A QUALITATIVE STUDY ON HIGH SCHOOL STUDENTS' CONCEPTUAL UNDERSTANDINGS OF ELECTRICITY AND MAGNETISM

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Abstract

The present study is designed to explore a group of high school students' perceptions of fundamental principles of electricity and magnetism. Primarily, this research is guided by the following research questions: (1) what are the common conceptual knowledge do high school students possess about electric current and magnetism? And (2) what are the possible difficulties or misconceptions and possible solutions students have in the concepts? To summarize, we sought to investigate high school students' conceptual and cognitive understandings of electricity and magnetism at a local public school in the state of Ohio in the United States. The findings revealed that most of the students could retain only inadequate amount of the topics studied in elementary physics courses and for that reasons remedies are suggested to enhance their knowledge such as including problem-based learning (PBL) strategies in the curriculum studies.

Key Words: Physics Education, Science Education, Electricity and Magnetism, Conceptual Changes.

LİSE ÖĞRENCİLERİNİN ELEKTRİK VE MAGNETİZMAYI KAVRAMSAL ANLAYIŞLARI ÜZERİNE NİTEL BİR ÇALIŞMA

Öz

Bu çalışma bir grup lise öğrencilerinin elektrik ve manyetizma kavramlarını nasıl anladıklarını keşfetmek için dizayn edilmiştir. Bu araştırmadaki araştırmayı yönlendiren sorular: (1) Lisede okuyan öğrencilerin elektrik ve manyetizma kavramlarını nasıl anlamaktadırlar? ve (2) Elektrik ve magnetizma kavramlarını öğrenirken yaşadıkları zorluklar nelerdir? Kısaca, Lise öğrencilerinin elektrik ve manyetizma kavramlarını anlamak için nasıl bir süreçten geçtikleri ve yaşadıkları zorlukları bu araştırmanın ana sebepleridir. Bulgular göstermektedirki öğrencilerin çoğu öğrendikleri bilgileri hemen unutmaktadır ve bunun çözümlerinden birisi olarakta problem çözme ile öğrenme tekniğinin kullanılması tavsiye edilmektedir.

Anahtar Sözcükler: Fizik Eğitimi, Fen Eğitimi, Elektrik ve Magnetizma, Kavramsal Değişimler.

1. Introduction

Physical phenomena around us have been wondering humans since first human being appeared on the surface of the World. While, the investigations and explorations of the physical world around us goes back to the beginning of human kind on the Earth, physics education research (PER) is considered a rather younger discipline compared to science education. For this reason, it is required to study, understand, and modify our current research agenda to enhance the students' knowledge and understanding of physical concepts. Furthermore, to maximize their conceptual understanding of various topics in physics, more research and investigations are needed from physics educators. Therefore, more investigations are required and essential to provide higher understandings of physics concepts.

Previous researches over the last three decades the perception of concepts of physical science such as motion, force and energy, have been extensively examined.[1] Students' conceptions of electric current have been extensively studied, ranging from the simple notions treated in primary school science[2] [2] up to the more sophisticated notions only addressed in his book of published journals collection, Duit et al.[3] provided an overview of the research conducted up to 1985. His book revealed the conceptions that students Most of the studies that investigated understanding of electricity by children conducted their research use the same research structure. Students are given a battery, same wires and a torch lamb and then are asked to light the bulb. While they are working on the task, their actions and behaviors are observed.[4] The result of his study revealed that very few students were capable of building a successful circuit.

Related studies were conducted at both secondary and college level environments. For instance, Fredette and Lochhead[5] have studied North-American university students' conceptions of simple circuits. They explored some conceptual difficulties with college students with regard to simple direct current circuits. They conducted clinical interviews with 57 freshman engineering students. The results of their study exposed that many students enter college engineering department without a clear knowledge of circuit models.

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1 Driver, R., Squires, A., Rushworth, P., & Wood-Robinson, V., *Making Sense of Secondary Science: Research into Children's Ideas*, Routledge, New York, 1994, p.102.

2 Borges, R., *Aspects of Understanding Electricity*, Kiel: Schmidt & Klaunig, 1999, pp 205-214.

3 Duit, R., ''The Meaning of Current and Voltage in Everyday Language and Its Consequences for Understanding the Physical Concepts of the Electric Circuit'', *Physics Education*, 71 (3), 1985, pp. 81- 93.

4 Tiberghien, A., *Critical Review of the Research Aimed at Elucidating the Sense that Notions of Temperature and Heat have for Students Aged 10 to 16 Years,* In. Proceedings of the First International Workshop Research on Physics Education, Editions du CNRS, Paris, 1983, pp. 73-90.

