Chapter 4.6
Designing Animated Simulations and Web-Based Assessments to Improve Electrical Engineering Education

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ABSTRACT

Over the past decade, our research group has uncovered more evidence about the difficulties undergraduate students have understanding electrical circuit behavior. This led to the development of an AC/DC Concept Inventory instrument to assess student understanding of these concepts, and various software tools have been developed to address the identified difficulties students have when learning about electrical circuits. In this chapter two software tools in particular are discussed, a web-based dynamic assessment environment (Inductor) and an animated circuit simulation (Nodicity). Students showed gains over time when using Inductor, and students using the simulation showed significant improvements on half of the questions in the AC/DC Concept Inventory. The chapter concludes by discussing current and future work focused on creating a more complete, well-rounded circuits learning environment suitable for supplementing traditional circuits instruction. This in-progress work includes the use of a contrasting cases strategy that presents pairs of simulated circuit problems, as well as the design of an online learning community in which teachers and students can share their work.

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INTRODUCTION

Students often have specific difficulties understanding basic electricity concepts (e.g., Duit, et al., 1984; Caillot, 1991). One of the primary difficulties students have in learning about and understanding circuit behavior is the *current consumption model*, where current is viewed as a substance that is "consumed" by a device, such as a light bulb or resistor (Reiner et al., 2000). Students may conceive of a battery as a constant current source rather than a source of invariant voltage (Engelhart & Beichner, 2004). Students may also fail to differentiate between current and voltage, and power and energy (McDermott & van Zhee, 1984). Previous research has primarily been concerned with simple direct current (DC) circuit problems, and this may inadvertently guide one towards instructional decisions that reinforce misconceptions and difficulties students have when learning in other contexts. As part of an Office of Naval Research (ONR) funded project at Vanderbilt University, we extended research of student understanding of electric circuits into the domain of alternating current (AC) circuits. We were motivated by questions such as, to what extent do students exhibit the same misconceptions that they exhibit for DC circuits? How do students interpret time-varying phenomena?

Student Interviews

In interviews with students working on electrical circuit problems, we found that students had much greater difficulty understanding time-varying phenomena in circuits. We also found that students focused on manipulating formulas and performing numerical calculations during problem solving, and not applying the underlying principles or *invariants*, such as Kirchoff's or Ohm's laws, that govern circuit behavior. Analyzing common student difficulties that we identified, and by studying expert problem solving behavior, we developed a web-based tool (Inductor) for assessing and guiding students' learning of DC and AC circuits. Using Inductor we explored an additional research question: What are the effects of automated, invariants-based feedback on self-assessment and learning of electric circuit behavior? We found that by using this feedback students improved their problem solving performance in a short time, and were able to better explain their understanding of electric circuits.

Our protocol analysis of interviews with students solving circuit problems brought to light a number of difficulties students exhibit in both DC and AC circuit domains (Schwartz, et al., 2000; Biswas, et al., 2001). The misconceptions appeared to fall into three general categories: (i) those specific to particular AC or DC concepts (such as believing an AC voltage varies in space along the wire rather than in time), (ii) general difficulties (such as a failure to differentiate concepts, or incorrect simplifying assumptions when multiple invariants have to be applied to analyze circuit behavior), and (iii) lack of basic circuit knowledge, such as when to apply particular invariant properties and laws of circuit behavior, and in analyzing the behavior of dynamic elements, such as capacitors. We created a list of misconceptions related to understanding AC circuits (Table 1).

AC/DC Concept Inventory

The catalog of student difficulties had performing circuit analysis formed the basis for the development of a set of multiple-choice questions to assess student understanding with larger groups of students: the AC/DC Concept Inventory (Holton, Verma, & Biswas, 2008). The questions asked for qualitative (not quantitative) answers, and unlike traditional multiple choice tests in which only the correct answers matter, these questions have foil responses that are specifically linked to particular misconceptions our group and others have identified. The correct answers to our test questions matter as well, because they are written to specifically target core invariant principles of circuit behavior that experts use (see Table 2 below). We can analyze both correct responses and incorrect responses for information about students' understanding of invariants, their misconceptions and other learning difficulties.