Differentiating Electrical Energy From Current

A Challenging Conceptual Change

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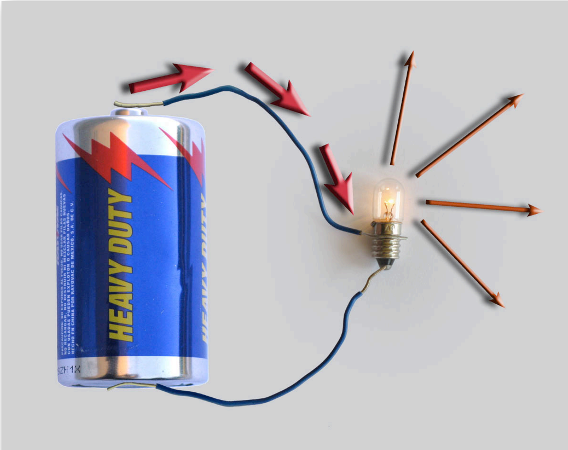
Current and Energy are different!

Electrical Current:

Conventional electrical current flows in one direction from the positive end of the battery to the negative end within a complete loop of conductors. The current reading is the same everywhere in a single loop.

Electrical Energy:

The current carries energy from the battery to the light bulb. In the light bulb electrical energy is converted to light and thermal energy which leaves the circuit never to return. This is why batteries wear out.



The Problem: Generalized "Electricity" Conception

Concept Differentiation:

Students often have difficulty understanding electrical circuits (Shipstone, 1985; Duit, von Rhoneck, 1998). One major difficulty is differentiating "electricity" flow into two separate concepts - current and energy flow. This "concept differentiation" (Dykstra, 1992), a form of "cognitive restructuring", is not easy. Learning science often involves fundamental restructuring of pre-existing or pre-instructional knowledge (Vosniadou, 1994). Restructuring is a difficult, troubling, and time consuming process that students often fail to undergo (Carey, 1988, Posner et al. 1982).

Problem:

Generalized Electricity Flow Model

Students in a 101 Physics class on electric circuits adopted an idea of "electricity" that flows in the circuit. This generalized "electricity flow" had many of the characteristics of both energy and current.

In previous semesters, students *measured current* in circuits but only *discussed* how *energy* is transferred. While it was evident that current and energy do not have the same flow behavior in circuits, students did not resolve this conflict on their own. Their descriptions often used the words "current" and "energy" interchangeably in the same sentence to describe what appeared to them as one thing, not two. They had to go through considerable logical gymnastics to describe energy transfers in circuits yet account for the fact that bulbs do not use up current.

Demonstrating energy measurements to students helped some but was not sufficient.

Student idea: current changes to energy inside the bulb, and changes back to current when exiting the bulb.

We wondered…Would a new activity that asks students to measure energy flow rate (power) in circuits help more students make this conceptual differentiation?

Course and Methods: Not your typical physics course!

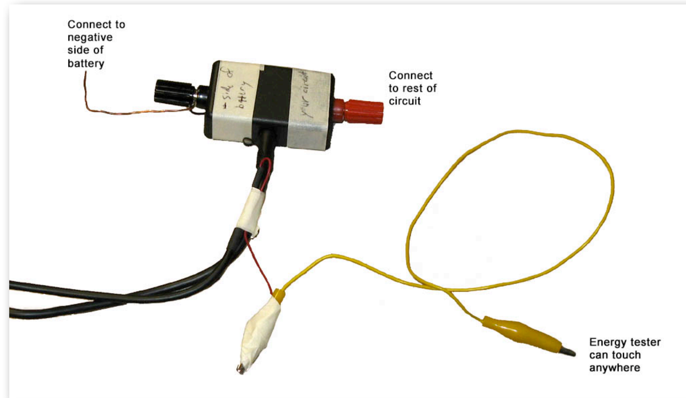
Course:

Survey of Physics at BHSU focuses on developing students' conceptual understanding. Students perform experiments, consider questions, make predictions, and make sense of their results like scientists. By following the activities students reliably construct ideas that are similar to scientists' ideas. This "guided inquiry" technique has repeatedly been shown to be much more effective in terms of conceptual understanding than the traditional lecture method.

However, before this research there was no student-driven experimentation with energy flow (power).

Proposed Solution:

We invented an "energy flow rate sensor" and activity. The energy flow rate sensor can indicate both current and energy flows. Students measured current and found that it has the same flow rate on both sides of a bulb. Then students measured energy flow rates and found that energy flows into a single bulb but does not flow in the second wire.