5 Fredette, B., & Lochhead, J., ''Students' Conceptions of Simple Circuits'', *The Physics Teacher*, March 1980, pp. 194 – 198.

The concept of electricity and magnetism are very elemental issues in the study of physics since it constitutes a significant part of physics concepts. In the state of Ohio, every high school students have to complete a year-long physics course which consists of several electricity and magnetism chapters. Most importantly, in the Ohio Graduation Test (OGT), 20% of science questions are generally stem from these chapters. The OGT is a mandatory and statewide exam that is required for the students to graduate from high school. The OGT has five subsections and one of them is science with questions from basic scientific process, the nature of science (NOS), physics, chemistry, and biology. Because all students are supposed to pass OGT, these two concepts of physics are very crucial for those students in their academic futures. The students who participated in the current study have successfully completed concepts of electricity and electrical energy, which was mostly accomplished with the aid of hands-on and group activities (e.g. laboratory experimental activities).

Based on previous researches reviewed above, the investigations of students' (high school or college) conceptual understandings of electric and magnetic concepts are suggested to investigate more from different perspectives. As an example of different approach from previous research, this study is designed as a mixed method approach. Principally, the present study aims to explore students' perspectives of the nature of electric current and magnetic field following a course of instruction at high school. Particularly, this study only focused on the students' understanding of the concepts of charge, current, and electricity.

2. Method

We designed this exploration to reflect a group of high school students' perceptive of fundamental principles of electric current and magnetic fields. As reached in the previous research, it is expected that a few of the students would be able to shows adequate level of understanding and manage to set up the right circuit at the first trial.

The current research was guided by the following research questions:

1. What kinds of conceptions do high school students have about the electric current and magnetism?
2. What are difficulties or misconceptions and possible solutions students have in the concepts?

Initially, the students already took a physical science course, which consists of physics science, earth science and biology concepts at elementary level, in the previous year. The interview and data collection process were administered after studying electricity and magnetism concepts in second semester of the academic year. A student interview protocol was main source of data collection, which contains five questions and each question had three or four subsection.

During the interview process, each student was initially given a small light bulb, a D-size battery and one piece of wire (Figure 1) and asked to construct a simple circuit to light up the bulb in five minutes period. After several trials at the end of the allowed time period, all of them weren't able to build a circuit that lights it up when they were provided with a second wire to achieve it.

Afterwards, we initiated second phase of the interview by asking questions pertaining to the small experimental task and conceptual ideas behind that. The purpose of asking such questions was even though they weren't able to accomplish to build up a circuit; we aimed to investigate their theoretical and conceptual understandings and knowledge about the concepts. Finally, we managed to compare their degree of understandings of the electric current and magnetic field theories. The small circuit focused on mainly current and charges. In conclusion, we managed to gather information and relationship between their conceptual understanding and type of teaching strategies applied to the class. Finally, table 1 emerged based on the findings resulted from collection of data through students' trials and interview processes. Classifications illustrated on table 1 were first suggested by Bloom in his 'Levels of cognition' identification scale. The scale simply describes at what level of cognition, learners are expected to show their learning based on how they answer measuring questions such as repeating definitions and applying concepts to a certain world problem.

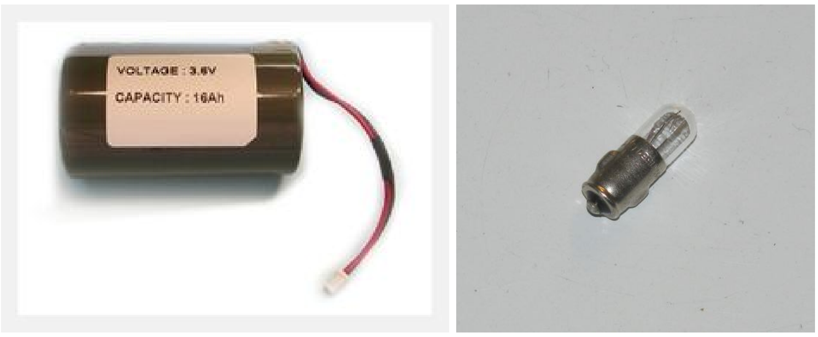

Figure 1: Materials Distributed to the Students for the Experiment.

2.1.Participants

Five high school students enrolled in 11th grade (16-18 years old) were by the head of physics department at a public high school in Toledo school district in the state of Ohio. They were all enrolled in an AP (Advance Placement) physics class. Students are required to have a grade point average (GPA) of 3.00 of their prior mandatory science courses such as Physics Science and Middle school general science. The requirement to take the course satisfied our student selection criteria, which was the only condition to be included in the study. Moreover, the goal of conducting this investigation with using qualitative research methodology lies in gathering students' individual perspectives and reasoning toward electric and magnetic concepts. To better investigate research questions related to their conceptual understandings, deep and longitudinal research technique was required.

