Designing Simulations for Evaluating Collaborative Problem Solving in Electronics

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Abstract: Collaborative problem solving (CPS) is a skill critical for the 21st century workforce, particularly in STEM fields. Assessment of CPS skill has thus received increasing attention. This paper describes a program of research in which we seek to design a suite of CPS simulation-based electronics tasks suitable for assessment use. We focus on the pilot study of one task, describing the task design and subsequent modifications implemented to better capture evidence of students' skills.

Introduction

Collaborative problem solving (CPS) has been identified as a critical competency important for the 21st century workforce (Burrus, Jackson, Xi, & Steinberg, 2013). CPS skills are particularly important in STEM fields, which often involve individuals with diverse skill sets and perspectives working together to solve a problem as opposed to individuals working in isolation. In this paper, we describe a program of research in which we have designed a suite of online CPS simulation-based tasks in the domain of electronics that 1) provide students free online access to solve real-world problems in electronics, 2) provide us a way to collect detailed data about how students work collaboratively (or not) to reach common goals, and 3) provide us the opportunity to develop methods to define and evaluate the contributions of and strategies employed by team members as they work collaboratively.

Collaborative electronics tasks

Evidence-centered design (ECD; Mislevy, 2011) was used to guide the iterative design of the simulation-based tasks. ECD provides a framework for combining domain information about the concepts covered in the simulation environment with information about the environment's specific goals, constraints, and logistics in order to create a blueprint for measuring performance within the environment.

Basic electronics provided a rich environment for study of student behaviors because 1) it is easily and efficiently represented graphically, 2) is easily simulated with minimal mathematical constraints, and 3) is directly representative of real-world activities with which students are familiar from laboratory experiences. One simulation in the suite of activities, the Three Resistor Activity, deals with the relationship between resistance, voltage, and current summarized by Ohm's Law: $V = I \cdot R$ (see Figure 1). Three students work as a team on separate computers, and each is provided with one simulated, variable resistor that is part of a series circuit (see circuit schematic in bottom of Figure 1). Students can measure the voltage across their own resistor (or current or resistance) with a simulated digital multimeter (DMM), and change their resistance value in an effort to achieve a prescribed "goal voltage drop." However, they soon discover that a change made to any one resistor affects the current through the circuit and therefore the voltage drop across all resistors. Thus, for all team members to achieve their goal voltage drops, they must coordinate their efforts, aided by the use of a chat box. The Activity has five levels of increasing difficulty. As students work through each level, their on-screen actions (e.g., DMM mode changes, resistor changes, calculator usage, chats) are captured, time coded, and saved as log files.

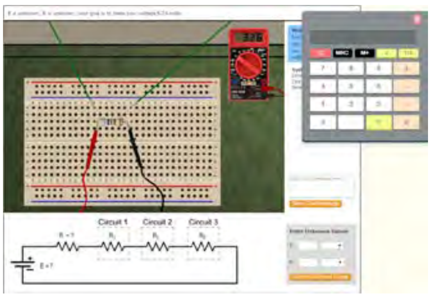

Figure 1. One student's screen in the Three Resistor Activity.

Pilot study

In a pilot study, students at a technical high school (15 teams), community college (36 teams) and public university (32 teams) participated in the Three Resistor Activity. That is, groups of three students, each located in different parts of the computer lab, were assigned to a circuit, and connected only by the chat window and the simulated wires joining their resistors. Our expectation was that students would approach the task much as they would a homework problem: determining and using the external voltage (E) and the external resistance (R_0) to calculate the resistance values that would yield their goal voltage drops, and set their resistance values accordingly. We expected either that the calculation might be accomplished by one team member and then communicated to other teammates, or that it might be reached by progressive consensus involving more than one team member. However, log file analyses indicated that this assumption was largely incorrect. Rather, many teams employed a strategy that resulted in exceptionally fast finish times (well under 60 seconds), few or no chats, and no calculations. Examining the log data revealed that, in these situations, each team member adjusted their resistance value up and down, trying to approach their goal voltage. Of course, because the resistors are connected to each other, each time one student changes their resistance and their voltage drop, everyone else's voltage drops change too. The log data showed that students simply persisted in their adjustments to their own resistance until everyone's voltages converged to the desired values. As a result, the students did not need to find E or R_0 or demonstrate any understanding of the circuit theory. Furthermore, since students who employed this strategy did not require any discussion, we were not able to capture much information about students' collaborative problem solving skills.

Closer investigation into the task design suggested that our user interface (UI) that permitted conveniently adjusting the resistance values with a horizontal "slider" actually encouraged students to scroll R values back and forth while viewing real-time changes in their voltage drop on the DMM. In effect, the log data allowed us to see that many students (though not all) demonstrated an ability to "game the system" with little or no verbal communication between themselves, and little or no application of physics knowledge. We called this a "voltage regulator strategy," since each student in effect behaved exactly as a digital voltage regulator would. In an effort to discourage this behavior in favor of more strategic collaboration, we produced a revised version of the activity, eliminating the slider, and instead requiring students to use a dropdown menu to choose a single new resistance value in order to observe the resultant voltage change. For our purposes, the dropdown menu removes the temptation for the student to simply slide the cursor back and forth in response to the voltage reading on the DMM, with little regard for the actual resistance value. By eliminating this possibility we hoped to subtly discourage them from adopting the voltage regulator strategy, and instead rely on collaboration. Additionally, for the more difficult levels we added input boxes for students to provide the E (voltage source) and R_0 (internal resistance) values. We anticipate that these UI changes will create better opportunities for us to capture information about students' content understanding and collaborative problem solving skills, as they will now presumably have more need to strategize with the electronics concepts, calculations, and discussions.

Conclusions and future work

Our pilot study has demonstrated how even very small changes in task UI can have major effects on the usefulness of a simulation-based task for assessment. Through an iterative design process, and by logging all student actions, we have been able to determine which design features create better opportunities for students to provide evidence of their skills. Currently, the revised version of the Three Resistor Activity is being evaluated to determine whether our UI modifications can better capture students' skills.

References

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