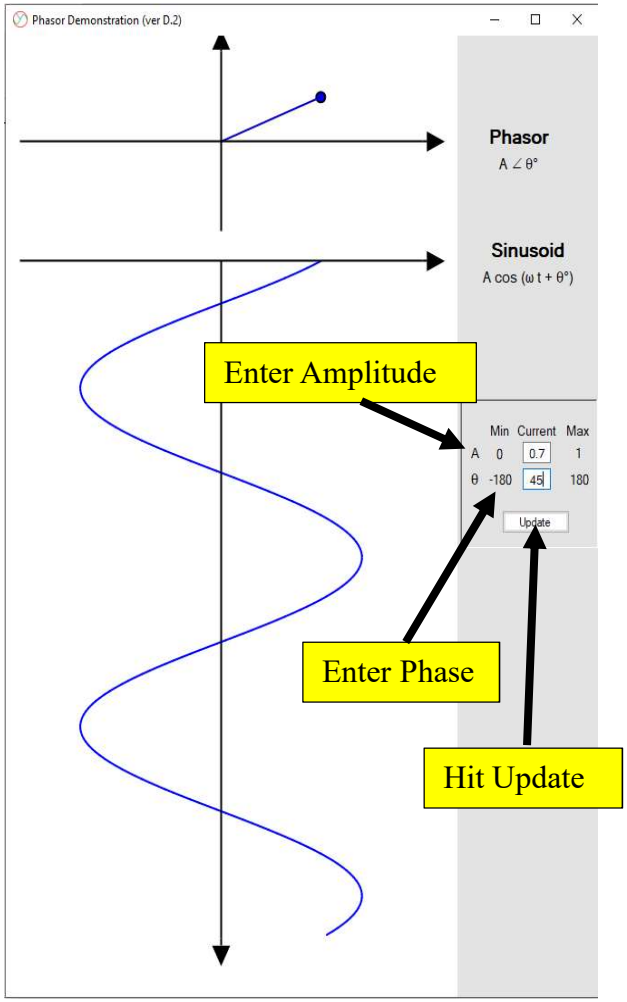
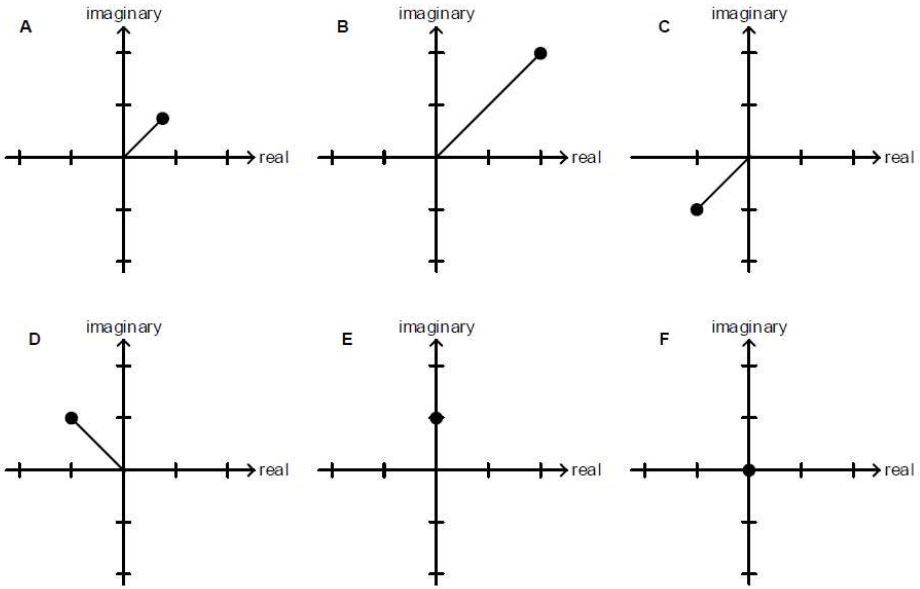
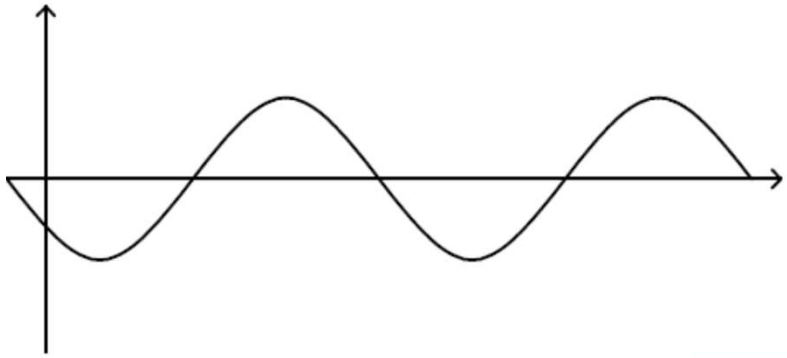


