Electromagnetic induction for high school students: An historical approach

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Abstract
Teaching electromagnetic induction in high school introductory courses can represent a challenge, not only because of the conceptual vastness involved but also for the high abstraction level required to get formalization. That is why it has been generated a teaching sequence that incorporates internal history perspective related to electromagnetic developments in the first third of nineteenth century, emphasizing the influence of Faraday's induction law and its impact in today's society.

Keywords: Faraday's induction law, History of electromagnetism, Attitudes toward physics, Secondary school

Resumen
La enseñanza de la inducción electromagnética en los cursos introductorios de bachillerato puede representar un desafío, no sólo por la amplitud de conceptos involucrados, sino también por el alto nivel de abstracción necesario para obtener la formalización. Es por eso que se ha generado una secuencia de enseñanza que incorpore la perspectiva de la historia interna relacionada con la evolución electromagnética en el primer tercio del siglo XIX, haciendo hincapié en la influencia de la ley de inducción de Faraday y su impacto en la sociedad actual.

Palabras clave: Ley de inducción de Faraday, Historia del electromagnetismo, Actitudes hacia la física, Bachillerato

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I. INTRODUCTION

It has been documented that embodiment of historical elements in teaching science allows to present thematical contents with better logical perspective for students [1, 2]. Introducing students to internal problems which gave rise to landmark researches and their later development, offers an opportunity to show them a more realistic view of scientific knowledge production, as well as to identify and avoid conceptual difficulties in learning specific topics [3, 1, 4, 5]. Finally, history of science can improve attitudes of students towards their learning process [3].

This research wants to prove that using history of electromagnetism allows students to improve their attitudes towards Physics and science in general, and also to create stronger logical connections between historical events (Volta's battery, Oersted's compass, etc.) and electromagnetic induction research in nineteenth century.

In the following sections it is mentioned the general characteristics of educative conditions of the study case, later are presented poll results of students preferences to learn science contents, and finally a preliminary testimony of the experience.

II. METHODOLOGY

This educative research consisted in a study case applied to a group of 29 students registered in their second course of basic Physics in the Institute of Higher Secondary Education in Mexico City.

The first stage of the survey was to apply students a poll and find out what are their preferences towards different aspects planned for the didactical sequence. In one poll section students were asked to rank from nine categories, considering their own preferences of studying science contents. The categories were: A1. Biographies of scientists; A2. Anecdotic data; BB. Origins of researches; CC. Political and economical context; D1. Scientific theories; D2. Application of theories; E1. Crucial experiments; E2. Operation of measuring instruments, and E3. Making school experiments. These categories were subdivided into three groups, the first two related to historical issues: internalist view (A1, A2, E1 and BB) and externalist view (CC); and the last pertaining to the specific study of scientific theories (D1, D2, E2 and E3).

A second phase of teaching sequence for electromagnetic induction, was to use selected chapters of the eighties TV series *The Mechanical Universe... and Beyond*, to complement theoretical and experimental discussion of relation between forces in nature (Chapter 11), electric circuits (Ch. 33) and electromagnetic induction (Ch. 37). This TV series was produced by the Institute of Technology California in collaboration with Intelecom, Inc., and presents in almost equal proportions, the origins of researches and its relationship with some historical aspects, theories supported with not so difficult mathematics and different approaches to experimentation. Also, these videos shows computer animations to model physical and mathematically.

As I mentioned before, the center of my teaching sequence was electromagnetic induction and it was presented through symmetry reasoning and Faraday's experiments. To present a theatrical representation of his work, I used the *Mechanical Universe* chapter called *Electromagnetic induction* to enrich previous discussions on this topic. As a closing strategy a Predict-Observe-Explain activity type was implemented, in which students know the phenomenon of magnetic levitation of an aluminum ring located in a region of variable magnetic field (*Thomson coil*) but now they were to be capable to explain it. The results of this experience will be explained later in this work.

FIGURE 1. Photogram of *Electromagnetic Induction*: Faraday experiments with coils and magnets.

III. RESULTS

The rank score was "1" for the most relevant and increasing up to "9" for the less relevant. The results of the poll applied to a sample of 20 students are shown in the next table.

TABLE I. Preferences of each students.

	A1 Biograhies	A2 Anecdots	BB Origin of researches	CC External context	D1 Theories	D2 Applications	E1 Crucial Experiments	E2 School experimentation	E3 Measuring instruments
Student 01	9	7	1	8	6	4	2	3	5
Student 02	1	2	3	4	6	5	7	9	8
Student 03	7	3	1	9	6	8	2	5	4
Student 04	1	8	4	2	5	3	7	9	6
Student 05	3	2	1	4	5	6	7	9	8
Student 06	4	5	2	1	6	7	3	8	9
Student 07	1	8	7	2	3	4	5	9	6
Student 08	3	2	1	4	6	7	5	9	8
Student 09	7	6	1	3	4	2	5	8	9
Student 10	3	7	1	8	2	4	5	6	9
Student 11	1	8	4	6	2	9	5	7	3
Student 12	7	6	9	3	1	4	2	8	5
Student 13	7	8	1	9	6	2	3	5	4
Student 14	5	8	2	7	1	3	6	9	4
Student 15	1	6	2	7	4	3	5	9	8
Student 16	2	3	1	4	9	5	6	8	7
Student 17	3	2	1	4	8	6	5	9	7
Student 18	4	8	1	9	6	2	5	3	7
Student 19	1	9	2	8	6	7	4	3	5
Student 20	6	4	3	7	1	5	2	9	8
Mode	**1**	**8**	**1**	**4**	**6**	**4**	**5**	**9**	**8**
Absolute Frequency	**6**	**6**	**9**	**5**	**8**	**4**	**7**	**9**	**5**
Relative Frequency	**30%**	**30%**	**45%**	**25%**	**40%**	**20 %**	**35%**	**45%**	**25%**

