

# The Perceptions of Cypriot Secondary Technical And Vocational Education Students About Simple Electric Circuits

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## Abstract

The purpose of this study was the assessment and evaluation of Cypriot Secondary Technical and Vocational Education Students' perceptions about simple electric circuits and their comparison with the corresponding perceptions of students that were found in similar research. The research sample constituted of 73 students from the A' Technical School of Limassol, Cyprus. **Determining and Interpreting Resistive Electric Circuits Concepts Test (DIRECT) 1.2**, translated and adopted in Greek language by the researcher, was used as a research instrument. The comparison of the results to those obtained from similar research indicates that these perceptions are harmonised to a great extent with the perceptions of students from other countries and previous years, a fact that proves their universality and diachronicity. The observed divergences are mainly caused by the erroneous way that students receive information related with electric phenomena from their social environment, a fact that makes students develop erroneous perceptions persistent to teaching.

**Keywords:** Secondary Technical and Vocational Education, Simple Electric Circuits, Misconceptions.

## 1. INTRODUCTION

### 1.1 *The misconceptions phenomenon*

During the last decades a series of observations and empirical researches (Brumby, 1982; Clement, 1979; Driver, 1973; Driver & Easley, 1978; Driver, Squires, Rushworth & Robinson, 1994; Engelhardt & Beichner, 2004; Fredette & Clement, 1981; Gunstone & White, 1981; Osborne & Freyberg, 1985; Selman, Jaquette, Krupa & Stone, 1982) showed that students had significant difficulties in understanding, describing, interpreting and predicting natural phenomena. These difficulties were observed even among students that performed well on textbook problems (Reif, 1986; Champagne, Gunstone & Klopfer, 1983; Koumaras, 1989).

After further investigations it was found that the reason for these students' failures was not the absence of theories, but the persistence of *preconceptions*, preformed ideas and theories about how the natural world works, theories that students bring with them to the science class and stand as an obstacle to what students are expected to learn (Bruner, 1966; Champagne *et al.*, 1983; Pfundt & Duit, 2006).

diSessa (1983, 1988) argues that preconceptions can be described as a fragmented collection of loosely connected intuitive ideas, involving cognitive elements that are minimal abstractions of common events through which students interpret their experience. diSessa calls these ideas "phenomenological primitives" or "p-prims" (diSessa, 1983, p.15).

Chi & Roscoe (2002) differentiate between two forms of prior conceptions: preconceptions that can easily and readily be revised through instruction, and *misconceptions*, preconceptions that are robust and highly resistant to change, even when not supported by observations.

This study will focus on students' misconceptions, as we think that after many years of formal instruction, the majority of the study's participants (aged between 15 - 18), must have abandoned those preconceptions that can be easily revised through instruction.

Although the existence of students' misconceptions has been detected in various fields of physics, a more coherent discussion of the issues can be presented when attention is focused on one field at a time. Hence, the subsequent discussion will focus on the field of electricity.

Students' misconceptions about electricity have been the topic of study for researchers in the last 30 years. These studies have focused in simple electric circuits, flowing current in the electric circuits and especially the brightness of bulbs in simple circuits (Shipstone, 1984; Osborne & Freyberg, 1985; Psillos, Koumaras & Valassiades, 1987; Heller & Finley, 1992; Driver, Squires, Rushworth & Robinson, 1994; Chambers & Andre, 1997; Engelhardt & Beichner, 2004; Küçüközer & Kocakulah, 2007).

These misconceptions are usually formed before students enter formal education and tend to persist despite instruction (Osborne & Freyberg, 1985). But misconceptions can also be created during formal education and can be firmly held despite science teaching (White & Gunstone, 1992; Sencar & Eryilmaz, 2004).

The reason that a pleiad of misconceptions exist despite the fact that electricity is a distinct concept which students frequently encounter in everyday life is perhaps owed to the fact that electric current is not something visible and the students is unable to comprehend what happens when a current of electrons flows through a circuit (Carlton, 1999). In a study Garnett & Treagust (1992) have determined that students understand current as a flow of positive charges (mainly protons) through wires, a perception that is maybe owed to the fact that students confuse the conventional with the real flow of current in an electric circuit.

After a detailed review of the related literature (Cohen, Eylon & Ganiel, 1983; Osborne & Freyberg, 1985; Psillos, Koumaras & Tiberghien, 1988; Shipstone, Jung & Dupin, 1988; Koumaras, Psillos, Valassiades & Evangelinos, 1990; Driver *et al.*, 1994; Borges & Gilbert, 1999; Koltsakis & Pierratos, 2006) we have gathered the most common students' misconceptions that have been investigated and recorded in the thematic region of simple electric circuits. Below are these misconceptions presented; most of them in the form of mental models.