Figure 2: Phasor Simulation version D, with Discrete User Interface

- **Step 3:** 10 minute, 15 question quiz performed without access to simulation program
  - **Questions 1-5:** Background information including:
  - **Question 6:** Student self-assessed knowledge of phasors (Likert 1 to 5)
    - "*How well do you feel you understand the relationship between a phasor and its associated sinusoid?*"
  - **Question 7:** Student rating of effectiveness of program for teaching phasor concepts (Subjective pre-test rating)

- **Questions 8-14:** Multiple choice questions on phasor concepts (Objective Knowledge).
  - *Match a phasor representation A-F with a given sinusoidal wave for:*





- **Question 15:** Student rating of effectiveness of simulation program for teaching phasor concepts (Subjective post-test rating)

Results

- One-tailed t-test for the sample size of N=137 students, *($N_{continuous}$ = 75 and $N_{discrete}$= 62),* showed the higher observed objective learning scores for the continuous user interface were **statistically insignificant** with p=0.14

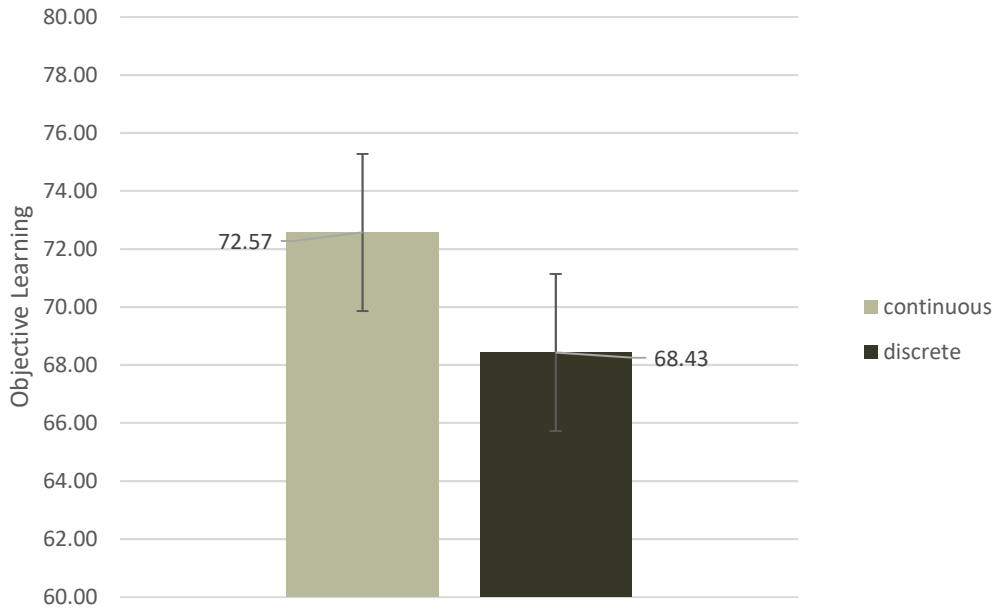
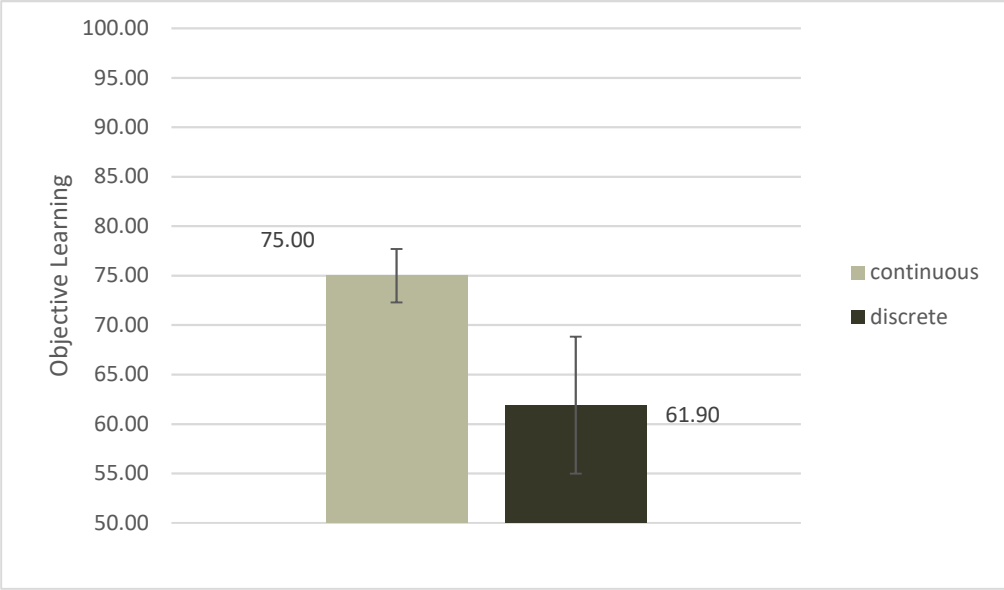


