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What microscopic explanations can students give about the electric current?

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Abstract

In this paper we present views of the students of the Alexandroupolis Department of Elementary Education, on the electric current at a microscopic level as they emerged through their written answers to an extensive questionnaire which included mostly open questions. From our research, which is quantitative and follows a more limited qualitative research, it appears that the vast majority of students are unable to give microscopic explanations of electrical phenomena that are in line with the scientific model.

Keywords: conductors, surface charges on a current conducting , Electric field

Introduction

It is well known that several researches have been made about alternative learners' ideas for electrical current, especially at the macroscopic level and less on the microscopic. In our previous publication (Kountouriotis & Mihas, 2006) we have made an extensive review of the relevant literature and we do not consider it appropriate to repeat it here. The interested reader can go there. Here we will just refer to a more recent survey and some work that is directly related to our own research. Afra, Osta & Zoubeir (2009), in an article, they describe the effort that they made to implement a research-based teaching intervention in Secondary Education students that emphasized the conceptual understanding of electrical circuits. Their intervention was based on the Electrical Circuits section of the McDermott & Shaffer Tutorials In Introductory Physics(1998). For the evaluation of the results of their didactic intervention they used the test under the name DIRECT of Engelhardt & Beichner (2004). This test is a test with closed-ended questions that was designed to evaluate learners' understanding of a variety of concepts in DC circuits. Based on the results of this test, the researchers found that their didactic intervention improved the understanding of the concepts by their students, who during the intervention had presented all the alternative ideas mentioned in the bibliography. De Posada, (1997) found that students of the last two grades of High School used in a percentage of 50% the free electron model to explain the conduction of metals, while other explanations were that the currents from the positive and the negative pole of the battery collide, or that the charge is transferred from the battery, or that atoms let the electricity pass through them passively. Chabay & Sherwood (2006) have proposed and tested for a number of years an approach to the teaching of dynamic electricity that insists on the central role of the electric field in all electrical phenomena that links it to the microscopic model of matter. The integration of static and dynamic electricity is done through the study and visualization of single-circuit electric fields.

The identity of the research

The survey was conducted in November 2006 and a questionnaire was used as a research tool containing 19 open and 2 closed-ended questions. The questionnaire completion time was one hour. The students who answered the questionnaire were 89 and chose to participate in the survey. They were students in the third semester of their studies attending the Physics Principles course. There were 69 women and 20 men. At the Lyceum, 45 people, the Technological Direction 21 and the Positive 11, were studying the Theoretical Direction. Also 2 came from abroad and 5 had finished high school several years ago and said they had attended the “3rd Bundle” (where the emphasis is on classic Greek). Five people did not give details of their studies at High School. At the time they completed the questionnaire, they had not been able to deal with electricity in the framework of the Physics Principles course. The research tool was an improved version of a questionnaire used in earlier, smaller-scale, qualitative research.

Results and comments

In our work we will confine ourselves to some of the questions answered by the students, which in our opinion are of the greatest interest. Consequently they are not presented in the order and the numbering they had in the questionnaire.

Table 1 Questionnaire Questionnaire	
Question 1	*Identify the following materials as conductors or insulators: copper, plastic, wood, distilled water, tap water, sulfuric acid dissolved in distilled water, salt dissolved in distilled water, sugar dissolved in distilled water, gold*

.Table 1 shows a question asked in the questionnaire to see to what extent it is known whether some daily materials and some Chemistry materials are electrically conductive or not. The following bar graph of Figure 1 shows the numbers of students who have designated each of the above materials as conductors or insulators. It is worthwhile to note that distilled water in just over 30% was considered a conductor while gold at about 30% insulator. Distilled water, of course, is not a material of everyday use and perhaps that is the reason for the mistake. For the sugar solution in the distilled water, we see that it was considered to be a conductor at about the same rate (33%) with the pure distilled water while the salt solution in the water was considered a conductor at 82%. We see that the addition of salt was treated very differently from the addition of sugar as it should.

