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Electric Field Concept: Effect of the Context and the Type of Questions

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Abstract

We administered several open-ended questions to students after electrostatics is covered in an electricity and magnetism class at a private Mexican university. In the first part, the objective is to compare students' responses on electric field concept questions in the presence of charges and conductors to those in the presence of charges and insulators. In the second part, the objective is to analyze the difference in responses when the context is changed. This report compares students' answers to electric field concept questions while changing from abstract objects, i.e., point charge, non-conducting sphere; to already-used real materials in lab, i.e., charged tape, non-conducting pencil. Lastly, the objective is to analyze whether a guided question helps students to better answer electric field questions. This study compares students' responses to electric field concept questions with no guidance to responses to guided questions and the degree of guidance.

Introduction

An important concept but difficult to understand by Electricity and Magnetism students is the electric field [1]. Having no prior knowledge of electric interactions, students look for a familiar model to interpret what is seen at class. This leads them to use a Newtonian which sometimes help them but others do not [2].

This paper attempts to understand the models of electric field that the student has and how the influence of context or the type of questions can evoke more sophisticated models of electric field. Our objectives are: 1) to compare students' responses on electric field concept questions in the presence of charges and conductors to those in the presence of charges and insulators, 2) to analyze the difference in responses in which the context is changed, and 3) to analyze whether a guided question helps students to better answer electric field questions.

Methodology

This research was conducted in a large private Mexican university. Since this is a preliminary study, only open-ended questions were used. Students who participated in this study are in their EM course in this institution. All questions were administered after the instruction of electrostatics.

Following the methodology used by Barniol & Zavala [3], we compare different versions of questions with populations of students chosen randomly. This report compares students' answers to electric field concept questions while changing from abstract objects, i.e., point charge, non-conducting sphere; to already-used real materials in lab, i.e., charged tape, non-conducting pencil. All the questions were administered in Spanish.

Results and Discussion: Electric field due to abstract/lab-type conductors and non-conductors

The first sequence (CSAI) was administered to 143 students. The second sequence (CSLA), administered to 152 students, consisted on the same questions as the first sequence but replacing abstract items (point charge, conducting and non-conducting sphere) with objects students used in a previous lab (charged bar, conducting pith ball and a non-conducting pencil).

Table 1 presents the answer/reasoning of question 1.

- In CSAI, from the 73% of the students who draw a correct vector, 57% (from total), mention electric field lines that "are going to a negative charge".
- In CSLA, only 47% answered correctly and those who draw field lines to the negatively charged bar increased from 17% to 42%. This result indicates that students based their answers using electric field lines, something they have not mastered yet.

Table 2 shows the answer/reasoning to question 2.

- In CSAI, 43% answered correctly and 36% with a correct reasoning.
- 29% of students think that the electric field is not changed, most of them reason that the sphere is neutral so no electric field will be produced.
- 21% answered that the E-field changes but cannot say how and why.
- In CSLA, using familiar objects does not improve results.

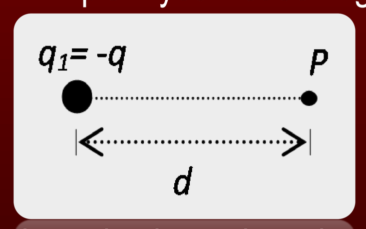
Table 3 shows the answer/reasoning to question 3 on both tests.

- Only 9% of students answered correctly.
- 29% of students think that the electric field is not changed, most of them reason that the sphere is neutral so no electric field will be produced.
- Again, this table shows that using familiar objects does not improve results.

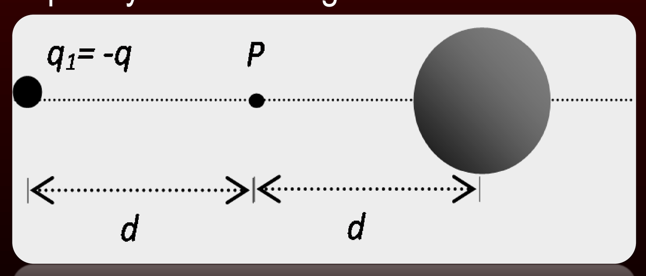
Comparing the results of table 2 with a conducting object to the results of table 3 with a non-conducting object, is evident that if the students have difficulty understanding induction of charge in conductors, they have even more difficulty understanding polarization.