Figure 3: Average Objective Learning Scores for Continuous and Discrete User Interfaces

- Students <= 19 years of age, one tailed t-test showed that greater observed objective learning for the continuous user interface is **nearly statistically significant** with p=0.051



$N_{continuous} = 28$
$N_{discrete} = 15$

Figure 4: Average Objective Learning for Continuous and Discrete User Interfaces for Underclassmen

- Students > 19 years of age, almost no difference is observed between objective learning scores for the continuous and discrete user interfaces

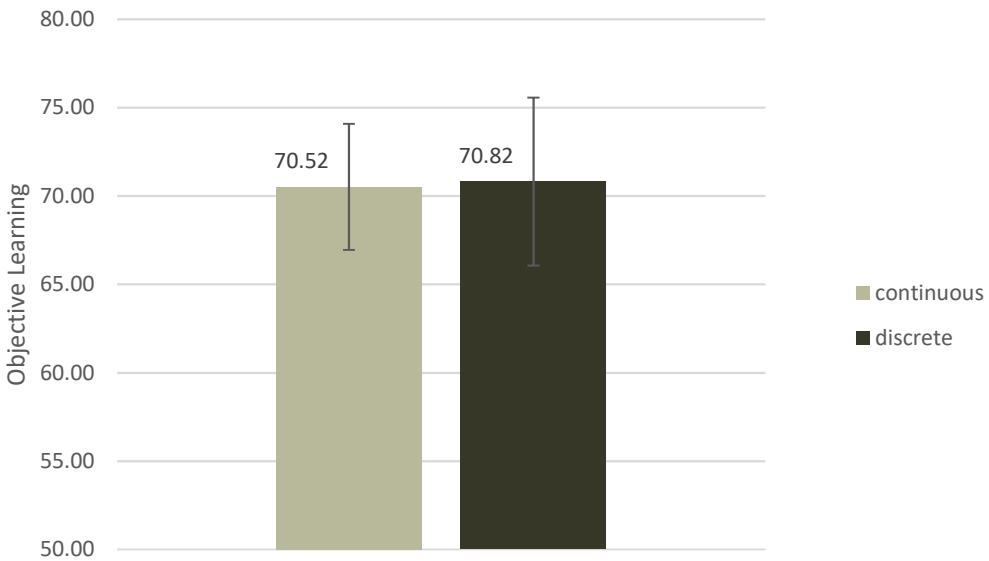


Figure 5: Average Objective Learning for Continuous and Discrete User Interfaces for Upper Classmen

- Upper classmen characterized by lower variability in objective learning and higher confidence in their abilities than underclassmen regardless of user interface.
- Underclassmen appear to have lower confidence and higher objective learning with the continuous user interface