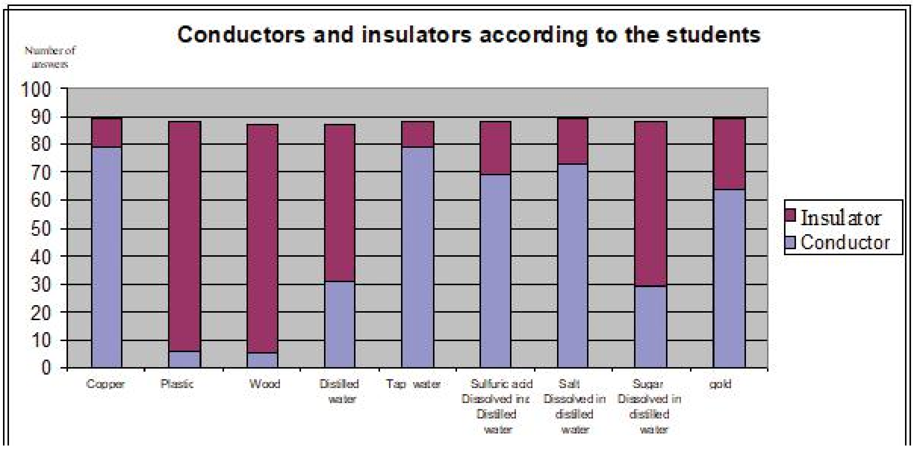

Figure 1 Bar graph giving the number of students who gave each answer

Table 2 Closed question from the questionnaire	
Question 2	*Describe the correct (C) or wrong (W) sentences:* • *Conductors are all the solid* • *Conductors are all the metals.* • *Conductors are all the molecular solutions.* • *Conductors are all the ionic solutions.* • *Conductors are all the ionized gases.*

The question of Table 2 is of a type correct / wrong and refers to which of the mentioned body categories are good electrical conductors and which ones are not. Here we try to investigate the knowledge about the conductivity of not individual materials but categories of materials very essential for the understanding of the conduction phenomenon. In Figure 2 we see the students' answers and the number (not the percentage) of the students who gave each answer. We must be careful that an impressively large number of students (84%) think that not all of the metals are conductors. Remember that 30% of the previous question considered that gold is not a good conductor of electricity. Instead, they give more correct answers for the molecular solutions were considered as 82% insulators while the ionic solutions were considered by 85% as conductors. The answers about ionized gases were more divided as 53% were considered as conductors.

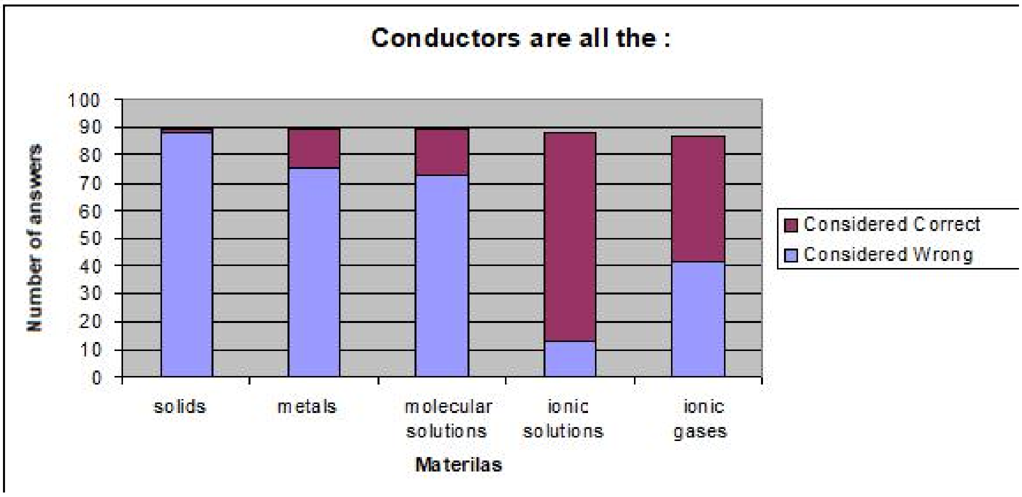

Figure 2

Question 3	Why do you think the electric current can pass through some bodies while some others do not?

Table 3

In Table 3 we see the next question concerning the explanation of the conduction of the bodies. Here it is the question of respondents themselves trying to give an explanation that will be considered as belonging to the "microscopic level", albeit simplified, without mentioning the details of the different categories of lawsuits. (metals, electrolyte solutions and ionized gases). The answers we received from the students and the students are shown in the diagram of Figure 3. There we see that most students (44%) could not give any justification because some bodies are conductors and some not. A significant percentage (31%) attributed it to the composition of only the bodies without reference to the microscopic level. Finally, an explanation based on the microscopic level attempted to give 21% of the students, but close to the scientific explanation was only 9% of the answers.