## 1.2 Mental Models and Misconceptions about Electric Circuits

1. **The unipolar or sink model:** In this model students believe that

in order to complete a simple circuit with a battery and a light bulb we only need a cable that connects the battery with the light bulb (Figure 1). The electric current flows from a pole of battery to the light bulb and does not return. If a second cable exists in the circuit then this is extra or unnecessary (Osborne & Freyberg, 1985; Koumaras *et al.*, 1990; Driver *et al.*, 1994; Borges & Gilbert, 1999; Koltsakis & Pierratos, 2006).

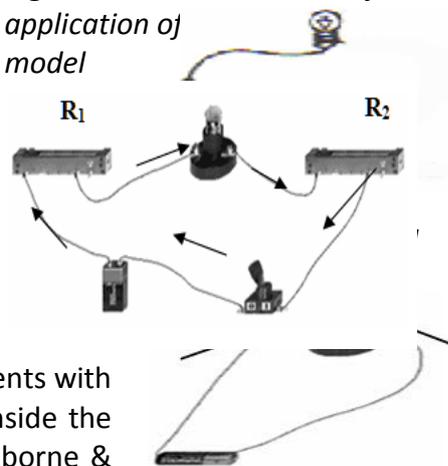
2. **The clashing currents model:** In this model (Figure 2), two cables are used to connect the battery with the light bulb. In the resulting circuit two electric currents with opposite directions flow inside the wires, “collide” inside the light bulb and cause the light bulb to illuminate. (Osborne & Freyberg, 1985; Driver *et al.*, 1994; Borges & Gilbert, 1999; Koltsakis & Pierratos, 2006).

3. **The weakening current model:** In this model students believe that there is an electric current that flows around the circuit, but this current weakens progressively. The explanation that is given for this decrepitude is that part of the electric current “is consumed” in the interior of the light bulb. (Osborne & Freyberg, 1985; Koumaras *et al.*, 1990; Driver *et al.*, 1994; Borges & Gilbert, 1999; Koltsakis & Pierratos, 2006).

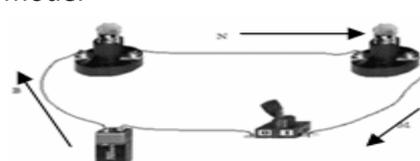
4. **The shared current model:** In this model (Figure 3), the students perceive that the electric current is shared equally among the light bulbs that illuminate the same. However and in this occasion the electric current is not maintained, because the light bulbs “consume” a part of it, so that less current returns in the battery (Osborne & Freyberg, 1985; Koumaras *et al.*, 1990; Driver *et al.*, 1994; Koltsakis & Pierratos, 2006).

1. **The sequence model:** In this model the students believe that messages about changes taking place in a circuit are carried forward in the direction of the current but not backwards. So when we present the circuit illustrated in Figure 4 to the students and ask them to predict what will happen to the brightness of the lamp if either  $R_1$  or  $R_2$  is changed, many understand that increasing or decreasing  $R_1$  will cause the brightness of the lamp to decrease or increase, respectively, but argue that changing the value of  $R_2$  will have no effect whatever upon the brightness since it comes after the lamp (Shipstone, 1984; Engelhardt & Beichner, 2004).
2. **The local reasoning model:** In this model students are focusing their attention entirely upon what is happening at one point in a circuit and completely ignoring whatever may be happening elsewhere. (Cohen, Eylon & Ganiel, 1983; Heller & Finley, 1992).

**Figure 1** The unipolar circuit used to test for application of model



**Figure 3** The shared current model





The Cyprus Educational System comprise the following categories:

- ✓ Pre-primary Education 3 to 6 years
- ✓ Primary Education 6 to 12 years
- ✓ Lower Secondary Education (Gymnasium) 12 to 15 years
- ✓ Upper Secondary Education (Eniaio Lykeio or Secondary Technical and Vocational School) 15 to 18 years
- ✓ Higher and University Education 18+

In our research we will focus on upper secondary education, and specifically the Secondary Technical and Vocational School (STVE). According to Bradshaw (1993) one of the primary concerns of the Cyprus government since independence from Britain in 1960, was the establishment and organization of technical education, because it was regarded as a contributing factor in the economic progress of the island. During the first 30 years, 11 technical schools were established. By entering a STVE school, students can choose either the vocational or technical section according to their interests. The technical section offers a curriculum with emphasis on mathematics, physical sciences, and a technology of specialization, and the vocational section emphasises on acquiring skills with much of the time devoted in workshop practice.

