Analysis of the learning of electrostatic concepts in pre-service physics teachers

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Abstract. The objective of this work is to analyze the explanations of pre-service physics teachers, when they experience with different electrostatic phenomena included in a teaching and learning sequence (TLS) designed for students to use the model of distribution and interaction between electric charges at first, for then promote that they explain certain more complex phenomena with the electric field model. The results show a significant improvement of the students' explanations throughout the TLS due to several factors, including the teacher's role.

1 Context and research questions

This research is framed within a electromagnetism course in the 3rd year of the Degree in Physics and Mathematics Education at the University of Santiago de Chile (USACH), in which Chilean pre-service teachers learn two key models for their prospective teaching activity: the model of distribution and interaction of electric charges (addressed to 13 years old students), and the model of electric field (addressed to 17 years old students). In this course, we propose a teaching learning sequence (TLS) based on previous research on students understanding of electrostatic concepts [1]. This TLS combines classroom group discussions [2], students' transfer of knowledge into new context [3], inquiry and modeling activities [4], and interactive demonstration [5]. The structure of the TLS includes students' prediction, observation, contrast, formalization and application, in which students deal with different electrification methods on dielectric materials (for example, attracting pieces of paper by a charged dielectric), induction on conductive materials (ex: induction of an electroscope by a Van de Graaff generator), electric field representation (ex: alignment of threads in oil by a circular electrode) or electric flux and Gauss's Law (ex: measurement of electric potential in a system of concentric electrodes).

In this context we wonder:

1. How do a group of pre-service physics teachers use the ideas of electric charge and electric field to explain different electrostatic phenomena, and how do these explanations evolve along the TLS?
2. What aspects of the experiences and the teaching approach used affect the evolution of the explanations?

2 Methodology

The TLS was first implemented in 2016 with 33 students, some refinements were made following a DBR approach [6], and then implemented again in 2017 with 17 new students. The analysis of students' explanations followed a qualitative approach, in which students' productions (text and drawings) were inductively categorized following a comparison by contrast technique and assuring the validity of results by triangulation of the analysis. In Table 1 we present some analysis highlights for each model addressed in TLS. More details will be presented in the conference.

Table 1. Structure of the analysis of students' answers for each model.

Model	Focus of the analysis	Example of the analysis performed
Model of distribution and interaction between electric charges	How students explain the electrization of dielectric and conductive materials with different methods (electrization by friction, conduction, polarization and induction)	Some students mix the explanations based on charges transferring (friction and conduction) with the explanations based on charges reordering (polarization and induction). Some alternative ideas also arise, such as the idea that the attraction of an object is due to an intrinsic property of a charged body.
Model of Electric Field	How students explain the nature of the electric field and its representation (electric lines and density of lines).	Some students confuse the idea of field line with the trajectory of the particles in an electric field.
Combined model of charge distribution and Electric Field	How students explain the distribution of electric charge to the resulting electric field (Gauss's law)	Some students focus their explanations on the nature of materials (for example, the Faraday cage) instead of reasoning in terms of charge distribution.

3 Results and Conclusions

We find that there is a progressive evolution of the models used by students to make their explanations in the different activities of the TLS, especially those explanations related with the model of distribution and interaction of charges. For example, 21 over 50 students move from an explanation based on the idea that "*a charged body can attract other objects*" to the idea that "*the difference between the magnitude of the force of attraction and repulsion lead to a rearrangement of the charges of a neutral body, causing its attraction or its reorientation*". However, at the end of the TLS, many students still show difficulties for combining the model of charge distribution and the model of electric field to explain complex systems, such as when they have to explain what happens in the case of a Van de Graaff generator enclosed inside a Faraday cage.

This evolution of students' explanations is due to a combination of pedagogical factors and scaffolding, such as graphic representations that promote students' explanations, specific experimental set-up that help students reasoning and combination of phenomena that allow students to refine their models. More details about the instructional design that allow this students progression will be presented in the conference.

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