TEACHING OF THE BASIC ELECTRIC QUANTITIES[1]

Maija Ahtee, Hilma Aaronen and Kaarle Kurki-Suonio
Department of Teacher Education
University of Helsinki
Ratakatu 2, SF-00120 Helsinki, Finland

During the recent years there has been great interest in studying the misconceptions or children's science in electricity (e.g. Andersson & Kärrqvist, 1979; Maichle, 1981; Cohen et al, 1983; Shipstone, 1984; Joshua, 1984; see also Aspects of Understanding Electricity, ed. Duit, Jung & Rhöneck, 1985).The results from the various studies are very much alike although they have been carried out with pupils with different ages and nationalities. Among the false ideas on electric current and voltage are e.g. the following:

- only one wire is needed to connect a bulb to the battery;
- current flows from both terminals to the bulb (clashing currents);
- current is used up by the batteries in the electric circuit;
- electric current gets weaker further away from the source;
- voltage is the same as charge, current, energy or power;
- current is stored in the battery which is the source of constant current;

Osborne (1983), Cohen et al (1983) and Shipstone (1984) have also tried to analyse the reasons for the common false ideas of electric phenomena. Andersson (1986) has gone one step further and introduced a more general explanation for children's alternative frameworks in different areas of physics, the so called experimental gestalt of causation. There has, however, been little discussion on the possibilities to meet these false ideas or on rectification of such inherent features of the conventional teaching which strengthen these ideas. Driver (1985) concludes that different ways of thinking should be introduced so that the pupils had to test their own models frequently in different contexts. The experienced physics teachers (e.g. Hewitt, 1983) often have pointed out that at the basic levels physics should be taught qualitatively based on phenomena.

Kurki-Suonio has introduced simple scheme of successive hierarchical levels of physical concepts as a framework for discussion of the concept formation in physics and for analysis of direction of approach in teaching (see his paper in this seminar). In teaching of physics in comprehensive school the first three levels should be of main importance. Kurki-Suonio emphasizes that, although the process of learning like the concept formation is rather a perception or pattern recognition process than a logical one, it has a well defined natural direction from lower hierarchical levels towards the higher ones. This defines also the natural direction of learning from observation towards concept formation. As a consequence, theory will be understood as an approximate but

[1] Nordisk Forskarsymposium: Naturvetenskapen i Grundskolan. Hindås,
Rapport utgiven av den lokala kommittén. Institutionen för pedagogic, Institutionen för ämnesdidaktik I lärarutbildningen.
GÖTEBORGS UNIVERSITET, Box 1010, S-431 26 MÖLNDAL, 1988, 136–140.

forever developing model with which the phenomena of nature can be described.

Analysis based on this scheme shows clearly that in the Finnish textbooks and in the Finnish tradition of physics teaching the main approach is exactly the opposite. The starting point is usually the accepted general theory. This treatment leads to the misunderstanding that the phenomena are approximate realization of the exact and invariable theory. As J.P. Snow says, one cannot understand scientific knowledge only on the basis of the products of science, also the process how the scientific knowledge has been achieved, has to be understood.

The traditional Finnish way in teaching electricity as seen from the text books is to start from the atomic model: an atom consists of a positively charged nucleus surrounded by negatively charged electrons. Electrostatic charge is then defined as an excess or deficit of electrons in the matter and the electric current as a flow of electrons. Charging of bars by rubbing with a cloth is told to be transfer of electrons from the cloth to the bar or vice versa. There is no experimental concept formation even on the lowest level

In an experimental approach the concept of charge should be based on observable macroscopic phenomena. There is no need for the atomic model and this should not be taken up before the world of basic electrostatic phenomena, quantities and laws are know the observational basis. This is also the direction of the historical development. The electric charge and many of its properties and basic laws were known first. This knowledge was used in the formation of the atomic model. Consequently, the teaching of electrostatics should start as done in 17th and 18 th centuries with the qualitative studies of the properties of charged bodies. These experimental observations should be followed by the observation that charge can move from one object to another and the studies on induction phenomenon. The electrostatic phenomena were given qualitative definition in terms of electrostatic forces and sparks, and simple tests using the Leyden jar were developed for verification. The attractive and repulsive forces, the conservation of charge, the transfer of charge from one body to another, the summation and neutralization of charges, conduction and isolation, polarization or electrostatic induction and the difference of conductive and nonconductive materials in these phenomena were verified experimentally and the qualitative basic model of the two kinds of charges and the two basic kinds of materials was developed. All this forms the level of phenomena or of qualitative information and its essential parts should be included also in the first level of teaching electrostatics. Only after these considerations the level of quantitative information can be reasonably reached and charge can be introduced as a measurable quantity with the aid of its force effect.