### **3. PURPOSE OF THE STUDY AND RESEARCH QUESTIONS**

The educational system of Cyprus is undergoing a major reform at this time period. One of the main objectives of this reform is the revision of the National Curriculum and the accompanying textbooks for every teaching subject. Special emphasis is given to the curriculum and textbooks of Mathematics, Physical Sciences and Technology because of the priorities of the European Union and the demands of the modern society (Educational Reform Committee, 2004).

One important task that has been assigned to the subcommittee for the development of the new National Physics Curriculum (of which I happen to be a member) is to design curriculum, instruction and the accompanying textbooks in such a way that students' prior conceptions for natural phenomena will be replaced with the corresponding scientific acceptable ideas and perceptions.

The researchers agree that the first step in the planning of instructive interventions and learning activities to this direction is the detection and the assessment of the misconceptions with which the students come to school and pre-exist formal teaching. (Shipstone, 1988; Davis, 2001; Koltsakis & Pierratos, 2006).

The purpose of this study was to determine Cypriot Secondary Technical and Vocational Education (STVE) students' misconceptions about simple electric circuits and to compare these misconceptions with those reported in the literature. The results of the study will hopefully constitute the background in the planning and creation of instructive interventions that will aim to replace students' pre-existing perceptions with the corresponding scientifically acceptable ideas and perceptions. The final objective will be to incorporate these interventions in the new National Physics Curriculum of Cyprus' schools.

The research questions of this study were the following:

1. What are the misconceptions of Cypriot Secondary Technical and Vocation Education (STVE) students about simple electric circuits?

2. Do these misconceptions differ from the misconceptions of students of similar ages that have already reported in the literature and to what extent?

#### 4. METHODOLOGY

The study was done between 12 to 23 April 2010. A diagnostic test was administered to selected students from A' Technical School of Limassol. Two classes from each grade -one from technical and one from vocational section- were randomly selected. The research sample constituted of 73 students i.e. 22 first grade (10<sup>th</sup> grade level), 28 second grade (11<sup>th</sup> grade level), and 23 third grade (12<sup>th</sup> grade level) students.

These students were asked to complete anonymously the diagnostic instrument Determining and Interpreting Resistive Electric Circuits Concepts Test (DIRECT) version 1.2., translated and adopted in Greek language by the researcher.

The diagnostic instrument as well as the data analysis procedure that followed, are explained in the sections below:

##### 4.1 Determining and Interpreting Resistive Electric Circuits Concepts Test (DIRECT).

DIRECT was developed by Paula V. Engelhardt and Robert J. Beichner, both professors of North Carolina State University to evaluate high school and university students' understanding of a variety of resistive dc circuits concepts. This instrument has been chosen because it fulfils many of the reasons that according to Cohen *et al.* (2000) make published tests attractive to researchers:

- ✓ It is objective;
- ✓ It has been piloted and refined (hence will use version 1.2);
- ✓ It has been standardized across a named population so it represents a wide population;
- ✓ It's reliability and validity has been tested and published (Engelhardt & Beichner, 2004; Ateş, 2005; Ross & Venugopal, 2005; Rosenthal & Henderson, 2006);
- ✓ It is a parametric test, thus allows sophisticated statistics to be calculated;
- ✓ It saves the researcher a considerable amount of time by sparing him from the task of having to devise, pilot and refine his own test.

DIRECT is a twenty-nine item multiple-choice test with five answer choices for all questions except one and it takes about 45 minutes (one teaching period) to complete. All the questions are of the same level of difficulty and a correct response is awarded one point, thus students' total scores for this instrument can range from 0 to 29.

The instrument is structured in four units: Physical aspects of DC electric circuits, Energy, Current and Potential difference (voltage), one for each constituent part component of scientific knowledge that is related with simple electric circuits. Via the questions of each unit it is attempted to elicit students' perceptions, for each constituent part component of scientific knowledge.

The instrument was constructed around a set of eleven instructional objectives about simple electric circuits, which involve a number of different aspects. These objectives are presented in Table 1.