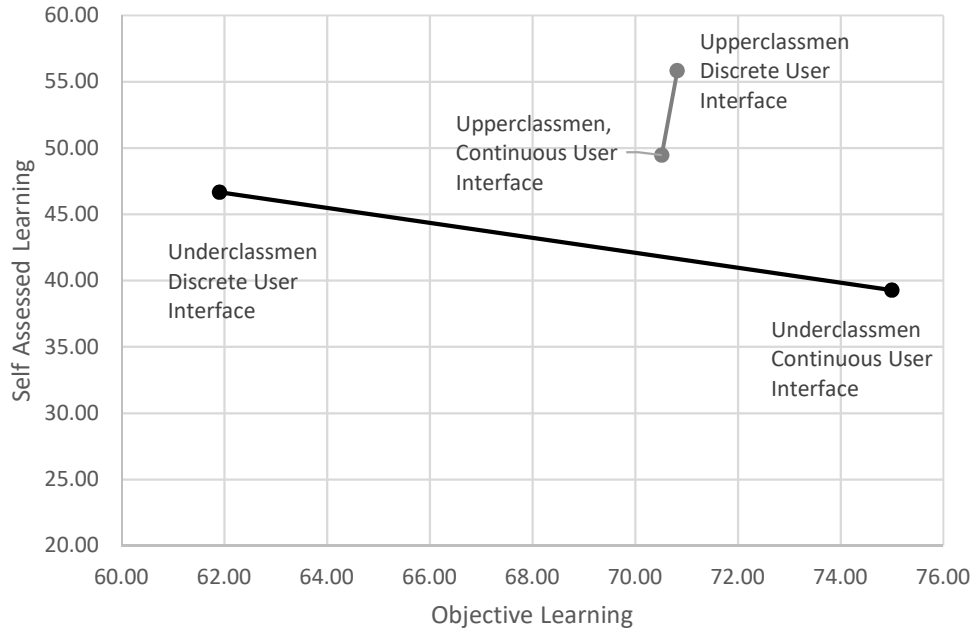


Figure 6: Self Assessed Learning vs Objective Learning for Underclassmen and Upperclassmen

- For both underclassmen and upper classmen, subjective ratings of the discrete user interface increase from their pre-test assessments to their post-test assessments.

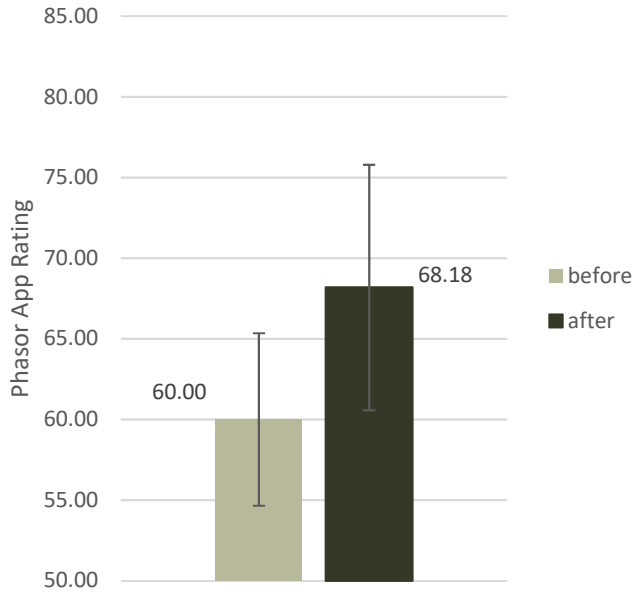


Figure 7: Rating of the Discrete Simulation App Usefulness for Underclassmen Before and After Conceptual Questions

