EPO-EKO —Learning Electricity in Middle Schools

M. Hopf[1], Th. Schubatzky[2], C. Haagen-Schützenhöfer[2], L. Dopatka[3], V. Spatz[3], L. Ivanjek[1], J.-P. Burde[4], Th. Wilhelm[4]

[1] University of Vienna, Austrian Education Competence Centre Physics; [2]University of Graz, Institute of Physics, Regional Educational Competence Centre; [3]Didaktik der Physik, Fachbereich Physik, Technische Universität Darmstadt; [4] Department of Physics Education Research, Goethe-University Frankfurt

Theoretical Background

Most middle school students leave the physics classroom without having reached a proper understanding of electric circuits. Even after instruction they use typical misconceptions such as

- Electric current is used up
- Voltage is a property of the current

Often students use the words current, voltage, energy and electricity synonymously [1, 2]

Despite decades of research on the teaching and learning of electricity, insights about domain specific learning have, however, rarely found their ways into middle and high school physics classrooms. As conceptual change is often not triggered by conventional instruction, misconceptions prevail.

Furthermore, only a small number of conceptual approaches for the teaching of electricity has been developed and even fewer have been empirically evaluated regarding their effectiveness in the classroom. To make things worse, the results of these evaluations are not very promising. The widespread flat water circuit analogy, for example, has proven to be ineffective in helping students develop a better conceptual understanding unless a disproportionate number of lessons is spent on helping students develop an understanding of the water circuit itself first [3].

Another problem, especially in the teaching of electricity, is the decline of middle and high school physics students' interest in physics as a subject in general [4].

Research questions

- Can the significantly better performance of students instructed using the electron gas model be replicated with another sample of teachers and students at the project partners' locations?
- What are the effects of integrating "interesting" contexts in the teaching concept on students' interest, self-concept and conceptual understanding?
- What pedagogical content knowledge (PCK) and beliefs about teaching and learning introductory electricity do the participating teachers have and how do they change due to the implementation of new teaching materials in their classes?

EPO-EKO

Electricity with Potential - Electricity with Context

In order to investigate these research questions, a large comparative empirical field study has been running since 2017. The research plan is a 2x2design with the variables „content structure" and „context".

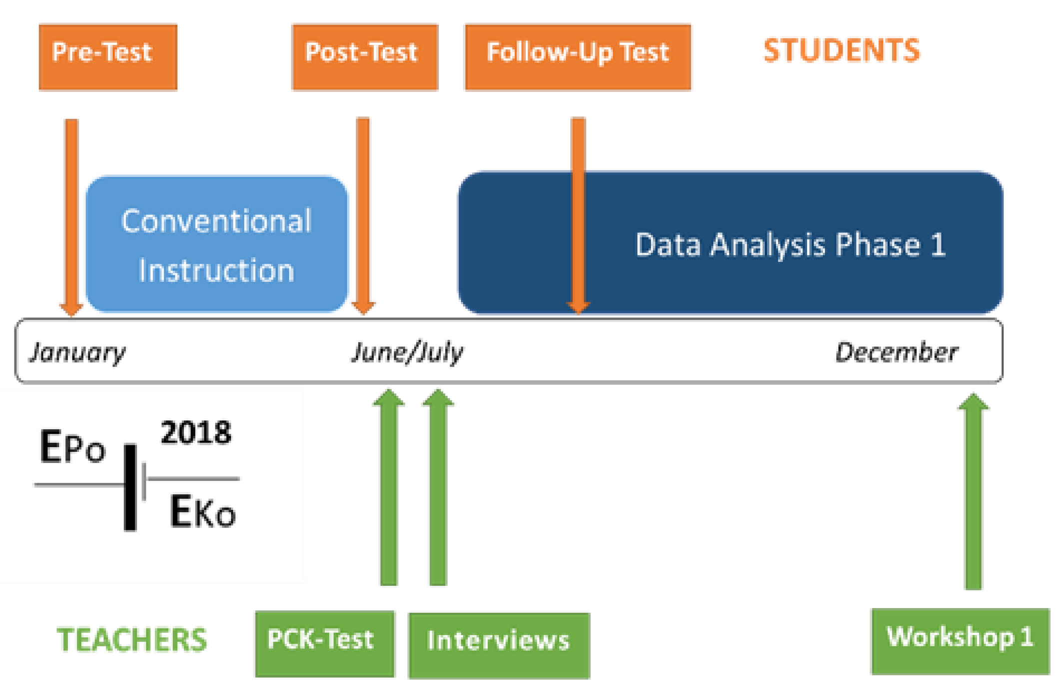
CONTENT STRUCTURE (columns) / **CONTEXT** (rows)