**Table 1: Objectives for DIRECT (from P. Engelhardt & R. Beichner, 2004, p.100)**

Objective	Question No
<b>Physical aspects of DC electric circuits (objectives 1-5)</b>	
<b>1</b> Identify and explain a short circuit	10, 19, 27
<b>2</b> Understand the functional two-endedness of circuit elements	9, 18
<b>3</b> Identify a complete circuit and understand the necessity of a complete circuit for current to flow in the steady state	
<b>Objectives 1–3 combined</b>	27
<b>4</b> Apply the concept of resistance including that resistance is a property of the object and that in series the resistance increases as more elements are added and in parallel the resistance decreases as more elements are added	5, 14, 23
<b>5</b> Interpret pictures and diagrams of a variety of circuits including series, parallel, and a combination of the two	4, 13, 22
<b>Energy (objectives 6-7)</b>	
<b>6</b> Apply the concept of power to a variety of circuits	2, 12
<b>7</b> Apply a conceptual understanding of conservation of energy including Kirchhoff's loop rule ( $\sum V = 0$ around a closed loop) and the battery as a source of energy.	3, 21
<b>Current (objectives 8-9)</b>	
<b>8</b> Understand and apply conservation of current to a variety of circuits	8, 17
<b>9</b> Explain the microscopic aspects of current flow in a circuit through the use of electrostatic terms such as electric field, potential differences, and interaction of forces on charged particles.	1, 11, 20
<b>Potential difference (Voltage) (objectives 10-11)</b>	
<b>10</b> Apply the knowledge that the amount of current is influenced by the potential difference maintained by the battery and resistance in the circuit.	7, 16, 25
<b>11</b> Apply the concept of potential difference to a variety of circuits including the knowledge that the potential difference diff. in a series circuit sums while in a parallel circuit it remains the same.	6, 15, 24, 28, 29
<b>Current and Voltage (objectives 8 &amp; 11)</b>	26

Although the validity of the DIRECT test has been determined and published, this has been done for the English version only.

To ensure the content validity of the Greek version, the instrument was sent to two Physics teachers, renowned in their field, that have years of experience in teaching STVE students. They were asked to check the instrument for a number of factors that according to Gay and Airasian (2003) affect the validity of a measuring instrument like DIRECT: a) unclear test directions; b) confusing and ambiguous test items; c) using vocabulary too difficult for test takers; d) overly difficult and complex sentence structures.

They both suggested that question 11 needed rephrasing, because the translation was obscure and would probably confuse students. Apart from that, both thought that in general, the test was suitable for the assessment of students' perceptions about simple electric circuits. After their suggestions were taken into account, the necessary modifications were performed and the test was given for completion to the students during a teaching period.

To insure the reliability of research and the validity of the data, the following measures were taken:

- Students didn't know beforehand that they will be asked to complete the diagnostic test, in order to ensure that their answers will reflect their preexisting knowledge and won't be a result of instruction.
- It was made clear to the students that the diagnostic test is anonymous, that its completion is made exclusively for research purposes and will not influence in any way their degree in the course of Physics.
- During the completion of the diagnostic tool students weren't allowed to collaborate with each other, or ask clarifications from the supervisor about the test.
- Due to the fact that the students weren't asked to complete the test all at the same time, after a team of students completed the test, both tests and answer sheets were collected, to ensure that students won't keep copies of the test and become familiar with the questions, or pass them to other students.

#### **4.2. Data Analysis**

The purpose of the present study was not only to evaluate students' achievement in the field of simple electric circuits, but mainly to assess and commit to paper students' misconceptions in this field of study. Having that in mind, the responses that students gave were not categorized only as correct or erroneous, but three categories of answers were created: a) correct answer, b) misconception and c) other (Paraskeyas & Alimisis, 2007).

In the first category we classified the correct answers according to the answer key given by DIRECT developers P.V. Engelhardt and R.J. Beichner.

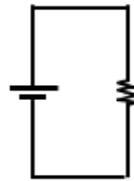
In the second category the answers that express students' alternative perceptions that contradict scientific knowledge were classified. This category was later analyzed into subcategories based in the specific misconception that corresponds to the answer that students gave.

In the third category we classified the remainder of the answers that students gave and didn't fall into any of the first two categories. For instance in Question 12 (Figure 7) answer (D) was classified in the first category, while answers (A), (B) and (C) were classified in the second category. Answer (E) didn't fall into any of the first two categories so it was classified in the third category.

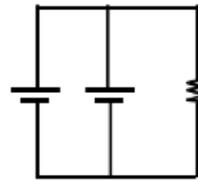
**Figure 7 Question 12**

12) Consider the power delivered to each of the resistors shown in the circuits below. Which circuit or circuits have the LEAST power delivered to them?

