

Prior experience and sense-making – a case study from DC circuit

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Abstract. This is part of a broader investigation, describes the sense-making episodes of student's engagement with a task in DC circuits. We investigated the variation of student responses using an open DC circuit. The instrument, ACQ, consisted of 8 questions, each comprised of forced choice responses and free written responses. The forced choice responses showed that the student responses are context dependent and the free written responses identified the reasons and foothold ideas behind these variations at a fine-grained level. The results of personal interviews suggest that, student's sense-making attempt is the driving force behind the contextual variations in their responses. We present such an episode from one of the eight interviews.

1. Introduction

Students come to our class with their own experience from their individual life and class room from different schools and teachers. These experiences are different and personal to each student. Among these, some are useful for scientific knowledge development, and some needs to be refined to suit the scientific community. There are two schools of thought, every day experience is considered as an obstacle in science education in one tradition and in other it is considered as resource for knowledge development. The tradition of misconception research argues that students' everyday ideas are strong enough to interfere learning and need to be replaced with scientifically acceptable conceptions (Brown, Clement, & National Science Foundation DC., 1987, Caramazza, McCloskey, & Green, 1981; Mcdermott, Rosenquist, & Zee, 1987). Thus, students every day experience and knowledge are considered as an obstacle in learning. The second tradition focuses on the productive, experiential and epistemological resources [4]–[7]. They consider students' prior knowledge must be taken in to account, be recognized and refined to more acceptable productive resources [8]. There are some recent attempts to reform introductory physics courses with focus on sense-making by students through discussion/lab, peer discussions, argumentations and presentation of ideas, rather than rote memorisation [9].

This paper is part of an ongoing investigation on first year university students experience-based understanding of DC circuits. We recently published the first two parts of this study. The first part was the development of the instrument, Aspect of Circuit Questionnaire ACQ (John & Allie, 2017a) in which we established that the student's responses are highly context dependent. In the second part we identified the foothold ideas from students' written responses (John & Allie, 2017b). ACQ comprised of eight questions with two sections, Forced Choice Responses (FCR) and Written Response (WR). Each question consisted of two electrically identical open circuits, one vertically orientated and the other

horizontally. Each circuit constructed with a battery, a wire and an element. Three elements (a light bulb, a heating element and a resistor) were interchanged in questions and words such as light up for a light bulb, heat up for a heater, current and charge flow were also interchanged. The questions were presented as a discussion by a group of students and their opinions are presented as forced choice responses (FCR) and the respondents were requested to select one of the options and explain in detail the reason to choose a particular option (WR).

The analysis of the student written responses was used to identify the foothold ideas used by students to answer the eight different contexts in an open dc circuit. The identified foothold ideas, productive and unproductive are published in our second paper (John & Allie, 2017b). All students who used the productive foothold idea – loop continuity – answered all questions correctly, irrespective of the context of the question. In contrast, students who used any other idea other than the *loop continuity* responded to the contextual triggers answered the questions incorrectly.

2. Methodology

This paper presents a case study of a student who responded to the contextual triggers in the presented task. The study used three types of data analysis, tallying of FCR, finding the foothold ideas from WR and finally the interviews. In this study we selected eight students for the interview. At this stage, it is to be noted that the answer to all questions was the same, since all circuits were open circuits and none of them will activate. The students were not selected randomly; they were selected on the basis of their FCR and WR i.e. (i) when a student opted for different FCRs for different question or (ii) when the opted FCR and WR were not making sense to us or (iii) the WR was not comprehensible (sometimes due to poor handwriting also).

