SIMULATION OF ELECTRICAL CIRCUIT IN INSTRUCTION BY FIFTH GRADERS

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Abstract:
Electricity is one of the key topics in school science, but it is on the other hand a very demanding phenomenon to understand. Research has revealed the conceptions held and the difficulties experienced by school children in understanding the concept of electric current. The simulation-laboratory combination environment has been found to lead to greater learning gains than the use of either simulation or laboratory activities alone. A simulation can help students to first understand the theoretical principles of electricity and by demonstrating through testing or hands-on activities the conceptual change will be possible. In this study the primary school students in the grade five (N=19) studied electrical circuits through simulation and hands-on activities. Students' ideas about the phenomenon electrical circuit were studied by asking them to choose before and after the intervention in the given figure those connections were the bulb will be lighted as well as to explain what happens in a simulation video. Students' explanations were analyzed and found that there was a slight change towards better understanding about the electrical circuit.

Keywords: simulation; electricity; conceptual change

1. Introduction

Electricity is one of the key topics in school science, but it is on the other hand a very demanding phenomenon to understand. Learning processes concerning electricity have been studied from several perspectives, in an attempt to improve the understanding of electricity at school.

Instruction on electricity should commence with the requirement of a complete circuit. In some cases, the current is introduced first, then the concept of electric energy, or *vice versa*. The concept of resistance is normally introduced in conjunction with the current. Voltage, regarded as a more difficult and more abstract concept, may not even be included in a primary level. According to many studies [1,2], the pupils have an ontologically wrong

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view of electricity which is difficult to change. The pupils' conceptions about electricity are based upon material predicates, so they understand electricity as a characteristic of electronic equipment [3]. Different approaches are being studied to make the understanding of electricity more stable for primary aged pupils. Analogies or metacognitive activities during the studying may help the learning process or make the learning experiences more permanent, but these approaches do not produce significant conceptual development [2, 4]. An understanding of the conceptual hierarchies of scientific concepts is needed so that the way of thinking can be applied for the learners own understanding [1].

Research has revealed the conceptions held and the difficulties experienced by school children in understanding the concept of electric current. Two major sources of such problems are found. Firstly, there exist fundamental differences between systemic reasoning and causal reasoning. The systemic reasoning is necessary to understand electrical circuits as systems in which all components interact with each other and a possible disturbance propagates in all directions. In causal reasoning, learners base their accounts on how electrical circuits function. Secondly, the problems are due to the lack of associations between successive levels of scientific modelling necessary for proper understanding. In particular, the problems derive from the lack of associations between the qualitative description of circuits, in terms of variables at the macroscopic level, and the underlying processes described by models at the microscopic level. Proposals on how to avoid these problems require a systemic view of the circuit [5].

Studies in the literature have also addressed children's understandings of the concepts of voltage, energy and resistance [6]. Most of the studies use the same basic structure in their solutions. In general, children are given a battery, some wires and a torch bulb, and sometimes also resistors, ammeters and voltmeters. There must be a complete circuit if any continuous processes are to take place. In children's accounts, the cause is located in the battery and the effect is the lighting of the bulb. A causal agent acts in between them. This causal agent is named as electricity, current, or energy. In the literature, four to six models have been found as to how pupils reason the phenomena [7, 8, 2]. The most developed of these is that a current flows around the circuit and transmits energy. The current is conserved and well differentiated from energy. The circuit is seen to be a whole interacting system. Electricity is seen as a field phenomenon [8]. The use of this scientific model increases from the age of 12 upwards. Several studies have indicated that even at an advanced level the current is the primary concept used by students, while potential difference is regarded as a consequence of the current and not as its cause. Ninth graders in the study of Carter et al. [9] had difficulties even in the construction of a simple circuit.

Model-based learning in the simulation context was characterized by Gobert and Tinker [10] as dynamic recursive process, in which learners are offered an interactive opportunity to build and refine their mental models of the topic. During the interactive process of working with the simulation model the learners are interacting with the causal and dynamic aspects of complex phenomena, in this case it was the model of electrical circuit. Chang et al. [11] offer an impressive list of studies on the advantages of simulation-based learning, but they also offer a list of prerequisites. According to Jaakkola and Nurmi [12], the simulation-laboratory combination environment can lead to greater learning gains than the use of either simulation or laboratory activities alone. They state that a simulation can help students to first understand the theoretical principles of electricity. In order to promote conceptual change, it is necessary to challenge further students' intuitive conceptions by demonstrating through testing that the laws and principles that are discovered through a simulation also apply in reality [12]. In the instructional intervention of this study both aspects are taken into account, students study electrical circuit through simulation and hands-on activities. The aim of this study is to find out how students explain the simulation of simple electrical circuit.