Similarly, the phenomenon of electric current should be introduced first and defined in terms of macroscopic qualitative observations including some properties of batteries, detection of heat generated in the wire and its effect on a magnetic needle as well as transport of matter associated with the current in electrolytes etc. highly structural physical quantities in their relation to the information structure of physics, but it is possible to introduce them as quantification of verified properties of the phenomena without referring to the theoretical considerations. The explanation that current is movement of charges should also be verified. The concept of voltage could be introduced by trying to answer the question: how to get charge to move.

On the basis of the scheme no conclusion can be made concerning the order in which electrostatic phenomena should be taught, at least not in the level of the comprehensive school. However, if one intends to make use of the atomic model their connections throughout the two different areas of charge and current should be made clear through observation and experiment, as was done around the time of publication of Volta's results. Otherwise the explanation of current as flow of charges not to say electrons- makes no sense.

There is the general demand that the pupils should learn the means how to evaluate knowledge and information critically and perhaps also learn how to extract new knowledge. To achieve these objectives which are consequences of central educational objectives one has to learn the scientific process of concept formation and creation of knowledge which is time consuming and more difficult than learning facts by heart without any visible increase in learning results. The present conventional way of telling the pupils what is now known in physics especially on the basis of the present theories works strongly against this aim. It only teaches the pupils to accept authoritative information. Therefore, it seems necessary to survey critically the physics curriculum at the lower secondary level in order to find out what kind of physical knowledge is important for a person just to adjust himself in the modern technological and information centred society and what kind of physical approach would help the development of a critically minded thinking person. Because of the high hierarchical structure of the concepts used in physics subjects taught and approach are intimately coupled. Subjects requiring concepts on high hierarchical level do not allow true experimental approach on the basic level.

References

Aaronen, H. 1986. Sähköopin perussuureet fysiikan kouluopetuksessa. Pro gradu arbete. Fysikaliska institutionen. Helsingfors universitet.

Andersson, B. 1986. The experiential gestalt of causation: a common core to pupils preconceptions in science. Eur. J. ScL Educ. 8, 155 - 171.

Andersson, B. & Kärrqvist, C. 1979. Elektriska kretsar. Report Elevperspektiv No. 2. University of Gothenburg.

Cohen, R., Eylon, B. & Ganiel, U. 1983. Potential difference and current in simple electric circuits: A study of students concepts. Am. J. Phys. 51, 407 - 412.

Driver, R. 1985. Children's ideas in science. Open University Press, Milton Keynes, Philadelphia.

Duit, R., Jung, W. & von Rhöneck, C. (eds) 1985. Aspects of understanding electricity. Proceedings of an international workshop. Institut für die Pädagogik der Naturwissenschaft (IPN), Kiel.

Hewitt, P.G. 1983. Millikan lecture 1982: The missing essential - a conceptual understanding of physics. Am. J. Phys. 51, 305 - 311.

Joshua, S. 1984. Students interpretation of simple electrical diagrams. Eur. J. Sci. Educ. 6, 271 - 275.

Maichle, U. 1982. Representation of knowledge in basic electricity and its use for problem solving. In Problems concerning students representations of physics and chemistry knowledge.

Jung, W., Pfund, H. & von Rhöneck, C. (eds). Proceedings of an international workshop, Pädagogische Hochschule Ludwigsburg.

Osborne, R. 1983. Towards modifying children's ideas about electric current. Research in Science and Technological Education 1, 73 - 82.

Shipstone, D.M. 1984. A study of children's understanding of electricity in simple de circuits. Eur. J. Sci. Educ. 6, 185 - 198.