Understanding electric circuits from the perspective of non-physics specialist teachers

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Abstract

This paper considers the teaching and learning of electric circuits from the perspective of teachers of general science in the lower years of secondary school. The teachers highlight aspects of the topic that they consider are fundamental to a meaningful understanding, for both themselves and their students, but which in many cases were missing in their own learning experiences or in the textbooks they consulted when preparing to teach. These include: the relation between electron flow and conventional current, a model for visualising how electron flow occurs and the role of a battery in a circuit, a qualitative understanding of resistance and hence an explanation for why a light globe glows but connecting wires do not, and the distinction between electrical charge and energy. The teachers consider how, in the absence of these understandings, their teaching was limited to practical activities or the use of 'simple' but meaningless formulae. The data comes from assignments completed by participants in a postgraduate course, who were experienced science teachers with limited physics background, seeking to improve their confidence and competence in teaching physics topics and concerned to present physics in ways that could engage and enthuse their students.

Introduction

More than two decades of research into student misconceptions [1] has highlighted some challenges faced by teachers at secondary and tertiary levels of education, in teaching the topic of 'electric circuits'. In company with Arons [2] and others, I have previously argued in relation to the topic of 'forces' [3, 4] that, to some extent, the misconceptions and confusion catalogued in the literature result from a failure on the part of teachers and textbooks to articulate some fundamental assumptions and preliminary concepts that underpin the understanding of experts. For teachers and authors these underpinning concepts may have become so taken-for-granted, so invisibly built into the foundations of their own knowledge, that they no longer recognise what role they play in supporting a meaningful conceptual structure. In this presentation my intention is to identify some underpinning concepts for the topic 'electric circuits' that need to be made explicit if novices are to construct an understanding that is meaningful in their own estimation.

1 Data collection

My views on teaching and learning electric circuits have developed over many years based on my reading of the literature, ideas gleaned from respected colleagues, and 'data' gathered from interactions with my students. In 2001, as a result of a successful tender to the (then) Victorian State Government Department of Employment, Education and Training (DEET), I taught a Post-Graduate Certificate (PGC) Course in Physics Education for 26 experienced secondary school teachers of general science whose discipline backgrounds included little or no physics. The course was intended to increase the teachers' competence and confidence to teach physics, as part of a general science course in the lower years of secondary schooling, in ways that are engaging and meaningful for their students.

As one of the assessment requirements, the students completed a written reflection on their experiences of learning two topics that they selected from those covered in the course. Electric circuits and 'forces' were the most commonly selected topics. I kept copies of those reflections which assisted me in my quest to bring to light the kind of underpinning concepts I have described above. After seeking the students' consent to use the assignments for my research purposes, in accordance with the ethical approval I had obtained, I had permission to make use of a total of 8 reflections on electric circuits, plus a second reflection completed by one of these students (student 8) on electrostatics. All of these students were female, a fact that reflected the predominantly female enrolment in the course and the greater capacity of the female students to communicate their insights.

2 The teaching sequence

The topic electric circuits was the focus of two 2-hour workshops held on consecutive days. The teaching sequence I used included the following activities:

1. Students were given a torch globe, some pieces of conducting wire with the plastic insulation stripped from the ends and a dry cell; they were asked to use

these materials to make the globe light, and then to explain why some of their attempts worked and others did not;

2. Students were asked to construct simple series and parallel circuits, noting the relative brightness of the globes and readings on suitable meters;

Students were asked to record the questions that emerged for them while completing these activities. The resulting questions were then discussed with the whole group and two models developed to explain the observations.

Model 1: Students stand in a circle, and are given two sheets of A4 paper, one marked "-" and the other "+". Each student holds the "-" in front of the "+", to represent the "free" electrons in a metal conductor and the positively charged atom in the lattice of a metal conductor, so that the circle of students represents a conducting wire. The teacher models the role of the battery, in removing an "electron" (one of the A4 sheets with a "-") from one end of the conducting wire, and feeding it into the other end. The "electrons" are then shuffled around the metal lattice as the battery continues the process.

Model 2: Students, this time representing electrons, walk around a "circuit", collecting two smarties from the "battery" and depositing them at the "globe". One and two globe circuits are modeled to show how the energy from the battery is distributed to the globe or globes, in order to explain the observed differences in brightness of identical globes in series and parallel circuits.

3 Analysis and findings

The criteria for the assignment provided me with some broad categories for analysis of the students' reflections. These were:

1. the students' understandings prior to their learning experiences in this PGC course;
2. the understandings of electric circuits that they had reached at the time of completing the assignment;
3. the key experiences which had led to a change in their understanding;
4. insights gained into what makes learning meaningful for them or their students.

Within these broad categories I defined an exhaustive set of sub-categories that encompassed all the themes emerging from my reading and re-reading of the students' reflections. In this presentation I wish to focus on the concepts which the students identified as essential elements of a meaningful understanding.

In summary these were:

- Developing meaningful definitions of terms (students 4, 7, 8);
- Being able to distinguishing between energy and current, which generally included constructing a model for the electrons' role in energy transport (students 2, 4, 5, 6, 7, 8)
- Being able to visualise how and why electrons move through the ciruit and give up energy (students 4, 5, 6, 7), which generally included constructing a model for what caused resistance (students 2, 5, 6, 8)
- Being able to relate conventional current and electron movement (student 1)
- Making a distinction between the drift speed of the electrons and the speed of energy propagation around the circuit (students 1, 3, 7)
- Developing a model to explain the different brightness of globes in series and parallel circuits (students 2, 4)
- Being able to explain why the filament of a globe glows (students 2, 6)
- Developing a model to explain the role of the battery (student 7)

Selected quotations from the students' writing illustrate the role of these conceptual elements in helping them construct an understanding that was meaningful in their own terms.

4 Discussion

Several of the students note that certain conceptual elements, which for them were crucial in constructing a meaningful understanding, were generally overlooked in their previous learning experiences, and by the textbooks they consulted in preparing to teach this topic. Two features of the students' reflections stand out: their need to form visual representations that could explain what was happening in the circuit; and their need to construct a holistic account of the circuit's operation, which was narrative-like in that it had a 'plot' with a 'beginning', a 'middle' and an 'end'. They had no problem accepting that the analogies or models that we discussed in the workshops had limits, and broke down if they were pushed too far. But they still saw such models as vital for meaningful understanding, even though from a physicists' perspective they may seem naïve, or even dangerous.

References

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