2. Method

Participants in this study were 19 fifth graders in a rural Primary school. Nine of them were female and ten male. The students filled an online questionnaire before and after the intervention. The first part of the questionnaire was classical; the students chose the suitable alternatives of different battery-bulb-wires-connections in which they thought the lamp will be lighted (Figure 1). They also explained the choice.

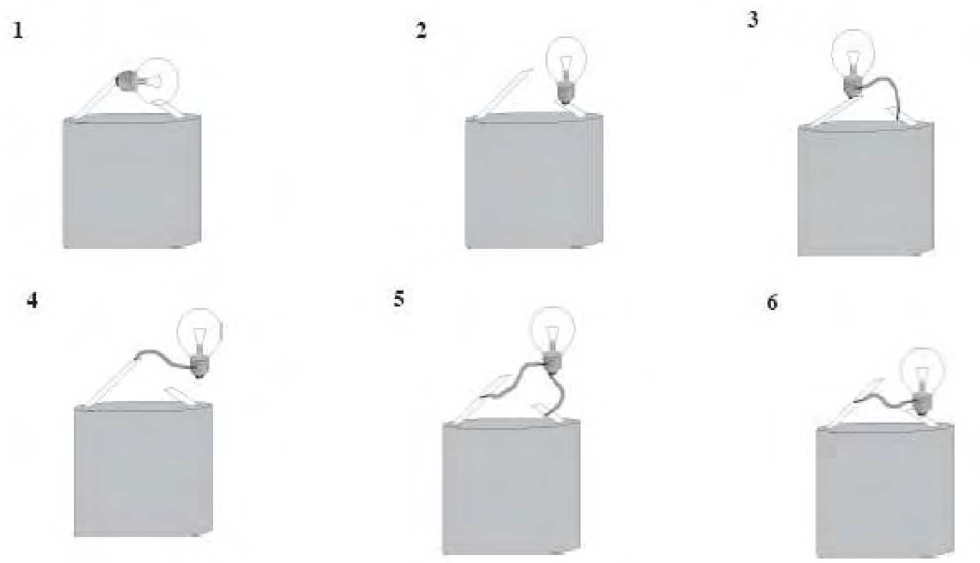

Fig. 1 *Different battery-bulb-wires connections.*

In the other part of the questionnaire the students explained what happened in the video where the students could change voltage and observe the effects of it in the circuit (Figure 2, video clip made by recording battery-resistor circuit simulation from http://phet.colorado.edu/simulations/sims.php?sim=BatteryResistor_Circuit).

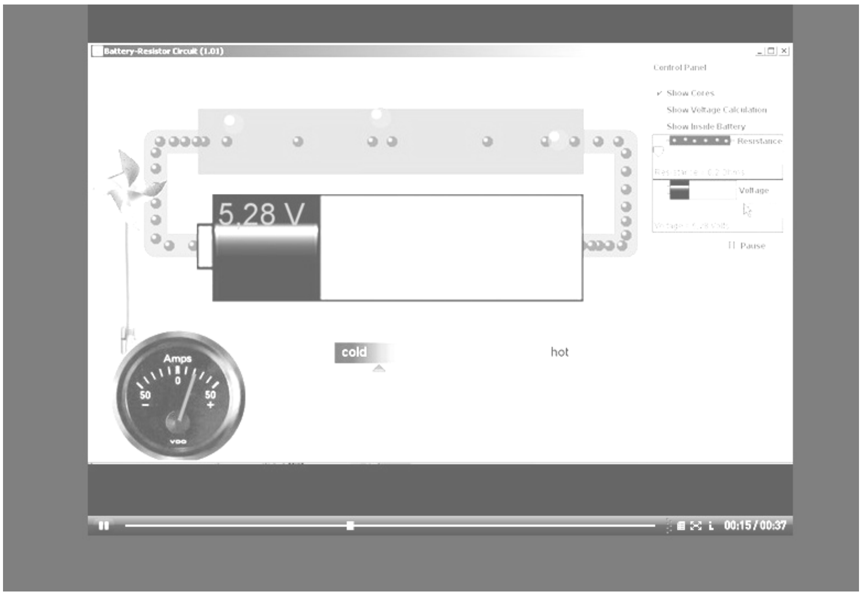

Fig. 2 *Simulation on the dependence between voltage and the heat in resistance.*

Students' explanations were analyzed by content analysis. The focus was on how the students explain the connections between the changeable voltage and the heat in the resistance. The explanations were categorized in six categories. The students also answered to the questions concerning the working methods.

