An action research project investigating

Inquiry Methods in Laboratory Electronics for Physics Majors

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Introduction

Research in physics education conducted in the last two decades has shown that misconceptions about physical phenomena are common and deeply engrained. Studies by Dr. Lillian McDermott's physics education research group at the University of Washington and others have demonstrated that a student's ability to "solve quantitative problems is not a reliable measure of conceptual understanding."[1] Such conceptual errors about electricity are rampant in our culture's common mindset, from "current follows the path of least resistance" to reinforcement through errors in recent textbooks (Fig 1.)

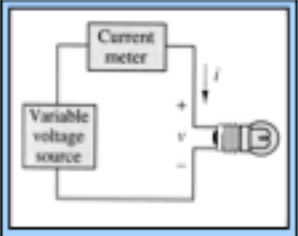


Figure 1. This graphic, from Giorgio Rizzoni 's 2007 "Principles and Applications of Electrical Engineering"[2], is intended to assist a discussion of element constraints. It also contains a circuit error.

This action research project was carried out in the sophomore-level Laboratory Electronics I course required in the physics curriculum at Montana State University. Data was collected in two offerings of the course, Fall 2006 (n=18) and Fall 2007 (n=20), to allow comparison of treated and untreated populations.

Research Questions

Research Questions	Data Methods
How does physics-by-inquiry pedagogy affect the ability of physics majors to evaluate simple DC electric circuits?	α, β,γ, δ
Is it easier for physics majors to solve circuit problems if values are assigned to the circuit elements?	α, β, γ
Does follow-up sampling suggest any long term (2-3yr) post-treatment changes in the retention of this material?	α

Data Collection Methods Key

α – DIRECT instrument
β – Practical exam and interview
γ – Formative and summative assessments
δ – Reflective journaling

Treatment

The Laboratory Electronics sequence (PHYS261 and PHYS361) makes up two 2-credit courses offered in consecutive Fall and Spring semesters. The schedule provides for 1 hour of lecture, followed on a different day by a 3 hour lab period. The first semester (PHYS261) as taught over the last 5 years focused on passive and active DC circuits. Reactive elements (capacitors and inductors) are introduced in the last few weeks of the first course in the sequence.

In the Fall 2007 semester the first three weeks of material on series and parallel resistors, Kirchhoff's laws and power supplies were replaced by the first three sections of Part A of Electric Circuits from the text *Physics By Inquiry, Volume II* by Lillian McDermott.[3]

Methods

DIRECT

"Determining and Interpreting Resistive Electric Circuit Concepts Test"[4] is a 29-question inventory designed to evaluate a student's understanding of several basic concepts, including voltage and current, of an electric circuit. This instrument provides;

- Bench mark for students enrolled in the Laboratory Electronics I compared to a large number of high school and university students
- Comparison between treated and untreated groups enrolled in Laboratory Electronics classes offered Fall 2006 and 2007)
- Pre- and post-instruction measure of learning gains made in the Fall 2007 group

Formative and Summative Assessments

Quizzes and classroom assessment techniques were used to probe students' performance on two problems that are electrically identical. In the first case, a problem referred to as Francis' Fabulous 8 Bulb Problem (FF8BP)[5] in Figure 2, provides the instructor with an opportunity to probe conceptual, qualitative understanding of electric circuits.

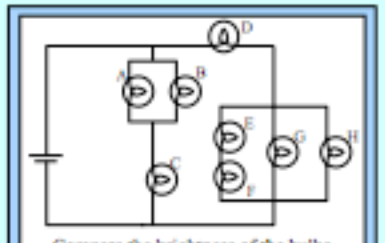


Figure 2. FF8BP provides a qualitative test of conceptual understanding.

The Quantitative 8 Resistor Problem (Q8RP) shown in Figure 3 is the electrical twin of the qualitative FF8BP. The structure of this problem invites students to apply formal circuit analysis methods. Computing the operating point of this circuit should be light work for a student enrolled in Laboratory Electronics.

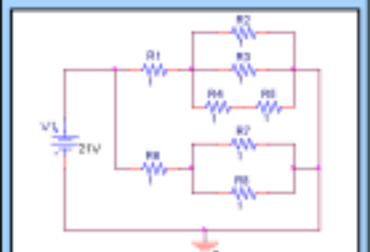


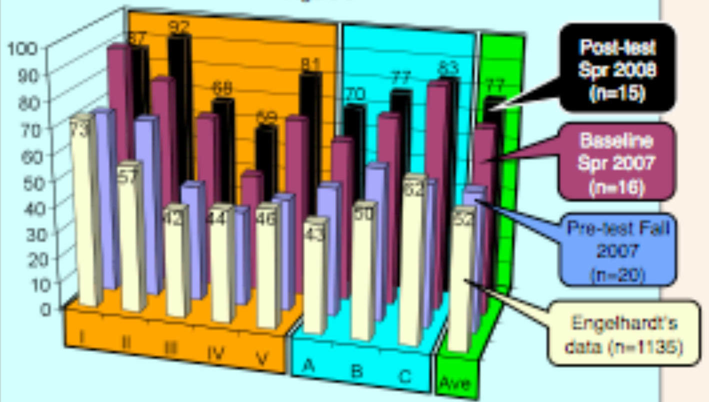
Figure 3. Q8BP provides an opportunity to evaluate understanding of conventional analysis methods.

