

Using Real-Time Sensors in the Engineering Classroom: The Ongoing Development of an Engineering Education Experiment

Matthew W. Ohland and Elizabeth A. Stephan
General Engineering, Clemson University, Clemson, SC 29634

Abstract

Clemson's NSF-sponsored EXPerimental Engineering in Real-Time (EXPERT) project is investigating the effect of using real-time sensors on student learning through graphical representations of various physical concepts and to facilitate learning the concept itself. This paper will address the development and adaptation of the experiment as a model for other engineering education experiments, describing the ongoing challenge of implementing an experimental protocol in a classroom environment, the expansion of the experimental protocol to include other test sites, and how formative assessment shaped the educational experiment.

Introduction

The goals and methods of Clemson's EXPerimental Engineering in Real-Time project have been described in detail in our earlier work.^{1,2,3} We seek to use real-time sensors in the classroom to provide quicker feedback to students during hands-on laboratory modules. To establish the efficacy of using the real-time sensors to improve student learning, an educational experiment was carefully designed to evaluate the laboratories in actual classroom situations, when used by various instructors, and when compared to laboratories that are pedagogically similar except that real-time sensors are not used.

In fall 2004, changes to the experiment design and project management were required due to the construction of a classroom to use student-centered activities in a large-enrollment classroom.⁴⁻⁹ There were changes related to the use of different classroom facilities, a change in class size from 44 to 72, a change in the number of students per table from 4 to 8, and a change in the number of lab sections from 20 to 12. In addition, another laboratory experiment was added to the experimental design to provide a more definitive experiment.

The experimental design for Fall 2004

In Fall 2004, three laboratories were used to provide a more definitive experiment. This allowed for use of the sensors in certain sections for the first lab, crossover of the intervention to other sections for the second lab, and the continuation of the intervention in those sections for the third lab. This required the development of a third lab that could be delivered in "sensor" and "non-sensor versions" that were otherwise pedagogically equivalent. Parallel versions of a fluid-mixing laboratory were developed for this purpose, and are detailed separately in these conference proceedings.¹⁰

Crossover and continuation design with blocking

Crossover designs allow each participant to be exposed to all “treatments” in our case the presence or absence of the use of sensors as a data collection agent. There are three “phases” to the experiment: Lab 1 Spring stiffness, Lab 2 Fluid mixing, and Lab 3 Beam stiffness. A total of eight section of CES 102 were selected for study. These sections, however, were not randomly selected. The principal criterion for selection to the study was the instructor. Of the 12 total sections of CES 102 taught in the Fall of 2004, 8 section were collectively taught by two instructors (4 sections each). This scheme provides us with a replication of the experiment with different instructors.

All sections in Phase 1 were randomly assigned to be in the Sensor or Non-Sensor groups (See Table 1 for a model of the design implemented). Each of the lab sections had an approximate enrollment of 72 students. Four sections were exposed to the use of sensors in the lab for collecting measurements and data entry and four sections used manual measurement and data entry. The same eight sections were used in Phase 2 of the experiment. The treatments were “crossed over” such that if a section used sensors in Phase 1, they did not use the sensors for data collection in Phase 2. Sensor/non-sensor assignments from Phase 2 were duplicated in Phase 3. The crossover design requires that lab (phase), the sequence to which the students were exposed to the sensors, and instructor constitute blocks, and can be used to determine if the use of the sensors as a data collection agent has a significant effect on students’ ability to understand the observed phenomena.^{11,12}

Table 1. Crossover and Continue Experimental Design

	Lab					
	Phase 1 Spring stiffness		Phase 2 Fluid mixing		Phase 3 Beam stiffness	
	Non- Sensor	Sensor	Non- Sensor	Sensor	Non-Sensor	Sensor
Dr. A ^s Sections	Section 1 Section 3	Section 2 Section 4	Section 2 Section 4	Section 1 Section 3	Section 2 Section 4	Section 1 Section 3
Dr. B ^s Sections	Section 5 Section 6	Section 7 Section 8	Section 7 Section 8	Section 5 Section 6	Section 7 Section 8	Section 5 Section 6

Testing Measures

Pre-tests and post-tests were developed for each lab and given to all students. Using a matched-pairs design, the change in grade (post-test – pre-test) will be recorded for each student and the overall section average were calculated to determine if a significant improvement was experienced by students in the sensor group versus the non-sensor group. Data collected during this semester is still being processed.

Deficiencies in Crossover Designs

The two-treatment, two-phase crossover design is very commonly used in many types of research. Problems arise in the “carryover effect” that may be experienced by the participants. The carryover effect is the effect of a treatment that continues into the next treatment period. In the original 2X2 crossover design, carryover effects are confounded with all other effects and cannot be removed or separated from the analysis without considerable assumptions. In the case of this research, the carryover effect is learning itself.¹² In this revised design, the continuation of the intervention to Phase 3 provides a mechanism for studying the carryover effect. Steps have also been taken to reduce the carryover effect:

1. Predicted grade-point ratios are available for use as a pre-semester baseline measure.
2. The labs focused on different phenomena, which may mitigate any “learning” effect the students may have experienced as it affects performance in other laboratories.
3. End of semester grades are available to use as a post-semester measure.

