Investigating Aspects of Modelling in Electrostatics

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Abstract

Research shows that the knowledge and use of models and modelling by teachers is limited particularly for predicting phenomena. An area of concern relates to the effective use of microscopic models by teachers to explain and predict physical phenomena in several areas including electrostatics. In this context we developed and applied a sequence of three simulated models focusing on polarization embedded in a model based instructional unit aiming at enhancing primary student teachers' understandings both about polarization and the predictive power of models. Selected pre- post tests and group interview results are presented showing students' cognitive evolution and suggesting moderate success of this model-based intervention in enhancing the use of models by students.

Introduction

Recent research indicates that teachers' knowledge of models and modelling is limited (Van Driel & Verloop 1999, Cullin & Crawford 2003). In particular, the predictive function of models is hardly understood (Treagust et al 2002, Cullin & Crawford 2003). Recently there is an interest for developing and applying innovative approaches aiming at facilitating teachers' use of models in treating physical phenomena and potentially apply modelling procedures in their classes (Justi & Van Driel 2005).

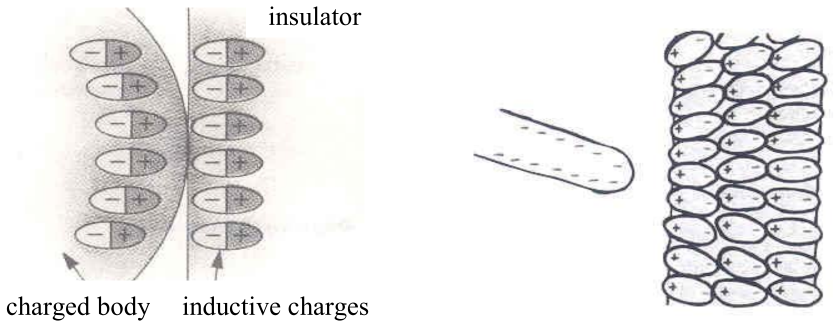
Regarding models and modelling, an area of concern relates to the long-standing didactical problem of the effective use of microscopic models by teachers and students to explain and predict physical phenomena in school topics such as electrostatics. Electric polarization and related phenomena in particular, is an area in which student teachers face difficulties in providing explanations and predictions (Barbas & Psillos 2003).

In this context we have been engaged in a series of "teaching experiments" (Steffe & D΄ Ambrosio 1996) including both development and research by developing and applying successive interventions to small groups aiming at enhancing student teachers' knowledge and use of microscopic simulated models in electrostatics and their understandings of the function of models. By investigating in depth students' reactions we aim at revealing crucial points and learning obstacles so that instruction will be gradually adapted to students' thinking. We present here a sequence of simulated causal models embedded in a 3 hours instructional unit aiming at enhancing student teachers' understanding of polarization and the predictive power of models.

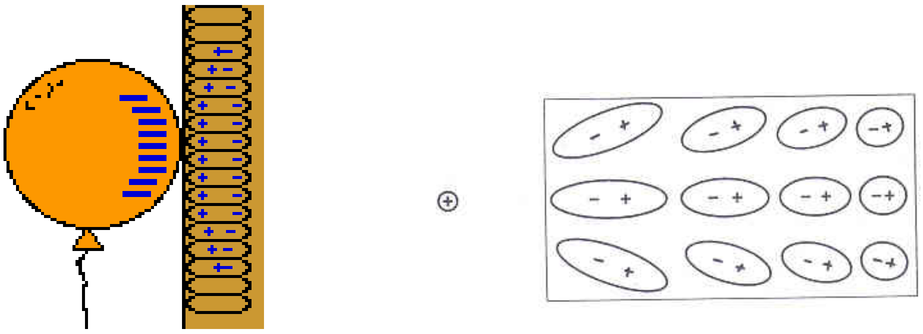
Overview of the Representation of Polarization

Well-known textbooks like Serway (1990) and Hewitt (2002) usually adopt static pictorial models to represent the microscopic level when a charged body is nearby an uncharged one (figures 1a, 1b).

