

## SUPPORTING GLOBAL REASONING IN ELECTRIC CIRCUITS: A FUNCTIONAL APPROACH TO ADDRESS COMMON MISCONCEPTIONS ABOUT ELECTRIC CIRCUITS

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### 1 INTRODUCTION

Electric circuits are crucial in basic physics curricula and have applications in every-day life. Therefore, students' alternative frameworks and reasoning schemes in this content area have been extensively addressed in science education research. Results can be briefly summarized as follows:

- difficulties concerning conceptual understanding of current. Very common ideas are, e.g.: in a series circuit, current is used up when passing from one bulb to another; current provided by a battery is independent of the circuit's topology [1-3];
- difficulties concerning potential difference. Often potential difference is confused with current or energy; many students think that it represents the "strength" of a battery [4]; moreover, students often fail to understand that potential differences in a circuit depend on its topology [3]; finally, one common students' idea is that across an open switch there cannot be a potential difference because the current is zero;
- difficulties concerning resistance. Students often fail to identify parallel and series connections and to recognize that total resistance in parallel circuits decreases as the number of connected resistors increases, contrarily to what happens in series circuits, [3]. In some other cases, the relationship between current and resistance and between potential difference and resistance is misunderstood [5];
- difficulties related to a local and sequential reasoning. Local reasoning refers to the fact that often students focus only on what happens in one point of a circuit: as a consequence there is a failure to realize that changes in one part of the circuit affect its whole functioning [2] [6]. Sequential reasoning refers to the students' tendency to analyse circuits in terms of 'before' and 'after': as a consequence, there exists a privileged direction of the current and only changes 'before' an element affect its behaviour [2]. Both these reasoning schemes may lead to wrong predictions about the value of current and potential differences across bulbs and resistors.

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## 2 THE FUNCTIONAL APPROACH TO ADDRESS CONCEPTUAL DIFFICULTIES ABOUT ELECTRIC CIRCUITS

Most of the above difficulties seem resistant to traditional teaching. Therefore, many efforts have been devoted to design, develop and validate Teaching-Learning Sequences (TLS, [7]) to address them, especially those about current and potential differences. Nevertheless, it appears that low focus has been put on how to favour the adoption, on behalf of students, of a global viewpoint when analysing and interpreting circuits' functioning. In this paragraph, we briefly summarise the main features of a proposal which tries to tackle such issue.

As a first step, it is essential that students, since the beginning, treat the circuit as a unique system characterized by a well-defined functioning. To this aim, it seems reasonable to relate such with circuit's topology in order to let students easily understand that local changes affect global functioning. In this way, the necessity to introduce some physical quantities (current, resistance, potential difference) which systematically describe such complex behaviour naturally arises, avoiding the risk to introduce difficult concepts without making the students aware of their importance first.

Secondly, since local and sequential reasoning emerges also when students have to interpret abstract representations of circuits, it is essential that students familiarize and experience with circuits' diagrams in order to recognize that different circuits' schemes may correspond to the same actual circuit. Since such an approach to the teaching of electrical circuits focuses mainly on fostering the understanding of how the global behaviour of a circuit is affected by local changes, we call it *functional*.

Drawing from previous research results [8], the proposed approach builds upon two simple conceptual reference models: *logical circuits* [9] and *equivalent resistance*. The role of *logical circuits* is to help students familiarize with circuits' topology and to address difficulties related to local and sequential reasoning. *Equivalent resistance* allows to interpret the behaviour of a circuit in terms of current and potential difference and to address difficulties related to resistors' series and parallel connections.

As far as the methodological framework is concerned, the functional approach is inspired to a broad laboratory-based scientific inquiry. Accordingly, in the proposed approach, students: - conduct laboratory work by themselves (i.e. circuits are set up by students); - interact to share ideas and hypotheses; - analyze data and infer conclusions. Of the many instructional supports to inquiry based teaching [10], our approach relies mainly on the Prediction, Observation and Explanation (POE) Cycle [11].