Findings

Results from testing the laboratories in the Fall 2003 at Clemson University showed that students in the labs without electronic sensors did just as well as those using the electronic sensors. This finding would support what many other studies have shown—that good teaching is what matters most if all other things are held constant. This finding points to the critical need for faculty development—if educational design is more important than classroom technology, improving engineering education requires that a large number of faculty are supportive and informed about modern teaching methods.

The Fall 2003 data did indicate that classes that were “behind” at the beginning of the semester seemed to “catch up” by the end of the semester, possibly indicating that the use of the sensors helped level the playing field for students who did not have the chance to work with quality lab equipment in their public school.

Conclusions

Data collected in Fall 2004 at Clemson and other test sites will add to the findings from Fall 2003 that were published earlier. The experimental design of the EXPERT project is both statistically sound and educationally appropriate. The results of the study will establish the efficacy of using real-time sensors while controlling for variability due to individual preparation and ability, lab, instructor, and pedagogical style. The pre- and post-tests for the semester and each laboratory will be published along with the results of the study when available.

Acknowledgements

We are grateful to Amy G. Yuhasz, former postdoctoral student, who created the experimental design. This material is based upon work supported by NSF DUE CCLI EMD Award Number 0127052, “Clemson’s Experimental Engineering in Real-Time (EXPERT) Program.”

*Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition
Copyright © 2005, American Society for Engineering Education*

References

- [1] Ohland, M.W., E.A. Stephan, and B.L. Sill, "Clemson University's EXPerimental Engineering in Real Time (EXPERT) Program: Assessing the benefit of real-time sensors in the curriculum," *Proc. Amer. Soc. Eng. Ed.*, Nashville, Tennessee, June 2003.
- [2] Ohland, M.W., E.A. Stephan, B.L. Sill, and W.J. Park, "Applications of real-time sensors in the freshman engineering classroom" submitted to *Proc. Amer. Soc. Eng. Ed.*, Salt Lake City, Utah, June 2004.
- [3] Yuhasz, A.G., M.W. Ohland, E.A. Stephan, "The Use of Sensors in the Engineering Classroom: Experimental Design Considerations" *Proc. Amer. Soc. Eng. Ed.*, Salt Lake City, Utah, June 2004.
- [4] Beichner, Robert J., and John S. Risley, "SCALE-UP (Student Centered Activities for Large Enrollment University Physics)," <https://www.fastlane.nsf.gov/servlet/showaward?award=9752313>
- [5] Beichner, Robert J., and John S. Risley, "SCALE-UP (Student Centered Activities for Large Enrollment University Physics)," <https://www.fastlane.nsf.gov/servlet/showaward?award=9981107>
- [6] Beichner, R.J., L. Bernold, E. Burniston, P. Dail, R. Felder, J. Gastineau, M. Gjertson, and J. Risley, "Case study of the physics component of an integrated curriculum," *Physics Education Research Supplement to American Journal of Physics* **67**(7), S16, 1999.
- [7] Beichner, R.J. J.M. Saul, R.J. Allain, D.L. Deardorff, D.S. Abbott, "Introduction to SCALE UP : Student-Centered Activities for Large Enrollment University Physics," Proceedings 2000 American Society for Engineering Education National Conference.
- [8] Saul, J.M. D.L. Deardorff, D.S. Abbott, R.J. Allain, and R.J. Beichner, "Evaluating introductory physics classes in light of ABET criteria : An Example of SCALE-UP Project," Proceedings of the 2000 Annual meeting of the American Society for Engineering Education.
- [9] Beichner, R.J., J.M. Saul, R.J. Allain, D.L. Deardorff, D.S. Abbott, "Promoting collaborative groups in large enrollment courses," Proceedings of the 2000 Annual meeting of the American Society for Engineering Education.
- [10] Ohland, M.W., E.A. Stephan, and B.L. Sill, "Adapting Engineering Laboratories to Enhance Learning using Real-Time Sensors in Freshman Programs," abstract accepted, *Proc. Amer. Soc. Eng. Ed.*, Portland, Oregon, June 2005.
- [11] Kuehl, R. O. *Statistical Principals of Research Design and Analysis*. Duxbury Press, Belmont, California 1994.
- [12] Ratkowsky, D. A., Evans, M. A., and Alldredge, J. R. (Editors) *Cross-over Experiments: Design, Analysis, and Application*. Marcel Dekker, Inc., New York 1993.

Author biographies

MATTHEW W. OHLAND

is an Assistant Professor in Clemson University's General Engineering program and is the President of Tau Beta Pi, the national engineering honor society. He received his Ph.D. in Civil Engineering with a minor in Education from the University of Florida in 1996. Previously, he served as Assistant Director of the NSF-sponsored SUCCEED Engineering Education Coalition. His research is primarily in freshman programs and educational assessment.

ELIZABETH A. STEPHAN

is an Instructor in Clemson University's General Engineering program. She received her Ph.D. in Chemical Engineering the University of Akron in 1999. Previously, she has been an instructor and visiting researcher at the University of Akron and a manufacturing engineer at Dow Chemical.