Fig. 1. Representations of dipole formation (a) Serway, (b) Hewitt, (c) a web-picture, (d) Chabay & Sherwood



a: Serway b: Hewitt

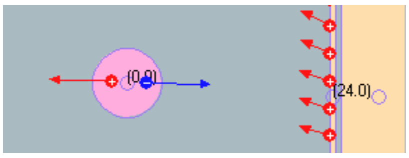


c: Web d: Chabay & Sherwood

The concept of "dipole" is introduced and in figures 1a, 1b dipoles seem to have the same shape even though their distance from the external charge is different. However, Chabay & Sherwood (2002), as well as some representations in the web (2006), propose the dipoles to be such deformed, as they are closer to the external charge (figures 1c, 1d). In some representations though there is no orientation of the dipoles (figures 1a, 1c) while in others appears (figures 1b, 1d).

Static models usually avoid the drawing of the forces on the atom or on the dipole that comprises the cause for the attraction between an uncharged and a charged body. Forces are introduced rather recently, mainly in Physlet applets (Wolfgang & Belloni 2003) (figure 2).

Fig. 2. Forces to a dipole



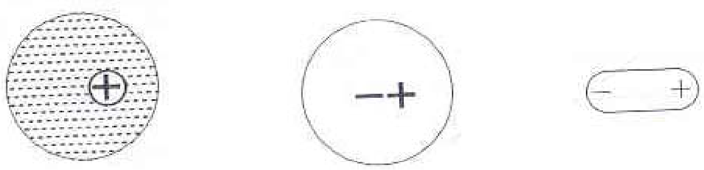
It appears that there is not a unanimous and comprehensive approach to the modelling of dipoles and dipole formations. Besides, research reveals students' difficulties in polarization (Barbas & Psillos 2003). To improve such situation we opted for didactically transformed comprehensive representations of polarization at introductory level.

DEVELOPMENT OF SIMULATED MODELS

We opted to develop three innovative simulated causal models representing electric polarization and specifically the behaviour of an atom and forces exerted on a dipole and an insulator when an external charge is placed anywhere near them. The aim was to have a sequence of models with which students could study the attraction between an uncharged and a charged body.

The introduction of the dipole was considered to be necessary, as we wanted to represent the forces exerted as the cause and the explanatory framework for the attraction between uncharged and charged bodies. Specifically, we structured the models for providing a smooth passage from the microscopic to the macroscopic level. We thus designed one model that shows the deformation of the electronic cloud in an atom; afterwards we pass to another model that shows the formation of a dipole upon external charge and then a third one showing an insulator when there is nearby an external charge. Following Chabay & Sherwood (1995) we developed the sequence: model of atom – model of dipole (figure 3), as the dipole (figure 3c) is appropriate for emphasizing the "*most important aspects of polarization*".

Fig. 3. Transition from the atom to the dipole



a b c

In simulations 1 and 2 the user can choose and move an external charge anywhere nearby to an atom or dipole respectively (figure 4). The red circle of the atom represents the nucleus and the blue circle represents the electronic cloud. The white dotted circle indicates the closest position of the external charge to the atom or dipole. When an external charge is moved close to the atom, the electronic cloud is deformed from spherical symmetry towards (or away) to the external charge, as being attracted (or repelled) to it depending on the polarity of the charge.

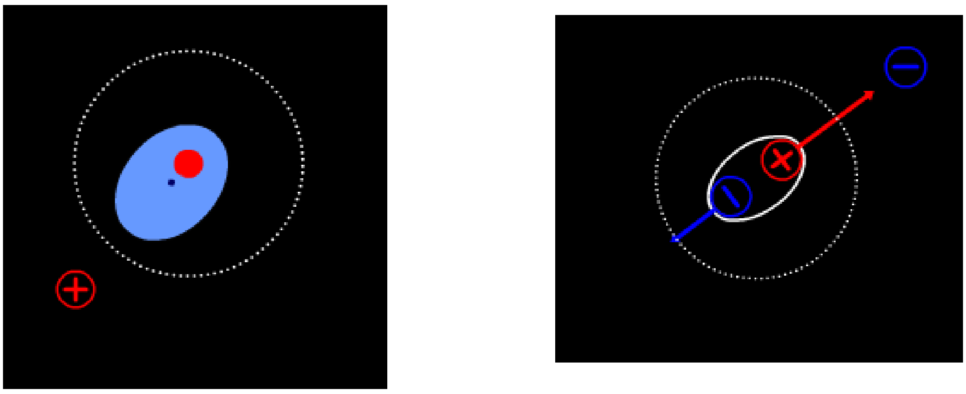


Fig. 4. Atom (left) and dipole (right) representations upon external charge

The red and blue circles of the dipole show the center of positive or negative charge. When an external charge is moved close to the dipole, the two poles separate due to Coulomb interactions. The attractive force appears bigger than the repelling one, obeying the rule of Inverse Square for distance.