	conventional		electron-gas	
convent-ional	$T1_{StY1}$ & $T2_{StY1}$ (=T) (control group)		$T1_{StY2}$	
context-oriented		$T2_{StY2}$		$T1_{StY3}$ & $T2_{StY3}$ (=T3)
	year 1	year 2		year 3

More than 70 Austrian and German physics teachers participate with their 7th-grade or 8th-grade physics classes. Within a time span of three years, the same teacher takes part in the control group as well as two different treatment groups. In the first year, all teachers teach the traditional way (control group). In the second year, the teachers are split into two groups: One half teaches their classes based on a new content structure ("electron gas model"), while the other half teaches their classes based on the traditional content structure but using context-based materials. In the final year of the study, all teachers will teach according to the new content structure based on the electron gas model now including context-based teaching materials.

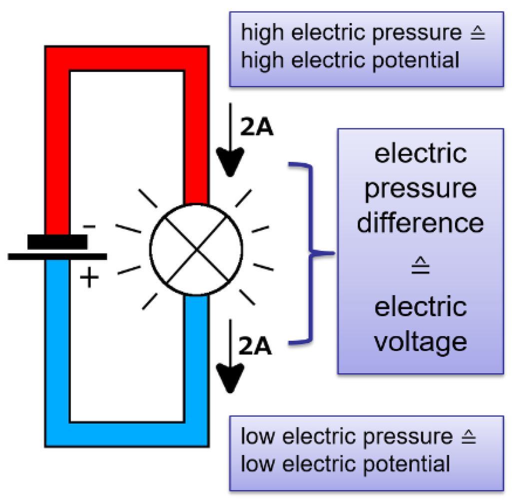
The conceptual understanding of the students is assessed with a newly developed two-tier Rasch-scaled questionnaire on simple circuits, current, voltage and resistance [5]. For this purpose, existing test instruments [1, 6] have been adapted and expanded. Additionally, students' interest and self-concept are investigated with likert-scaled standard instruments.

In parallel, the participating teachers' content specific PCK is diagnosed at the end of each year with questionnaires and interviews.



Electron Gas Model

Research in science education suggests that the explicit introduction of voltage as potential difference helps middle school students develop an adequate conceptual understanding of electric circuits [7]. Burde & Wilhelm developed a teaching concept that is based on a simplified electron gas model and introduces voltage as an „electric pressure difference". The idea is to build on students' everyday physical intuitions with air pressure, e.g. from their experiences with air pumps or bicycle tires. This approach is based on diSessa's "Knowledge in Pieces" theory [8]: students' intuitive understanding of air pressure serves as a qualitative model of the electric potential in conducting wires. Based on their everyday experiences, students easily understand that differences in air pressure cause an air flow. In analogy, the electron gas model is used to introduce voltage as a potential difference, which can be understood as an „electric pressure difference" across a resistor. As a result, students find it plausible that – similarly to air pressure differences that cause an air flow – electric pressure differences (electric voltage) cause an electric current.



Burde & Wilhelm showed that their curriculum helps learners to develop a better conceptual understanding of electric circuits than traditional approaches to teaching electricity [7].

Context-Based Teaching

Research in science education suggests that the use of everyday contexts can slow down the decline in students' interest in physics [9]. In particular, contexts on natural phenomena and the discussion of physical concepts in biological or medical environments have proven to be promising in that regard. [4, 9] Unfortunately, so far not much has been done to develop such context-based learning materials for middle school students in the field of electricity.