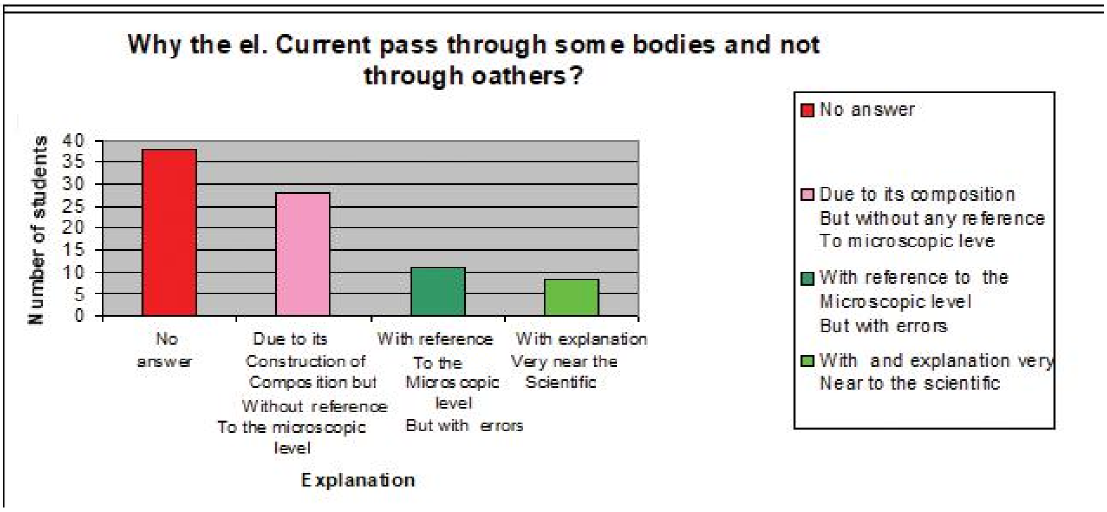

Figure 3

For the circuit of Figure 4 are the following three questions. It is a circuit that includes a battery and a cylindrical metallic conduit that connects the battery poles, but it has a peculiarity. Although it is made of the same material, a portion of it, as shown in the figure, has a smaller thickness. (diameter) The three questions asked in the questionnaire are shown in Tables 4, 5 and 6. Correct answers to the questions arise if one applies the principle of conservation of the charge that in a circuit like this (steady state) means that the current is conserved

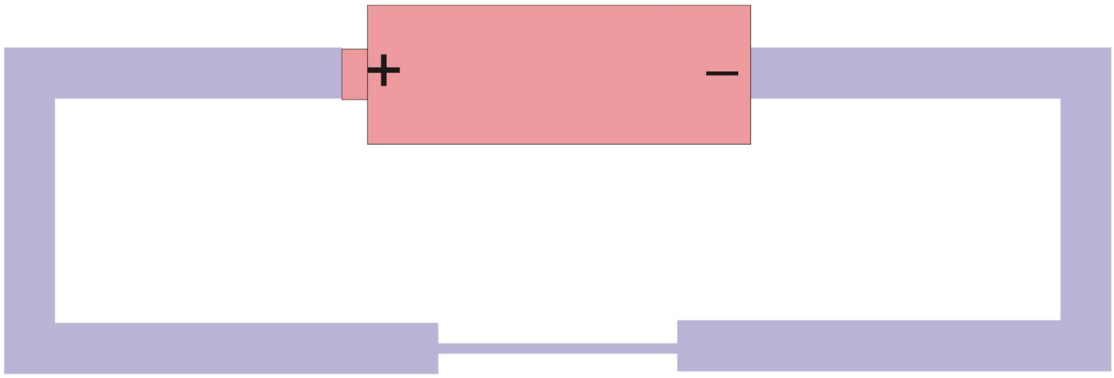

Figure 4

Qustion 4	In the circuit of Figure 4 all the cables are of the same material (eg copper) The circuit is closed, so it will flow current through it. Is the current passing through the narrow portion of the cable larger, less than or equal to the current passing through the wide section of the cable? Justify your answer.