2.1 Condensed version of the ACQ

Figure 1 presents the condensed form of the questionnaire ACQ. Each row arranged based on elements (bulb, resistor, heater) and each column based on the words (light up/heat up, charge flow, current). The first row presents three bulb questions, second row that of resistor and third row that of heaters. Similarly, first column presents light up and heat up, second column represents the questions related to

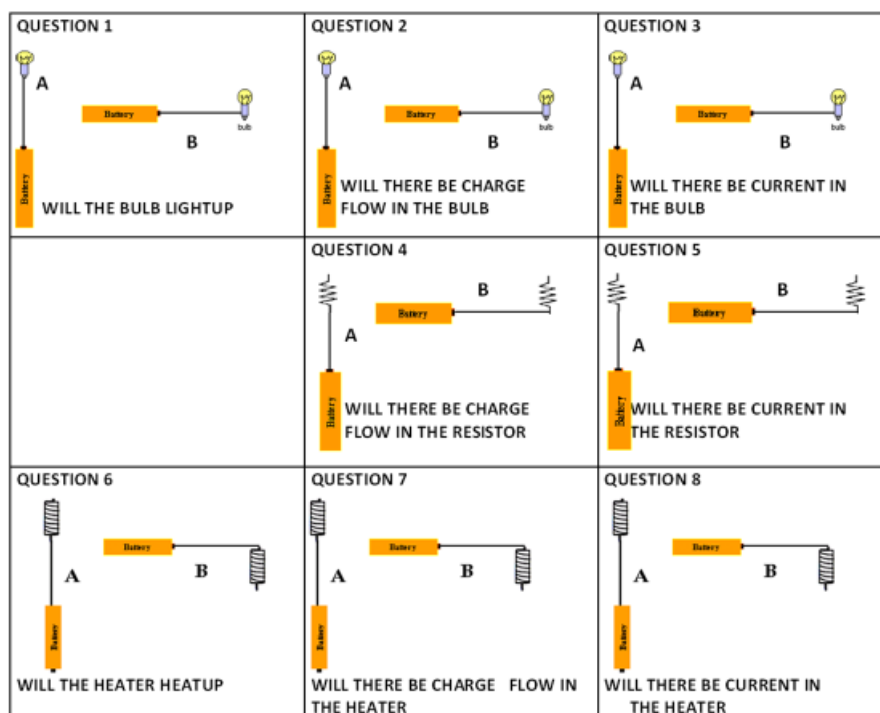


Figure 1: a short version of the eight questions are presented.

charge flow and the third column that of current in three elements. Each question was asking whether the bulb will light up or the heat will heat up or bulb/resistor/heater will have current/charge flow. The answer to all questions is the same: none of them will activate, since the circuit is not closed. In this paper we are presenting one episode from the interview. The student Baba answered five of the eight questions correctly (none of the elements will activate) in her FCR. However, the reason she provided in the WR were not related to circuit. She used different ideas in different contexts; for example, she answered two of the three bulb-questions correctly. However, the reasons provided were different and unrelated to circuit. In her opinion, bulbs will not light up because “charges positive and negative must be close to each other ...”; however, she had the opinion that the horizontal bulb will have charge flow, not the vertical bulb, because “battery lying horizontal ...”, and the bulb will not have current, because “we are using formula $I = V/R$ to calculate current, in the diagram we have no resistor ...”. Similarly, of the two resistor-questions, she was of the opinion that the resistor will not have current, because “... it has only one resistance, battery must be [+ -] in top ...”; however, both resistors will have charge flow because “... it is connected to positive charge of the battery ...”. In the cases three heater-questions she answered two correctly. She was of the opinion that the horizontal heater will heat up, because “... connected to positive charge ...”; however, heaters will not have charge flow, because “... battery must be connected [+ -] ... look in the same direction ...”, and the heater will not have current because “... the formula [$I=V/R$] we use to calculate current have resistor; in the diagram we don't have resistor ...”. Thus, the reasoning was incomprehensible prompted us to interview her.

3. Interview

Students were told that the purpose of the interview is to get some clarification from their scripts, not necessarily the answer is correct or incorrect, but because it was interesting. At the beginning, we asked some casual questions to put them at ease, then seek their consent to video record the interview. There after we gave the original scripts to the student and we kept a copy of it and asked them to read their written responses aloud and to explain what they meant.

3.1. Sense making with a TV remote.

The written response for the light up of a bulb is paraphrased below:

Because the charge + and – must be close together so that it can be connected like this [+ -]

The interview is paraphrased. In the following section **I** represents the interviewer and **R** represents the respondent.

We asked her to explain what she meant by the above writing.