In simulation 3 the user can move an external charge anywhere nearby to an uncharged insulator (figure 5).

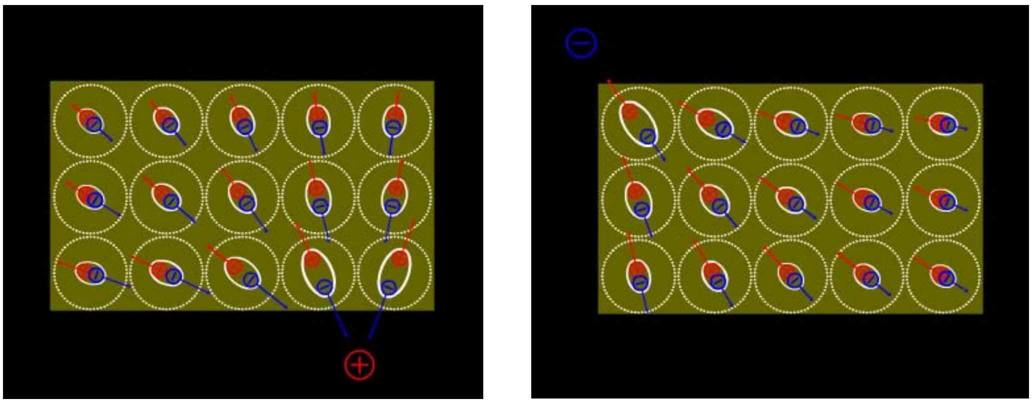


Fig. 5. Dipoles in an insulator

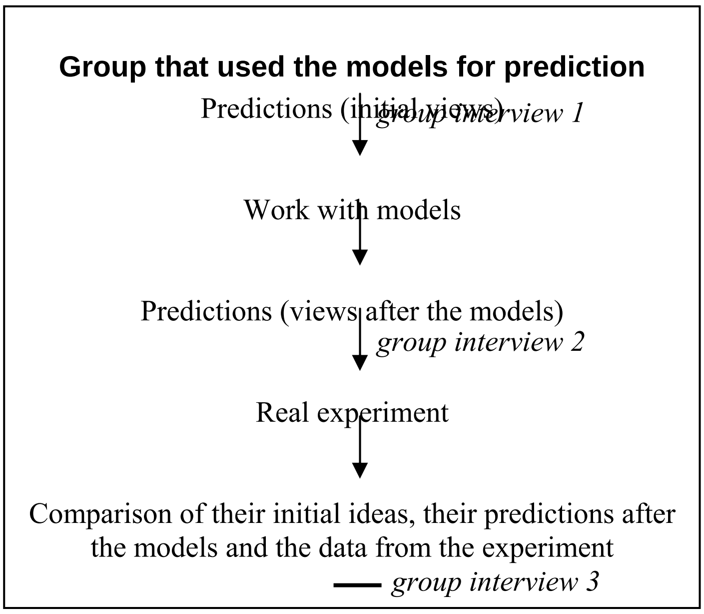
Both attractive and repulsive forces exerted to each dipole are indicated. Our aim was to put the students in a process of predicting the attraction between the uncharged and the charged bodies taking into account both the attractive and the repulsive forces.

TEACHING AND INVESTIGATING THE MODELS

A sample of 10 university pre-service primary education student teachers in Thessaloniki, Greece, was engaged in instruction with the simulated models. These students, opted for a larger program, worked in small groups with specially developed worksheets. Here we mainly focus on one 3 members group (S1, S2, S3). The main features of the interplay between instruction aiming at enhancing the use of models by students for predicting phenomena and monitoring of students' progress is shown in Diagram 1.

In carrying out their worksheet, the three students initially provided predictions on tasks in which they were asked to answer what would happen between an uncharged and a charged balloon; then they handled the three simulated models and tried to predict the same phenomenon again. After the second interview the real experiment with balloons was performed. Finally, the students compared their initial predictions with them after working with the models and the experiment.