First sequence:

Question 1. There is a point charge $q_1 = -q$ at a distance d from point P as shown in the figure. Draw on the figure and describe the electric field at point P. Explain your reasoning.



Question 2. A neutral conducting sphere is placed at a distance d from point P as shown in the figure. Draw on the figure and describe the electric field at point P. How the magnitude and direction of the electric field change at point P compared to Question 1? Explain your reasoning.



Question 3. It is the same as question 2 but replacing the conducting sphere for a non-conducting neutral sphere.

Table 1. Results of question 1

Answer/reasoning \ Test	CSAI		CSLA	
E to the left	73%		47%	
E-field lines go to a negative charge		57%		23%
Coulomb's Law		5%		5%
E field going into the charge	17%		42%	
E-field lines go to a negative charge		9%		22%
Coulomb's Law		4%		3%

Table 2. Results of question 2

Answer/reasoning \ Test	CSAI		CSLA	
E-field to the left increases	43%		39%	
Induction of charge		36%		33%
E field does not change	29%		29%	
The sphere is neutral		17%		16%
E-field changes	21%		24%	
Induction of charge		8%		12%

Table 3. Results of question 3

Answer/reasoning \ Test	CSAI		CSLA	
E-field to the left increases	9%		8%	
Polarization of object		7%		2%
E field does not change	79%		80%	
The object is neutral		52%		35%

Results and Discussion: Effect of guidance

Based on some Tutorials and its exercises [4], we tried to guide students to the right reasoning by asking a previous question before the electric field question when the conductor is placed. We designed three versions of a test. An original version (Original) which is the same as in the previous part. A guided version (Guided) in which question 2 of the original becomes the 3rd question. Question 2 is replaced by a question in which students are told that the sphere and the bar are attracted and asked why that occurred. An extended guided (E-guided) in which they are also instructed to draw the charge distribution.

Table 4 shows the results of the same question in the three versions.

- The original version results are similar to those of the previous subsection.
- Comparing the guided version to the original version, there is an increase of the correct answer and reasoning. However, it seems that some students who were not sure how the electric field changed, with the question guide, they answered the correct result.
- There is evidence that those students who do not understand induced charge (and electric field produced by that charge) are not helped by the guided question.
- The extended guided version results are very similar to those in the guided version indicating that further guidance did not help students to overcome their difficulties.

Guided version:

Question 2. (Showing the same figure as in question 2 in the original version). A conducting neutral sphere is placed at a distance d at the right of point P as shown in the figure. In the lab we saw that the conducting sphere was attracted to the charged bar. Why did that occur?

Extended guided version:

Question 2. (Showing the same figure as in question 2 in the original version). A conducting neutral sphere is placed at a distance d at the right of point P as shown in the figure. In the lab we saw that the conducting sphere was attracted to the charged bar. Draw in the figure the distribution of charge on the sphere and explain why.

Table 4. Results of question: How does the electric field at point P change placing a conducting sphere? Answers and main reasoning are included.

Answer-reasoning\ Question	Original	Guided	E guided
E-field to the left increases	36%	52%	51%
Induction of charge producing an E-field	30%	39%	30%
E-field does not change	26%	25%	23%
The sphere is neutral	16%	13%	13%
E-field changes	22%	12%	17%
Induction of charge	3%	5%	4%

Conclusions

This study is part of a preliminary study on the understanding of electric fields. The most important findings are:

•The electric field due to charges is not well understood. Students tend to draw what they think are electric field lines instead of thinking about interactions.

•Replacing real objects instead of abstract objects in the problem wording does not have an effect on the performance of students in electrostatic questions.

•The effect of charges on conductors is not well understood and subsequently the Superposition Principle is not well applied.

•The effect on charges on insulators in not understood at all.

•Guided questions help in some extent to help students who were otherwise unsure about their reasoning to get a correct answer and reasoning. However, the guidance is limited since there is a great number of students who did not answer the questions correctly even with the guided questions.

A current investigation is undergoing to study the levels of students' understanding of the electric field concept.

References

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