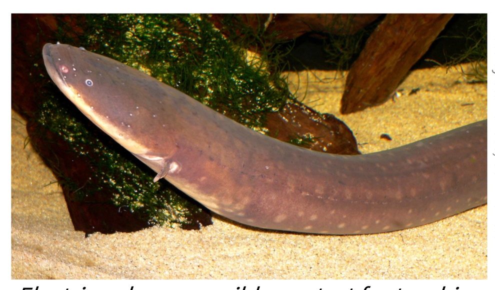


Photo by Stan Shebs, CC BY-SA 3.0

Electric eel as a possible context for teaching electricity.

First ideas on possible contexts are the functional principle of the lie detector, the use of electrical sensors in medical applications and the electric fence.

Discussion and Outlook

At present, the first cycle of the project is almost complete. In total, we have collected questionnaires from 71 classes in the control group and first data is also available on teachers' PCK. A more detailed evaluation of this data will take place in autumn this year.

Additionally, both versions of the teaching materials (electron gas model and context-based) are developed at the moment. In the first case, the materials are based on previous work of Burde & Wilhelm and will be available soon for the first cohort of teachers. The development of the context-based teaching materials is also underway. Here, a replication study of students' interests was undertaken as a first step and is currently analyzed. As a next step, it is planned to develop the context-based teaching materials and evaluate them in a field trial.

First comparisons of the different interventions will be available in autumn 2019.

Literature

[1] R. Duit, W. Jung, & C. v. Rhöneck (Eds.). Aspects of Understanding Electricity - Proceedings of an International Workshop (Schmidt & Klaunig, Kiel, 1985).

[2] J.-P. Burde (2018). Konzeption und Evaluation eines Unterrichtskonzepts zu einfachen Stromkreisen auf Basis des Elektronengasmodells. Berlin: Logos (259).

[3] H. Schwedes, W.-G. Dudeck, & C. Seibel (1995). Elektrizitätslehre mit Wassermodellen. In: Praxis der Naturwissenschaften – Physik in der Schule 44 (2), p. 28–36.

[4] C. Schreiner, & S. Sjøberg, S. (2004). The relevance of science education. Sowing the Seed of ROSE. Oslo: Acta Didactica.

[5] L. Ivanjek, M. Hopf, L. Morris, J.-P. Burde, Th. Wilhelm, V. Spatz, L. Dopatka, C. Haagen-Schützenhöfer, and Th. Schubatzky (2018). Development of two-tier instrument on simple electric circuits. Girep Proceedings.

[6] H. Urban-Woldron, & M. Hopf (2012). Entwicklung eines Testinstruments zum Verständnis in der Elektrizitätslehre. Zeitschrift für Didaktik der Naturwissenschaften, 18(1), 201–227.

[7] J.-P. Burde, & T. Wilhelm, T. (2018). Concept and empirical evaluation of a new curriculum to teach electricity. In L. Ding, A. Traxler, & Y. Cao (Ed.), PERC Proceedings 2017.

[8] A. A. diSessa (1993). Toward an epistemology of physics. Cognition and instruction, 10(2-3), 105–225.

[9] L. Hoffmann, P. Häußler, and M. Lehrke (1998). Die IPN-Interessenstudie Physik. Kiel: IPN. L. Hoffmann, P. Häußler, and M. Lehrke (1998). Die IPN-Interessenstudie Physik. Kiel: IPN.

Layout : Sarah Zloklikovits

universität wien | GOETHE UNIVERSITÄT FRANKFURT AM MAIN | TECHNISCHE UNIVERSITÄT DARMSTADT | KARL-FRANZENS-UNIVERSITÄT GRAZ UNIVERSITY OF GRAZ | UNI GRAZ

Primary Contact:
Univ.-Prof. Dr. Martin Hopf
University of Vienna
Austrian Educational Competence Centre Physics
Porzellangasse 4
Vienna, Non U.S. 1090