The functional approach has been implemented by means of a short TLS addressed mainly to the compulsory Lower Secondary School in Italy (11-13 years old students).

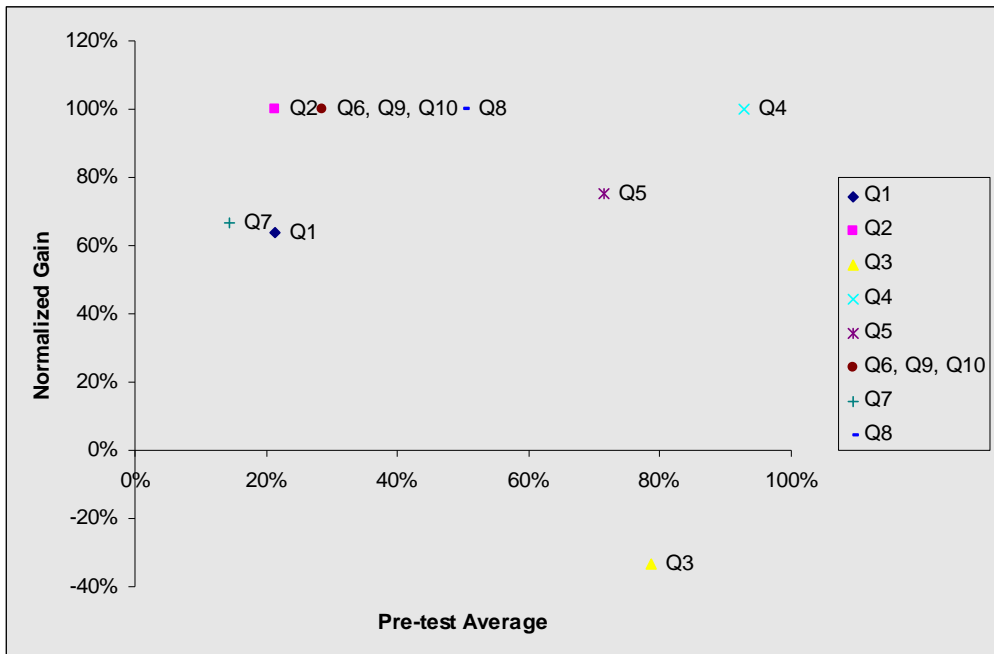
### 3 RESEARCH METHOD AND SAMPLE

To validate at a preliminary stage the proposed TLS, the research question addressed has been: (*RQ1*) “Which conceptual difficulties concerning series and parallel electric circuits’ have been addressed by adopting the functional approach?”.

The preliminary investigation about the effectiveness of the TLS has been carried out at the University of Udine with about 20 in-service teachers attending a 30 hours specialization class about Electric and Electronic Systems at the University of Udine. To answer the research question, we adopted the following method: *RQ1*) a questionnaire from a previous study [12] has been used as pre-post test; questions investigated conceptual difficulties mostly related to local and sequential reasoning, consumption of current, parallel vs. series connections, schematic vs. real circuits.

### 4 DATA ANALYSIS AND RESULTS

Overall, 14 teachers have completed both pre- and post-test. To contrast pre- and post-data results, we used the average normalized gain  $\langle g \rangle$  [13]. In Fig. 1, the average normalized gains for each question are plotted against pre-test averages.



**Figure 1** Normalized gain vs. pre-test averages.

The average number of correct answers in the post-test is  $0.91 \pm 0.13$ , almost double than in the pre-test,  $0.45 \pm 0.27$ . Globally, the resulting  $\langle g \rangle$  is 0.8, which is a quite high value. Such result shows that: - the functional approach has been effective in

addressing some of the sample's conceptual difficulties with electric circuits; - to focus on logical circuits, topology and equivalent resistance can result in a more powerful framework to interpret electric circuits' functioning at lower secondary school.

On such basis, future research will be devoted to improve the steps of the TLS in order to address issues related to current circulation models and potential difference.

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