The table above shows no pattern for student preferences, but it is worth to mention that 45% of students prefer to study landmark problems that gave rise to scientific researches (BB), rather than know about biographies of important scientists (A2). It is also remarkable that 40% of respondents chose to study scientific theories (D1) in the sixth position of their rank, possibly because of their lack of interest in formal contents. These results could represent a genuine interest of some students to study internal problems which influenced the internal development of scientific knowledge, instead of decontextualized theories.

Contrary to all my expectations, 45% of students chose school experiments (E2) as the last option for studying science, despite of frequent positive comments about lab work. This result should be revised in order to obtain more information and revaluate this atypical tendency.

Next graphic shows a resume of students preferences according the most selected choices (mode), number of students who selected each choice (absolute frequency) and the relation in percentile (relative frequency).

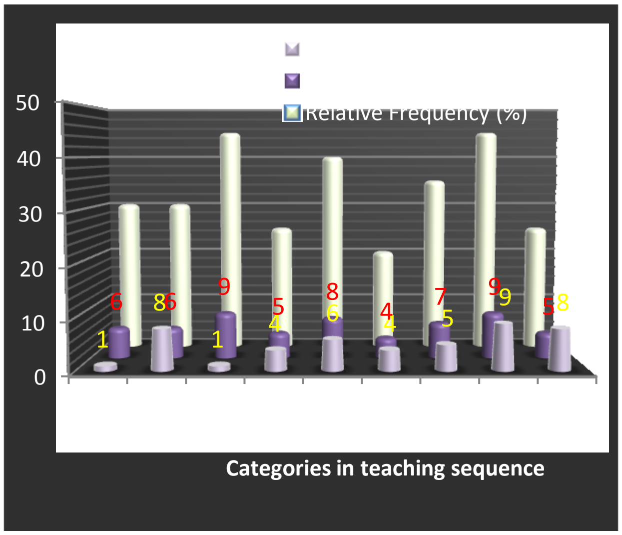

FIGURE 2. Comparison between Rank selection and frequencies of choice.

Another interesting result was that external context (CC) and application of theories (D2), ranked with 25% and 20%, respectively, in the first half of preferences. Again, this could be a possible interest from students to ask for different frames of reference for how we teach science contents.

Predict-Observe-Explain strategy was applied to 21 students, obtained scattered results. Most of the responses had misconceptions regarding the relationship between inducing and induced currents and fields. They also have difficulties to explain causality for the repulsive forces between the ring and the electromagnet.

In the closing sequence only five students (23%) were able to provide adequate explanations. One student made a remarkable explanation and supported with high quality arguments, supplemented by a few illustrations recovered from Caltech video. In a diametrically opposite direction, three students who were not unable to establish a coherent description of the phenomenon, and two other students proposed explanation linking only the electric forces and electric fields. The eleven remaining students (52%) made a proper association with the phenomenon and magnetic repulsion, but fail to justify the cause of it. On the other hand, only 28% of students referred to the warming in the ring conductor, correctly associated with the currents induced in it due to the variable magnetic field.

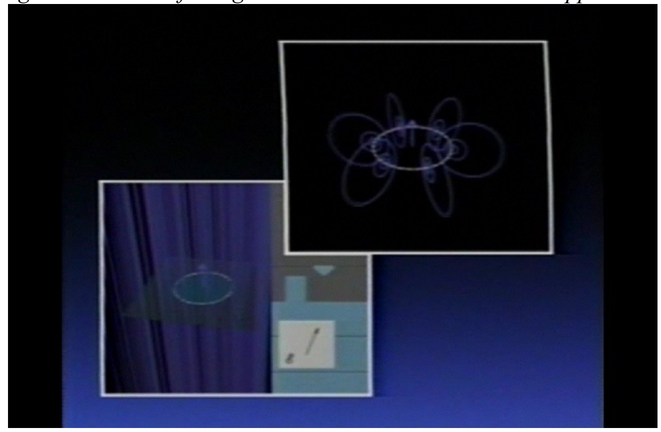

FIGURE 3. Photogram of *Electromagnetic Induction*: Field lines in a coil.

Based on these findings it is considered that the combination of historical context, the use of animations and video group discussion can provide positive outcomes for the learning of Faraday's law of induction, if they are complemented by activities to reinforce theoretical and experimental knowledge.

IV. CONCLUSIONS

This works shows that students may have better opinions unto historical contents that most of science teacher do. Accordingly, this is a good opportunity to explore new possibilities of presenting difficult concepts, as the electromagnetic induction, taking advantage of the interest in internal problems and also in everyday life applications, which I may refer in later works.

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