In addition, it is an advance science elective course and is intended to give student much deeper understanding of concepts on physics. It is a year-long course and not required for the graduation but it can be applied towards the freshman physics course if the necessary scores can be achieved based on the AP physics exam taken at the end of the academic year. The exam is administered by the College Board membership association. Additionally, the students participated in the study were instructed the concepts of electricity and magnetism during the same semester so they had fresh memory of the topics.

Textbooks generally used in a typical high school physics course are varied depending on the concepts including mechanics section was adapted from Physics[6]; thermodynamics from Physics: Algebra and trigonometry[7]; and electricity and magnetism from College Physics[8], relatively. Particularly, problems utilized to identify and reveal the students' levels of understanding of electricity and magnetism concepts after utilizing problem-based learning (PBL) as the main teaching system.

Data were collected by interviewing those students individually. Interview protocol was adapted from the previous studies.[9] Sample interview questions included:

- What makes the bulb light?
- What is going on in the battery while the bulb is lit?
- What is going on in the wires while the current is on?
- What is it that sometimes makes bulbs break?

3. Results and Finding

Data table which illustrate the students' levels of knowledge is constructed by the end of the data analysis. For evaluating their own level of command of the subject, we employed "Levels of Cognition" from "Bloom's Taxonomy –

[6] Cutnell, J. D., *Physics*, Wiley, 5th ed., 2001, pp. 451-480.
[7] Giancoli, D.C., *Physics: Principles with Applications*, Prentice Hall, 6th ed., New York, 2004, pp. 125-192.
[8] Serway, R. A., *Physics for Scientists and Engineers*, Saunders, 4th ed., New York, 1996, pp. 750-790.
[9] Boo, H. K., Pre-service Primary Teachers' Constructed Knowledge of Physical Science Concepts, *Proceedings of the Redesigning Pedagogy: Research, Policy, Practice Conference*, Singapore, May - June 2005.

Revised''.[10] Here are the 6 Levels of cognition; together with some questions one can ask one's self to evaluate readiness:

1. Knowledge Level - can recall terms, definitions, facts, ideas, materials, patterns.
2. Comprehension Level - can read and understand descriptions.
3. Application Level - know when and how to use ideas, procedures, methods.
4. Analysis Level - can identify sub level factors or salient data from a complex scenario.
5. Evaluation Level - equipped to make judgments about the value of proposed ideas, solutions.
6. Synthesis Level - can put together the parts or elements.

For example, in order to clarify above measurement scale, if a student can only recall definitions, materials and terms etc., then he/she only holds knowledge level of cognition. Alternatively, if a student can make judgments about a proposed explanation to a scientific problem, he/she possess synthesis level because he/she needs to synthesize his knowledge of topics, methods, and analyze complex scenario.

Based on the scale above, the conceptual understanding table was illustrated as:

Table 1: Students' Conceptual Knowledge of the Concepts.

Student	Present understanding of elec. and mag.	Understanding of electric concepts	Understanding of magnetic concepts
Student A	synthesis	application	comprehension
Student B	evaluation	analysis	application
Student C	synthesis	synthesis	knowledge
Student D	analysis	evaluation	comprehension
Student E	synthesis	application	comprehension

[10] Bloom, B .S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (Ed.), *Taxonomy of Educational Objectives: Handbook I: Cognitive Domain*, David McKay, New York, 1956, pp. 21-85.

Most of the students exhibit adequate conceptual knowledge of the definition of electricity. They indicated theirs responded that corresponded to Question one in the interview protocol and defined electricity as “lighting, negative power, lights and electronics, power, and electrical wires.” As indicated on Table 1, students’ understandings of electric concepts (i.e. circuit, electric current, electricity etc.) were understood with at least application level and one student possesses synthesis understanding level of these concepts. On the other hand, regarding magnetic concepts, students demonstrated lower achievement levels with only one student holding third level of understanding, application, and one student stands at lowest level of cognition and three students with secondary level. Overall, it can be concluded, students are not taught magnetism concepts with enough express of concepts. Possible explanations might include conceptual difficulties due to abstract nature of magnetism topics.

Only a few students (two out of six) successfully demonstrated how to light a bulb up from the given materials (a bulb, a D-size battery, and some wires). Almost every student, excluding two of them also showed adequate understanding of the basics of electric current. These findings might be expected because the subject matters investigated here require higher order thinking.