Using this device in the new activity forced many students to think about the relationship between current and energy whereas before students apparently did not consider the possibility of two things flowing.

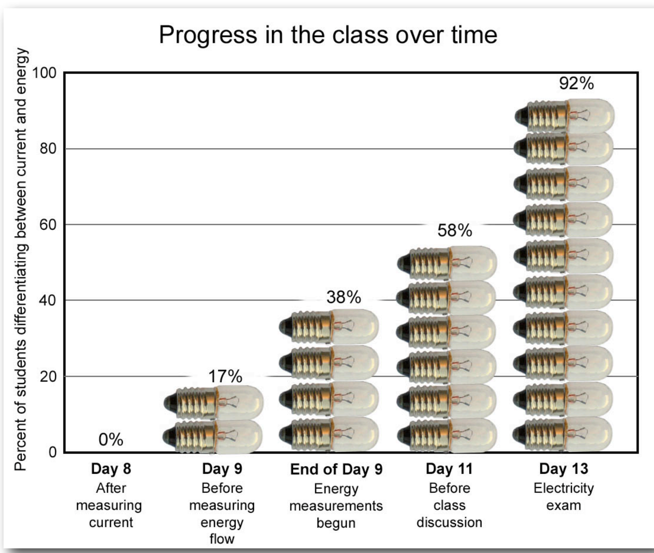
Research Methods:

Ideas from students were collected from group and class discussions, interviews, homework, student journals and exams. Key questions on the final exam plus final interviews were used to determine whether or not a student had fully distinguished between current and energy.

Findings: The Generalized Electricity Flow model is tenacious

Conceptual Change is a difficult process

Many students found it difficult to think of two separate things flowing in the same wires. Students tended to "cling" to the idea of only one thing flowing in circuits, even after making both current and energy measurements along with clear evidence that the two behaved differently.

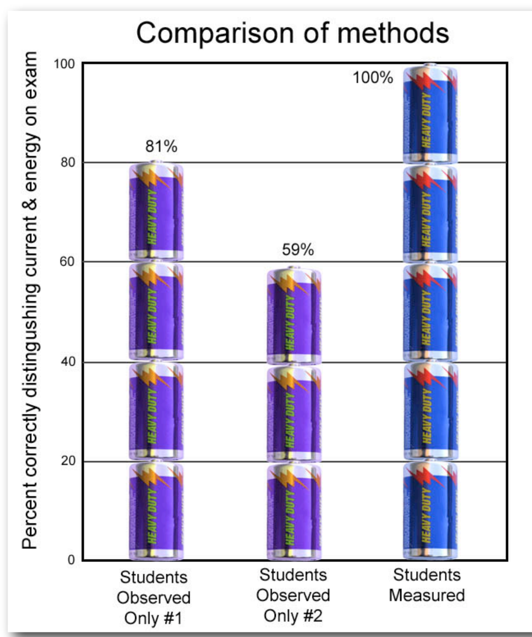


Different levels of understanding

Lower level understanding simply requires recalling a correct answer.

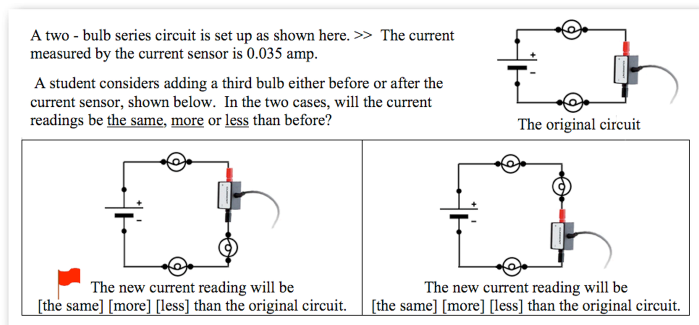
Higher level understanding is the ability to apply the ideas in a new context.

92% of the students reached the lower level; about 80% reached the higher level.



Additional issues:

Some students answered key exam questions correctly but on other questions offered answers that were not consistent with the conservation of current. This raised some red flags. We interviewed flagged students and found four who did not fully distinguish between current and energy. Nevertheless, most students answered a variety of exam and homework questions satisfactorily, showing -at the end of the unit - an understanding of current and energy.



Students who did **not** distinguish current from energy had additional conceptual problems:

- failing to use "conservation of current" ideas on exam questions
- interchanging the words "current" and "energy" at random
- referring to energy when asked about current
- misinterpreting the concept of electrical resistance

These findings suggest that differentiating current from energy is a key conceptual step in understanding electric circuits.

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