Diagr. 1. Structure of the intervention

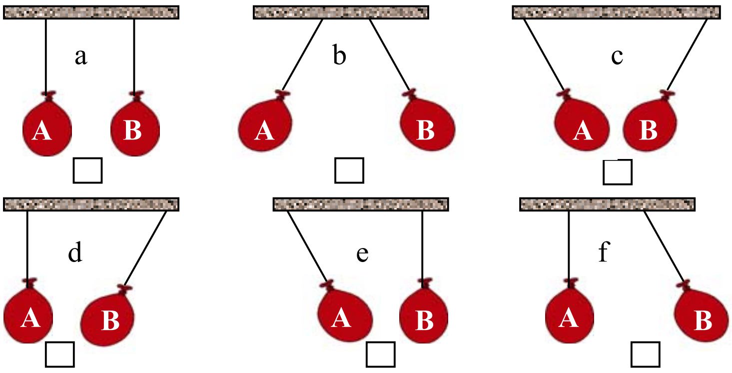


Data were obtained by pre- post written students' answers on the questions of the worksheets and analysis of tape recorded in depth group interviews.

RESULTS

Students were asked to predict what might happen between an uncharged balloon B and a negatively charged balloon A both attached to strings from the ceiling (figure 6).

Fig. 6. Pre post worksheet task



In the first interview students S1 and S2 thought that the balloons will not interact and chose figure a, while S3, chose the option f. The students justified their answers as follows.

Teacher (T): What did you answer?
S1: As the balloon B is uncharged there will be no attraction or repulsion.
S2: I agree! Even though the one balloon is negatively charged there will be no interaction as the other balloon is uncharged.
T: What about you?
S3: Even though I have written that the negatively charged balloon will repel the uncharged balloon, now I agree with the girls.

After working with the models, students were asked to carry out again their predictions on the task.

T: What did you answer?
S2: That finally there will be exerted attractive forces between the balloons and we will see them coming near; I would choose now the figure c.
T: When you say finally what do you mean?
S2: The exerted forces are not only attractive. Simply, the attractive forces are bigger than the repulsive.
S1: They are bigger because the distance between the opposite charges is smaller!
T: What do you think?
S3: I think that the charged balloon will exert attractive force to the uncharged one. I would choose know the figure d.
S1: No! According to the third model the uncharged balloon always will be attracted to the charged balloon A and because of the third law of Newton the balloon A, also, will be attracted to the uncharged balloon.
S3: I didn't think about it at all.

It seems that S1 and S2 predicted correctly the attraction between the balloons referring both to repulsive and attractive forces while S3 considered that the charged body attracts the uncharged and didn't speak about the existence of the repulsive forces.

Regarding the predictive use of models these students were asked to reflect on the features of the models that helped them in interview 3.

T: Did the models help you predict correctly?
S1: Yes!! While I was sure that there wouldn't be any interaction between the balloons, after working with the models I wrote that the balloons should be attracted to each other. The experiment also showed that!!

S3: When I saw the experiment I realized that I didn't make a right prediction…(she laughs). *I wrote that only the uncharged balloon would move close to the charged one…*
T: You?
S2: My prediction was right!
T: Now, can you underline the features of the models that helped you predicting?
S2: For my prediction the existence of the dipole and its behavior was important
S1: I can't say that the one model helped me more than the other. All the three models helped me. If I have to choose… may be the forces were the most important.
T: What about you?
S3: The one with the atom. The deformation of the electronic cloud helped me more.

It seems that S1, S2 recognized the power and employed successfully the models in their thinking while S3 was partially moved from her initial views. Besides, differential features of the models provided conceptual help to each student. Also, as expected, they used the real experiment in order to check their predictions.

CONCLUDING REMARKS

Following their engagement in the model-based unit the three student teachers succeeded in fulfilling their tasks by using the models. Reflecting on the models themselves, students considered them as conceptually helpful. Various features of each model, such as representation of deformation and forces appealed to each student's thinking. Similar results were found with the rest students of the sample as well. Having in mind the limitation of this small-scale study, we envision that this comprehensive representation of polarization, the required predictions before and after the introduction of the models, corroborated by real experimentation, facilitated students to understand both the specific content and the predictive power of models.

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