For example, one student described electric current as:

> *“…vibrating electrons, moving of electrons, circuit, flow of electrons, and a block of current etc.”*

Another example of a student’s description of magnetism:

> *“… I believe electrons are floating around in the air and are attracted by electric field. Then, they create magnetism and magnetic field. Magnetism and magnetic field is the same thing but their effects are different such as magnets and cells phones”*

As a result, analogous to the previous studies[11] findings, the current study revealed that the concept of electricity and its related concepts are very abstract and difficult for most students. This was no surprise since we expected at the beginning of the paper and several researches on students understandings of physics concepts (such as Newton’s laws of motion, modern physics[12], and relativistic concepts) concluded that they are not easily comprehended by the students therefore various suggestions of alternative instruction processes have been made.

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[11] Osborne, R., *Electric Current: A Working Paper of the Learning in Science Project*, N.Z., University of Waikato, Hamilton, 1980, pp. 25-50.

[12] Akarsu, B., Instructional Desings in Quantum Physics: A Critical Review of Research, *Asian Journal of Applied Sciences*, (Online first version), 2011, pp. 1-7.

As mentioned above, potential explanations to the low achievements of the students on conceptual difficulties and topics of magnetism discipline may consist of inefficiencies on students' training, conceptual content difficulties (e.g. abstract nature of topics), and curriculum troubles. For these reasons, students should be instructed with more hands-on activities to overcome the difficulties of concepts and maybe revise the curriculum to adjust students' needs. For example, they should be able to do more experiments when investigating magnetism topics to better understand the concepts. Our findings show similarities with prior research findings[13] and afterwards more studies need to be done to overcome current conceptual issues.

Based on the findings, we can easily conclude that treatment to the abstractness and strong higher order thinking requirement does lie on various teaching strategies applied to the concepts. In addition, PBL is a constructive alternative approach to teach these concepts which is a student-centered strategy in which they collaboratively solve problems and reflect on their experience. For future studies, PBL would a good application for other physical concepts and should be taken seriously alternative to other strategies.

In conclusion, we recommend another alternative instructional approach to enhance students' conceptual understandings of electricity and mechanistic concepts. It is to increase number of course hours dedicated to laboratory investigations in science curriculum at high schools. Today's standards are not enough because students are not provided with opportunities to learn physics from the first hand by building and constructing experiments to get used to learn how science works. This is necessary in order to teach concepts of physics to the students and let them learn by themselves by changing our role from being a teacher to being a facilitator.

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[13] Hewitt, P., ''Circuit Happenings'', *Latin American Journal of Physics Education*, 1(1), 2007, pp. 1-3.

BİBLİOGRAPHY

Akarsu, B. "Instructional Desings in Quantum Physics: A Critical Review of Research", *Asian Journal of Applied Sciences*, Online First Version, 2011, pp. 1-7.

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (Ed.), *Taxonomy of Educational Objectives: Handbook I: Cognitive domain*, David McKay, New York, 1956, pp. 20-30.

Boo, H. K., Pre-service Primary Teachers' Constructed Knowledge of Physical Science Concepts, *Proceedings of the Redesigning Pedagogy: Research, Policy, Practice Conference*, Singapore, May - June 2005.

Borges, R., *Aspects of Understanding Electricity*, Kiel: Schmidt & Klaunig, pp. 205-214.

Cutnell, J. D., *Physics*, Wiley, 5th ed., 2001, pp. 451-480.

Duit, R., "The Meaning of Current and Voltage in Everyday Language and Its Consequencesfor Understanding the Physical Concepts of the Electric Circuit", *Physics Education*, 71 (3), 1985, pp. 81- 93.

Driver, R., Squires, A., Rushworth, P., & Wood-Robinson, V., *Making Sense of Secondary Science: Research into Children's Ideas*, Routledge, New York, 1994.

Fredette B., and Lochhead J., ''Students' Conceptions of Simple Circuits'', *The Physics Teacher*, March 1980, pp. 194 – 198.

Hewitt, P., "Circuit Happenings", *Latin American Journal of Physics Education,* 1(1), 2007, pp. 1-3.

Giancoli D. C., *Physics: Principles with Applications*, Prentice Hall; 6th ed., New York, 2004, pp. 125-192.

Osborne, R., *Electric Current: A Working Paper of the Learning in Science Project*, N.Z., University of Waikato Hamilton, 1980.

Serway, R. A., *Physics for Scientists and Engineers*, 4th ed., Saunders, New York, 1996.

Tiberghien, A., Critical Review of the Research Aimed at Elucidating the Sense that Notion of Temperature and Heat have for Students Aged 10 to 16 Years, *Proceedings of the First International Workshop Research on Physics Education*, Editions du CNRS, Paris, 1983, pp. 73-90.