Student Model of Engagement in DC circuits

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Abstract. This is the culmination of a long and systematics study on contextual variation of student responses in the context of dc circuit. We published the contextual variation from their Forced Choice Responses of eight electrically identical questions with fine grained variations that are trivial to a physicist, the productive and unproductive foothold ideas, then narrated the six micro-episodes from interviews that sketches the complex cognitive terrain of sense-making path that links complex everyday experience, mathematical reasoning and language connotations with the idealised physics model. We reflect on how the overall findings might be used in order to introduce a curriculum on simple DC circuits.

Introduction

Teaching electricity successfully to the majority of students in first-year physics has become a worldwide challenge. One criticism of the way in which DC circuits is often taught is that it is too theoretical, thus it was suggested that involving students in practical work and simulations should improve the situation (Finkelstein et al., 2005). Consequently, many innovative curricula have been developed (McDermott et al., 1987). One very popular approach has been to use brightness of a light bulb as a visual proxy for current.

The theoretical framework that very often was that of “misconceptions” (Pesman, 2005), aim at “conceptual change” (Koponen & Huttunen, 2013). However, this framework has been criticized, in particular by di Sessa who proposed a different perspective which is now broadly referred to as “Knowledge in Pieces” (KIP) (diSessa, 1988). Key to this theoretical approach is that context plays a defining role at the time of student engagement with a given situation. From a curriculum perspective KIP leads to a different interpretation of conceptual change and therefore to a different pedagogical approach.

One of the main differences between the two areas is that, in mechanics, there are many artifacts and daily experiences that act as the starting point of the modelling exercise (Hestenes, 1992). Thus, the modelling leads from concreteness to abstraction. On the other hand, electricity starts out as being much more abstract, and daily experiences tend to be associations with light or heat or complex appliances. It would therefore appear that the cognitive and experiential starting points for dealing with mechanics and electricity are very different. While the idea of mass is intuitive, the notion of charge is much less so.

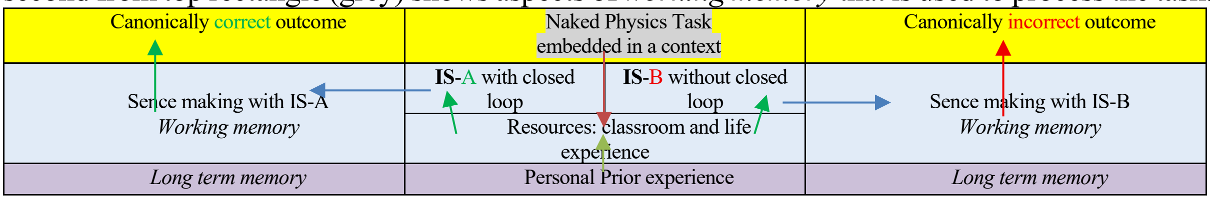
Thus, we carried out a systematic study to investigate the extent to which student difficulties could be related to this area (John & Allie, 2017b, 2017a, 2019). This work showed that context plays a key role in triggering ideas that are then used for subsequent reasoning. By context we imply different instantiations of the same idealized circuit e.g. using a light bulb in place of a resistor or drawing the circuit vertically versus horizontally. These “foothold ideas” that are triggered by the various real-world instantiations can be categorized as either productive or unproductive. Our study indicated that more than 70% of the group used foothold ideas that could not be generalized. The results showed that students who used the foothold idea of *loop continuity* answered all questions correctly irrespective of the context. Contrary to this, the students who used an idea other than *loop continuity* responded to the contextual triggers and answered incorrectly. Thus, the *loop continuity* is established as the key idea that needs to be pried when introducing DC circuits.

Theoretical framework

The results of the study are described by the **I**dea **S**pace model (Allie & Demaree, 2010) that uses the KIP perspective. The IS model is a set of resources that are triggered by a particular task that can be used in the service of solving the problem at hand. For the purposes of the present student Model, the most important aspect of the IS is that once resources are triggered, the set is bounded and fixed for the step of reasoning and sense-making attempts.

Functioning of Toy Model

The figure is divided into 4 large rectangles: the top rectangle (yellow) indicates the *external world* in which the *task* and the *student responses* are exhibited. The remaining 3 rectangles show aspects of the *internal, cognitive world of the student*. The bottom rectangle denotes the world of *past experiences* (blue) that gives rise to a set of *resources* (bottom grey) derived from particular experiential episodes. Both past experiences and resources pertain to *long term memory*. The second from top rectangle (grey) shows aspects of *working memory* that is used to process the task.



The process depicted can be described as follows: the physics task that is presented (yellow rectangle) can be regarded as comprising a "naked physics task" clothed in a specific context. When a student interacts with the given physics task (embedded in a real-time situation), it triggers the resources that have already been acquired from previous experience and the solution is found on the basis of a true-life situation. During this process, a student who has the naked physics resource identifies the physics situation embedded in the real-time situation, and finds the physics solution. On the other hand, a student who does not have the required canonical physics resources will use the available resources to solve the task at hand and will arrive at the wrong conclusion.

For example, in our study, in a typical context of DC circuits, the overall instrument can be thought of as eliciting the responses that would, to an expert, be a single Naked Physics Task (NPT) namely, that for a current to pass through a resistive element, the circuit needs to be closed. The NPT is then presented embedded within two contexts, that of the light bulb and that of the heater. The task that is presented at a given time triggers a set of resources that is primed to engage with the problem, and of which a subset A or B is then used to process the problem to its answer. The resources that are triggered depend ultimately on prior experience.

We found that the students who used the closed-circuit (Naked Physics) concept answered all questions correctly and the others who used other resources, did not.

References (Vancouver numeration and APA Style)

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