Table 4

In the question of Table 4 the number of students who gave the different answers is shown in Figure 5. Although the percentage of correct answers was relatively large (72%), only one student gave the correct scientific justification, ie he wrote that the current should be be the same in the narrow and broad section of the duct as a consequence of the principle of conservation of current. Usually those who wrote that the current would be the same in their highest proportion (50%) did not offer any explanation beyond the statement that the current would be independent of the thickness of the cable. In some responses there appeared to be a confusion between the concepts of current and charge that were given the same meaning. For example, a student wrote that "the current will be the same, but it will move at a different speed in the narrow and wide section". The sentence makes sense if you replace the word "current" with the word "charge". Those who wrote that the current is smaller in the narrow section (35%) mainly attributed to less electrons passing due to tightness of space without mentioning it at all during the passage. Those who wrote that the current is larger in the narrow section gave it the "crowding" of electrons.

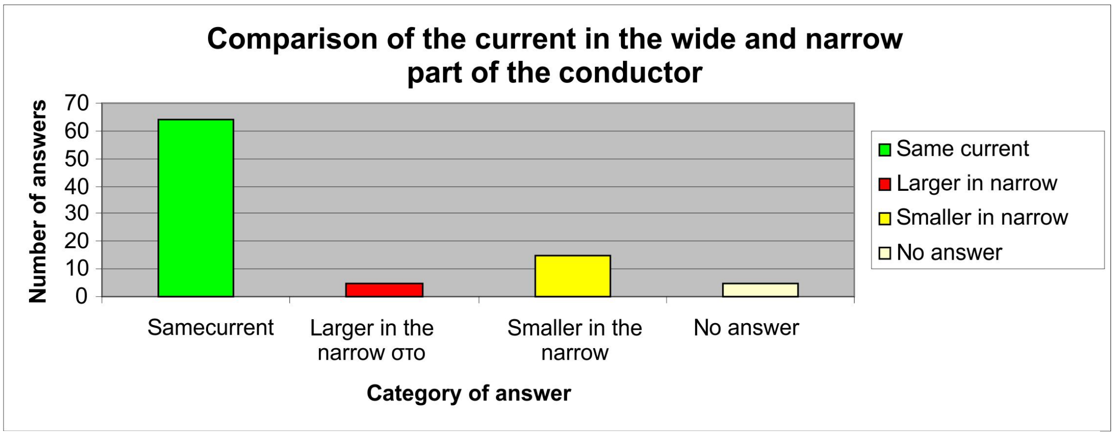

Figure 5

Question 5	In the circuit of the above figure, the electron velocity in the narrow portion of the cable is greater, less than or equal to the electron velocity in the wide portion of the cable? Justify your answer.

Table 5

In the question of Table 5, all the alternative answers were given by the majority but the wrong choices were that the speed was the same (37%) and that the speed was smaller in the narrow section of the duct (35%) compared to the wide one.

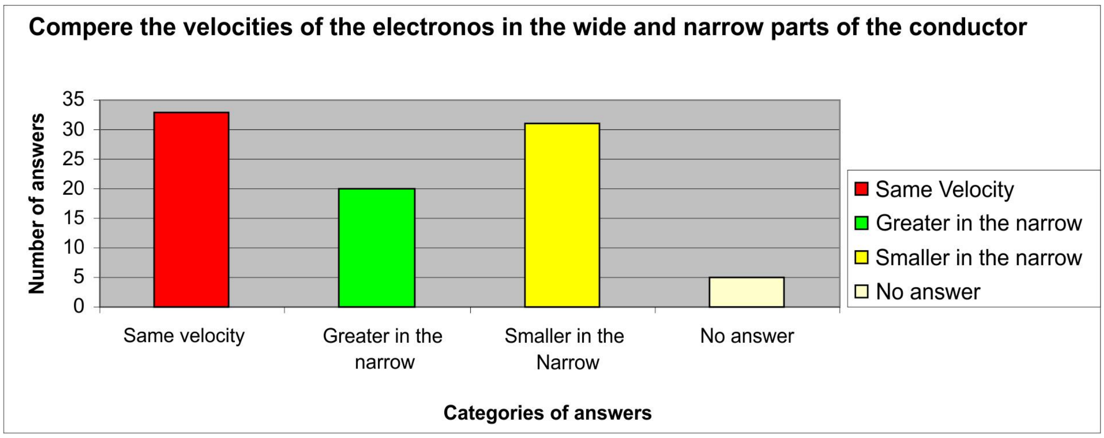

Figure 6

The choice that the velocity is the same in the narrow and wide section of the cable was usually given without substantive justification simply by saying that the electron velocity is independent of the thickness of the cable. In fewer cases the justification was that since the current is the same, the electron velocity will be the same.

