Ohm's law as a complex concept in electric circuit theory

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A common objective in physics is "to learn relationships". However, for a long time research in Science education has dealt with misconceptions of "single" concepts and research is often also often planned and performed within a mental model-based perspective.

We have previously argued (e.g. Carstensen et al., 2005) that we need to investigate "a complex concept", i.e. a concept comprising a holistic system of "single" interrelated concepts (Fig. 1a & 1b). In line with experientially based perspectives we see conceptions as reflecting person - world relationships.

Vygotsky (1978) and Cole (1996) have represented this relationship by a mediation triangle (fig. 2a) illustrating that there is no simple relationship between subject and object. In Peirce's and Dewey's theories of representation there is a triadic relationship involving intentionality, rather than a dyadic reflection between sign and the object represented. In accordance with these views we hold a non-dualistic world-view.

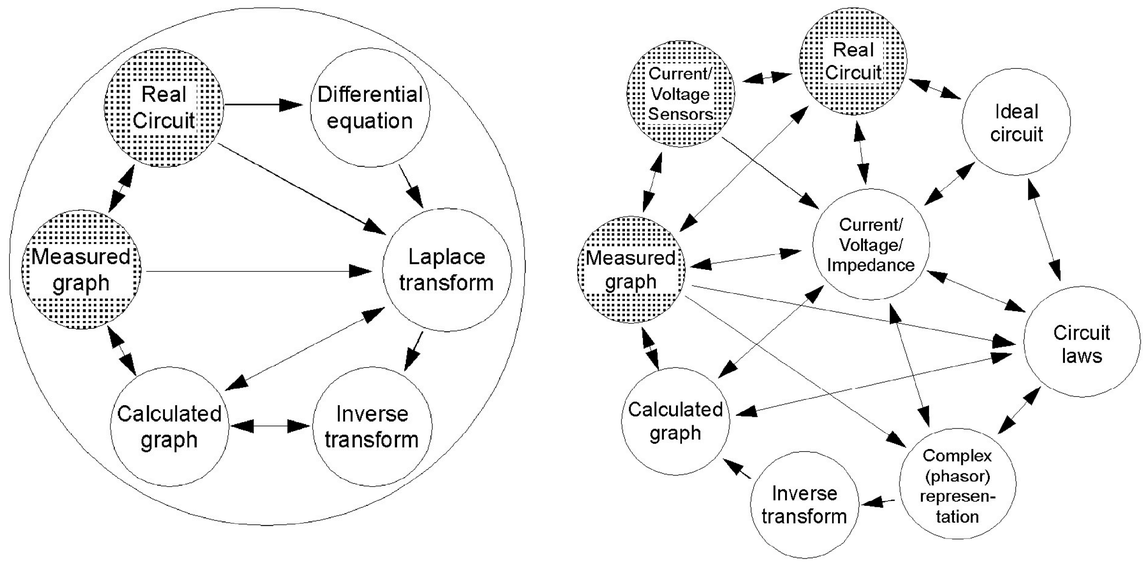

Figure 1: a) Our model of learning of a complex concept, illustrated by the Transient Lab example. The shaded circles represent knowledge placed in the world of objects/events and the other circles the world of theories/models. b) The model interpreted in the first AC-electricity Lab.

Using digital camcorders we have studied students' courses of action in labwork carried out in a first year university course on electric circuit theory for engineering students.

Findings from the analysis of two different labs presented are presented in figure 1a and 1b: the Alternating Current lab and the Transient lab (one of the first and one of the last ones in a series undertaken during the course). In fig. 1b and 1c, the different "concepts" taught in the labs are illustrated by circles and relationships by arrows. These arrows can represent either the relationships the teacher wants the students to establish (intended object of learning) or the relationships actually conceived by

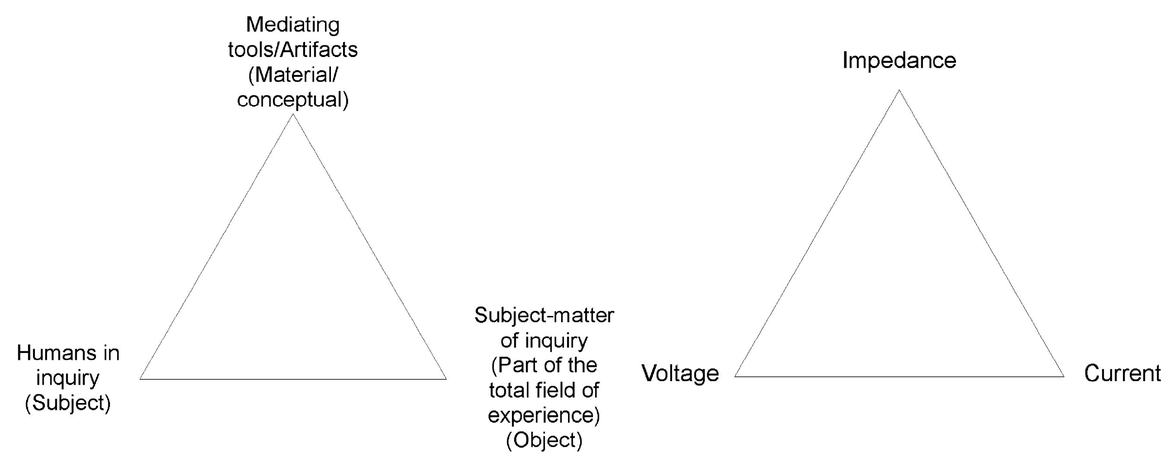

Figure 2: a) A model showing the concept of mediation adapted and modified from Vygotsky (1978) and Cole (1996): The triadic relationship between subject - mediating tools - object. b) the concept of electricity as a triadic relationship.

differents students (lived object of learning).

We have found the items in fig. 1a and 1b by analysing the questions the students raise during labwork.

Learning a complex concept can be seen as establishing multiple relations between "islands". A common finding in both cases is that the relationships between knowledge placed in different "worlds" are more difficult for students to establish. The most striking difference between them is that in the Alternating Current lab the circle representing the current/voltage/impedance/frequency-relationship is interpreted as being a hub in the middle that is central to the lab, whereas the central object of learning in the Transient lab is the larger encompassing circle - a gestalt of the frequency response of the circuit.

The central physical concept in our analysis is "electricity", i.e. a current/voltage/impedance/frequency-relationship represented by the Ohms law triangle in fig. 2b, which depicts that the "concepts" of current, voltage and impedance are interdependent and do not "exist" in isolation.

However, in both science education and science education research "single concepts" are commonly treated as having their own existence. In accordance with the thesis of M. Holmberg (Sampayo González, 2006) we argue that the commonly reported learning problems in electric circuit theory are due to the common failure to appreciate that concepts are relations. It is not uncommon to find statements, and proposals, in the literature that show that the researchers themselves have not adequately understood the concept of "electricity".

Learning a complex concept, in which several "single concepts" form a complex, is also closely related to the idea of threshold concepts (Meyer and Land, 2006) in which the integrative aspect is a central characteristic.

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