R If you take a TV remote and open it you will see two batteries orientated in opposite direction, one up and another down. If you turn it in the opposite direction, it will not work.

I Are you taking your experience from the ...

R from TV remote.

I so the key idea is that you need two batteries?

R yes.

3.2. Bulb is not a resistance

The written response to the current in a resistor is paraphrased below:

*There will be no current because the circuit is not closed. Battery must be [+ -] on top of resistor.
 $I = V/R$.*

I please explain.

R I was not sure.

I why did you use the formula for the resistor, not in the question of heater or bulb?

R it just appeared.

I will you use this formula in a bulb or a heater?

R No. Bulb is not a resistor.

3.3. Sense making with mathematical equation

I: This is a question relating to current in a bulb. You chose the option “none of the bulbs will have current”. Please explain.

R none of the bulbs will have current because there is no resistor in the circuit diagram. We calculate current using the equation $I = V/R$. In the diagram we have a battery for V ; there is no resistor for R i.e. $R = 0$ gives $I = 0$.

4. Discussion

Baba answered most the questions correctly in the forced choice responses. However, in her written responses, none of them were related to circuit theory, neither for the correct FCR nor the incorrect FCR. She did not have a single model for the dc circuit. She used different ideas in different context. When the elements, words and orientation of the circuit changed, the reasoning also changed. For example, when she saw a single battery in the circuit diagram, it triggered the battery element in a TV remote control. Thus, from her experience, there must be two batteries inserted in the battery compartment in a specific orientation for the remote to work. Therefore, if there is only one battery, the circuit will not work, and therefore the bulb will not light up. The second model is, charge will flow only from positive of a battery and in the horizontal direction, not vertically up. Thus, the circuit in which the bulb connected to the horizontal battery will have charge flow and the heater will heat up. However, in her written reason she used the reason for the horizontal bulb to have charge was because the battery is horizontal. To clarify the horizontal battery as the reason, she was unable to give clear reason for it during the interview. We may assume that this reasoning came from the water analogy used in the schools for current; she knew that the water cannot flow vertically up due to gravity and similarly, the charge also cannot flow vertically up. However, she had the opinion that both resistors will have charge flow, because they are connected to positive of the battery. A third model used by her for the circuits related to current in all elements; in her opinion, none of the circuits will have current. The reasons she gave during the interview was that “it just appeared” when she saw the resistor circuit. She used mathematical reason for the absence of current. In the ohms law equation, $I = V/R$; in her opinion, if $R = 0$, I also becomes 0. During the interview she clarified that bulb and heater are not resistors. Therefore, when you substitute the value of R as zero in the equation, the current also becomes zero. Furthermore, she used the reason “the circuit is not closed”, however, she was unable to construct a valid closed loop circuit. Instead, she drew two batteries side by side and few lines to show the bulb.

Thus, we can see that, this student had different ideas as pieces of knowledge [12] from prior experience, from her everyday life and formal schooling all entangled together. She was trying to make

sense in each situation with in her limited and available resources. Thus, using the everyday life experience to find the answers to the dc circuit problems lead her to logically correct but canonically incorrect answers.

Other example of everyday experiences was that light bulb do have polarity similar to a battery or LED. His experience of a bulb in the lab is that if it is connected to a battery with a closed loop, irrespective of the polarity of the battery, it will light up. In everyday experience, no battery operated device will work if we turn the battery polarity. This experience is construed as “the bulb has polarity”. He also had an experience of a live wire. If you touch a live wire, you get electrocuted. This idea lead to him to answer the question related to charge flow, that the charge will flow till the end of the resistor and dissipate.

Another student who successfully drew a closed loop circuit with a schematic resistor had only an experience of a bayonet caped bulb, not screw caped bulb. In his opinion, the bulb will not get activated because the connection in the diagrams are not to the bottom of the bulb. In his opinion, both connections must be to the bottom part of the bulb, the side of the bulb is just to hold the bulb.

Thus, student’s prior experiences are not helping them to understand the closed-circuit theory, rather they are triggering different cues from different contexts. We suggest that, the idea of a “continuous closed loop” must be taught to students as the primary requirement for any dc circuit to function, in any context.

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