The answer that the speed is smaller in the narrow section of the cable than the wide one usually has the justification that this is due to the tightness of the space. It is obvious here that there is the perception of electrons as ordinary particles that have difficulty going through a "narrow space".

The choice that the velocity is greater in the narrow section of the cable that is in line with the scientific standard was selected at 22%. However, only 7% gave a justification that was consistent with the scientific model, that is, they delivered the fastest speed to the need to keep the current and thus the load (since we refer to the steady state).

Question 6	In the circuit of the above figure the electric field strength (intensity)in the narrow section of the cable is greater, less than or equal to the electric field strength in the wide part of the cable? Justify your answer.

Table 6

For the question of Table 6 we see the number of students who gave the possible alternative answers in Figure 7.

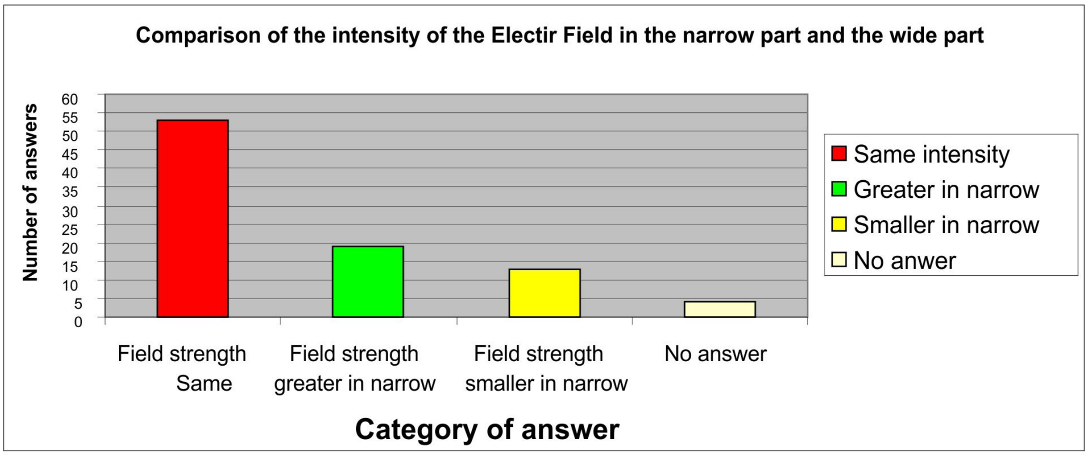

Figure 7

The answer that the field strength (Field intensity) is the same in the narrow and the wide section of the conductor was by far the most popular (60%) although it is not in line with the scientific model. Some of the answers showed that students (both male and female) did not understand the difference in the concepts of electric field strength and current intensity. Thus, the intensity is called by a student "charge velocity" (= Electric intensity). Also the justification because the electric field strength should be the same usually seemed like an argument because the electrical current is the same.

The answer is that the intensity of the field is greater in the narrow, which is also in line with the scientific model followed in popularity by a percentage (21%). However, only one student responded in a scientific way. (It is the same student who gave a correct answer with correct justification to the previous question) Some of the alternative justifications were that the intensity of the electric field is greater due to the accumulation of electrons, or due to the tightness of the space, or because at the same time they spend more electrons.

The answer that field strength is lower in the narrow section of the conductor accounted for a 15% response rate. Among the justifications given was that the intensity is lower because the narrow segment can not grow the field, or that it is proportional to the charges that are there, therefore, less in the narrow segment. Also in some expressions there was also a confusion between the concepts of electric field strength and current intensity.

Conclusion

Both female and male Students seem to have, for the most part, learned that some bodies are conductors or insulators as mere empirical events without being able to justify their characterizations on the basis of explanations at the microscopic level although it is known that they have been taught in High School.

To a large extent, they believe that conductivity is not a general property of all metals. In a large percentage, they are also unable to explain conduction at the microscopic level.

They are unable to apply the principle of conservation of charge to draw conclusions such as the constancy of the current in a simple circuit like that of Figure 4, or how the electron velocity is changing and how the electric field intensity changes in a conductor which is leaked by current when the thickness of the pipe changes.

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