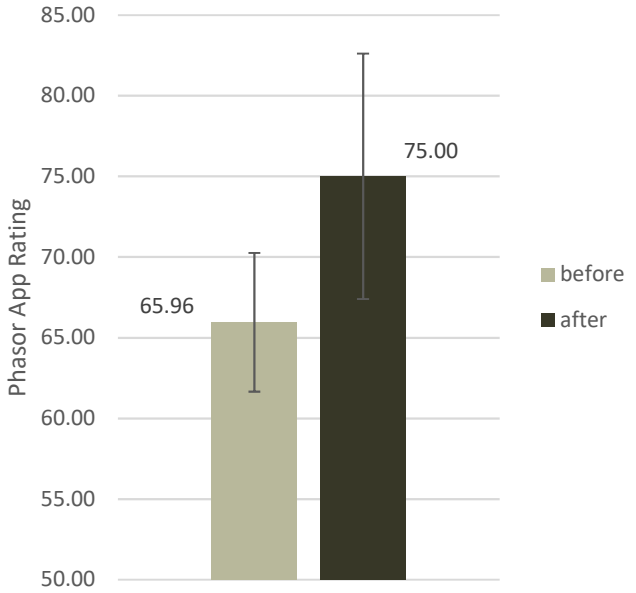


Figure 8: Rating of the Discrete Simulation App Usefulness for Upperclassmen Before and After Conceptual Questions

- For both underclassmen and upper classmen subjective ratings of the continuous user interface increase from their pre-test assessments to their post-test assessments.

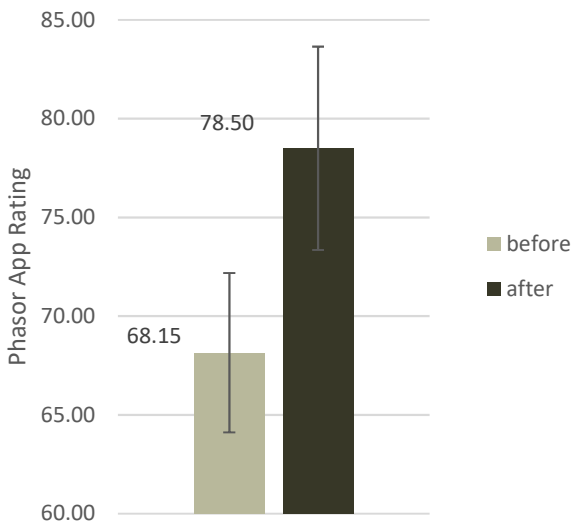


Figure 9: Rating of the Continuous Simulation App Usefulness for Underclassmen Before and After Conceptual Questions

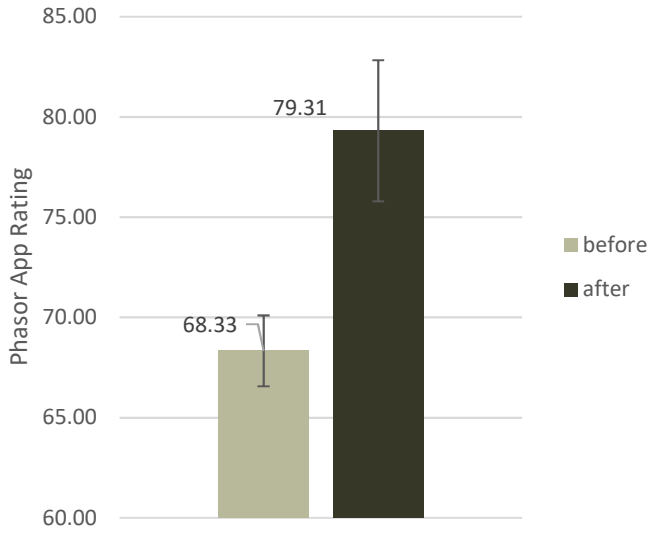


Figure 10: Rating of the Continuous Simulation App Usefulness for Upperclassmen Before and After Conceptual Questions

Conclusions

- **Younger** students **more sensitive** to user interface type
- **Comprehension was greater** with underclassmen using **continuous** version
- **Upper classmen** more confident and **interface** type **mattered little**
- Finding important—***implies more sophisticated simulation user interfaces positively benefit first year students.***

Future Work

- Explore significance level of .051 related to hypothesis that objective learning for underclassmen
- Seek to prove statistical significance using larger sample size
- Power test indicates sample size of 80 needed to obtain a significance level of .05 at power level greater than .8

Questions?

"…to produce educated, honorable men and women, prepared for the varied work of civil life, imbued with love of learning, confident in the functions and attitudes of leadership, possessing a high sense of public service, advocates of the American Democracy and free enterprise system, and ready as citizen-soldiers to defend their country in time of national peril."