The three circuits in Fig. 4, taken from a paper by McDermott et. al. (1992)[1], form a simple test of understanding of voltage and current. These circuits were used in this project for a practical exam to permit individualized evaluation of students' misconceptions.

Figure 4. McDermott's test of understanding. In her study, only 15% of calculus-based physics students were able to correctly rank the brightness of the bulbs.

Results

DIRECT



The bar graph in Fig. 5 presents the results of several topical groupings by the author of the instrument (Engelhardt) and a different grouping by the author of this project (Getty). The four rows represent the results for Engelhardt's original study, pre- and post-instruction results for the treated group, and post-instruction results for the un-treated baseline group.

Evaluator	Objective	Description
Englehardt	I	Mechanics of circuits
	II	Equivalent circuits
	III	Conservation of energy
	IV	Conservation of current
	V	Potential difference
Getty	A	Battery as voltage source
	B	Kirchhoff's voltage law
	C	Kirchhoff's current law
Both	Test Ave	Total correct answers

A plot of post-instruction DIRECT results for both the baseline and treatment groups (Fig. 6) show generally better performance on the DIRECT with higher GPA. DIRECT scores for the untreated population have greater scatter and show no, or perhaps even an inverse, relationship between the DIRECT score and GPA. The baseline group wrote the DIRECT in April of 2007. The treatment group data is from April of 2008.

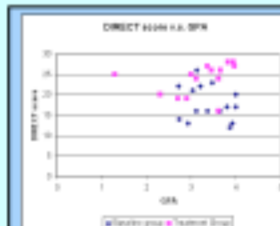


Figure 6. Comparison of post-instruction DIRECT score as a function of student GPA for both treated and untreated populations.

Formative and Summative Assessments

The treatment group, on assessments offered at different times, completed both of the twin problems, the quantitative FF8RP (Fig 2.) and qualitative Q8BP (Fig. 3). Even after exposure to the inquiry method, students performed better on the problem that could be solved using quantitative, formal algorithmic circuit analysis methods.

Qualitative versus quantitative test questions (n=20)	
Evaluation structure	Correct
Qualitative (FF8BP, Fig 2)	73%
Quantitative (Qnt8BP, Fig 3)	85%

Conclusions

These data suggest that incorporating inquiry methods into the Laboratory Electronics I course improved the ability of physics students to qualitatively evaluate electric circuits, even while they continue to depend on their strength in finding mathematical solutions to confirm their results.

Interpretation of the results of the several data collection methods lead to the following additional conclusions.

- Students develop skills needed to solve qualitative circuits problems when they are exposed to inquiry techniques. Results show an improvement among the treated class in nearly all categories evaluated.
- Data sufficient to quantify the effect of inquiry techniques on students' ability to solve quantitative problems was not obtained. However, personal observations indicate that even short exposures to inquiry methods encourage students to develop useful qualitative models.
- Physics students will often restate a qualitative circuit problem in terms of quantifiable variables to produce a solution.
- The laboratory is a powerful tool in the quest to help students develop a robust mental model.

Future Work

- Conduct a follow-up evaluation of the two groups in 2 or 3 more years to see if there are any longer-term impacts.
- Comparing the performance of students enrolled in the honors general physics class, (which has historically been based on the inquiry method), to students with similar academic preparation (GPA, SAT scores) could be informative.
- In this study, the data was insufficient to determine if student performance on quantitative problems was improved by exposure to the inquiry method. Since ability to solve such problems is an ongoing test for "doing physics," the answer to this question might strengthen the argument for including inquiry in our college curricula.

Literature cited

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2. Rizzoni, Giorgio (2007). Principles and Applications of Electrical Engineering. New York, NY: McGraw-Hill., P43, Fig 2.27, (used with permission)
3. McDermott, L. C. (1995). Physics by inquiry: An introduction to physics and the physical science, Volume 2. John Wiley and Sons.
4. Engelhardt, P. V., & Beichner, R. J. (2004). Students' understanding of direct current resistive electrical circuits. Am. J. Phys.. 72, 98-115.
5. Francis, Greg (2007), Lecture to PHYS500–Teaching seminar, Oct 15, 2007

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For further information

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