3. Instructional intervention

The pupils have had instruction about electricity also before the simulation session; during the previous lessons the class had had discussions about the use and the sources of electricity. The teacher mentioned especially that boys have worked with different circuits in technical handicraft lessons too. In this study, at the beginning of the session of two hours the students filled in the online questionnaire and they were introduced to the equipments and shortly how the simulation software could be used.

During the simulation session the students worked in four groups of four or five students, in the group one pair of pupils worked with the equipments (batteries, light bulbs, wires and voltammeters) and the other pair worked with the computer and circuit construction kit (Finnish translated version, see http://phet.colorado.edu/simulations/sims.php?sim=Circuit_Construction_Kit_ACDC). The pairs changed the equipments in the middle of the session. The purpose of this arrangement was to facilitate discussion between the students while they worked with similar assignments but different tools. However, the students seemed to find different interests with different tools, for example the use of simulation tool encouraged the students to conduct experiments with the circuits of their own design whereas the equipments were used to follow the tasks given by the teacher. The tasks guided the pupils to construct closed circuits by the aid of batteries, wires and bulbs and using both connections in series and in parallel. Later the students were asked to observe different intensities in light and in the case of simulation also the flow of electrons.

4. Results

Before the instruction sixteen students thought that in the situation of Figure 1.3 the bulb lights, eighteen thought that in Figure 1.5 and fifteen that in Figure 1.6 the bulb lights. If we compare the situation with the answers after the instruction twelve of the students chose number 3, eleven students chose number 5, and ten students chose number 6. When we take into account only those students who filled in the questionnaire before the instruction but not after the instruction, the amounts of students choosing the cases are eleven, fourteen and eleven, respectively. Other numbers were chosen only ones or twice. All the students mentioned the closed circuit as a reason for the lighting. The right alternatives are Figures 1.3 and 1.6.

In students´ explanations on the simulation there were five categories of explanations (Table 1). Firstly, before the instruction the students thought that the battery loads (six descriptions). Secondly, there were five mentions that connected voltage and heat or told about the increase of volts. Thirdly, the students thought that the electrons move and there will be electricity. Two times was written that voltage increases, and also that the motion increases, when something heats, as well as that it will be energy available. Afterwards, the students connected more the volts and heat (eight descriptions) as well as electrons´ motion and electricity. Also loading was mentioned. Ones the speed of motion was connected to the heat as well as energy mentioned.

Table 1. Students explanations on the simulation.

Category	Number before intervention	Number after intervention
Battery loads	6	3
Volts increase / Volts and heat are connected	5	8

Category	Number before intervention	Number after intervention
Electrons move and electricity exists	4	4
Motion increases when the heat increases	2	1
Energy from the current source or from wind	2	1

For example, Max explained before the instructional intervention that *"Electrons move and produce electricity and motion"*. Afterwards he explained *"Electrons move by the aid of the wires and through the current source to the heat resistance. When the electrons move, the propeller goes around whole time always more quickly and the heat resistance heats."*

When asking about the learning methods the students highlighted both the hands-on experiments and virtual instrumentation.

5. Discussion

Mostly the students understood the role of closed circuit for the lighting of the bulb in the given situations. They were aware of it already before instructional intervention. According to the school curriculum, the students had studied open and closed circuits in the lower grades. Thus the connection was learned earlier. There was very small change in the students' choices after the intervention. Because the pre-choices already were right then it was not expected that the students will make other choices. So the students also did not change their choices after the instruction.

After the instruction the misunderstanding that the battery loads was expressed only by half of those students than were before the instruction. On the other side also better understanding about the connection between the voltage and the heat in the resistance was described more after than before the instructional intervention. According to many studies [1,2], the pupils have a wrong view of electricity which is difficult to change. In this study it seems also that the short intervention has not been enough to change students' understanding. However, some of the students, for example Max, used more concepts to explain the simulation afterwards than before. But Max had the same idea already before the instruction than afterwards. Many students used the same way to explain the simulation before and after the instruction. In students' accounts, the cause is located in the battery and the effect is the lighting of the bulb as has been found also in previous studies [2, 7, 8]. In this study the students did not connect current and energy in a right way, however the circuit was seen in some way to be a whole interacting system.

The simulation was used as learning tool, but also as testing tool. As learning tool the students pointed out both methods; experiments by the equipments and the simulation. The simulation was used more creative. As testing tool, the advantage of the simulation was that the students could experience the effects. Based on their observations they could make conclusions; thus apply their knowledge. The disadvantage was that the simulation was very simple and the students could conduct it very quickly without more careful consideration of the phenomenon.

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