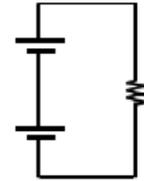
- (A) Circuit1
- (B) Circuit2
- (C) Circuit3
- (D) Circuit1 = Circuit2
- (E) Circuit1 = Circuit3



Circuit 1



Circuit 2



Circuit 3

For comparison reasons the results of the present study were compared with the results of the study conducted in 2002 by P.V. Engelhardt & R.J. Beichner, with 692 students from high schools and universities in Canada, Germany, and the United States (Engelhardt & Beichner, 2004).

### 5. FINDINGS AND DISCUSSION

The data obtained, were analyzed in a variety of ways. What we initially checked was the students' achievement in each of the instructional objectives that DIRECT examines. These results were compared with the results of Engelhardt & Beichner's study. The findings are analytically presented in the Table 2 below.

**Table 2** Objectives for DIRECT and mean rate of students' achievement in each objective.

Objective	Question No	Avg. Percentage Correct %	
		STVE Students	USA - Canada - Germany Students
1	10, 19, 27	41	56
2	9, 18	50	59
1-3	27	44	73
4	5, 14, 23	35	40
5	4, 13, 22	45	54
6	2, 12	23	28
7	3, 21	45	49
8	8, 17	38	59
9	1, 11, 20	22	19
10	7, 16, 25	39	38
11	6, 15, 24, 28, 29	28	34
8&11	26	26	40

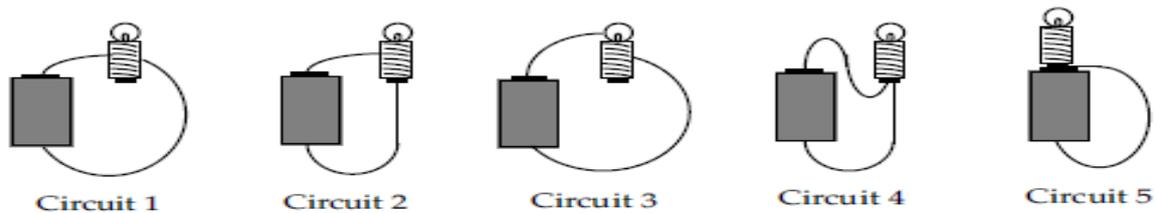
By studying the results it becomes obvious that STVE students' achievement is in general terms similar with that of students from other countries. Significant divergences were found only in question No 27 (objectives 1-3 combined) and in questions No 8 & 17 (objective 8). In question No 27 that examines students' ability to identify a complete circuit, a short circuit and to understand the functional two-endedness of circuit elements, indicates that

more than 55% of STVE students failed to predict that only the bulb in Circuit 2 (Figure 8) will light.

By analyzing the distribution of the answers that students gave to this question, we conclude that the reason for this failure is mainly due to the fact that students don't know where the contacts of the bulb are located. They believe that if we attach two cables connected to a battery anywhere in the surface of the bulb, then the bulb will illuminate.

**Figure 8 Question 27**

27) Will all the bulbs be the same brightness?



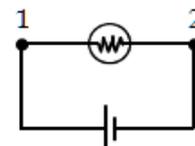
- (A) Yes, because they all have the same type of circuit wiring.
- (B) No, because only Circuit 2 will light.
- (C) No, because only Circuits 4 and 5 will light.
- (D) No, because only Circuits 1 and 4 will light.
- (E) No, Circuit 3 will not light but Circuits 1, 2, 4, and 5 will.

Questions No 8 & 17 (objective No 8, Figure 9) examine students' ability to understand and apply conservation of current to a variety of circuits. Here the majority of the students adopt the "weakening current" model mentioned in section 1.2.

**Figure 9 Questions 8 & 17**

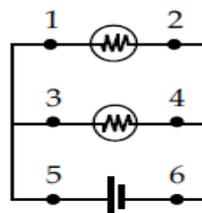
8) Compare the current at point 1 with the current at point 2. At which point is the current LARGEST?

- (A) Point 1
- (B) Point 2
- (C) Neither, they are the same. Current travels in one direction around the circuit.
- (D) Neither, they are the same. Currents travel in two directions around the circuit.



17) Rank the currents at points 1, 2, 3, 4, 5, and 6 from HIGHEST to LOWEST.

- (A) 5, 3, 1, 2, 4, 6
- (B) 5, 3, 1, 4, 2, 6
- (C) 5 = 6, 3 = 4, 1 = 2
- (D) 5 = 6, 1 = 2 = 3 = 4
- (E) 1 = 2 = 3 = 4 = 5 = 6

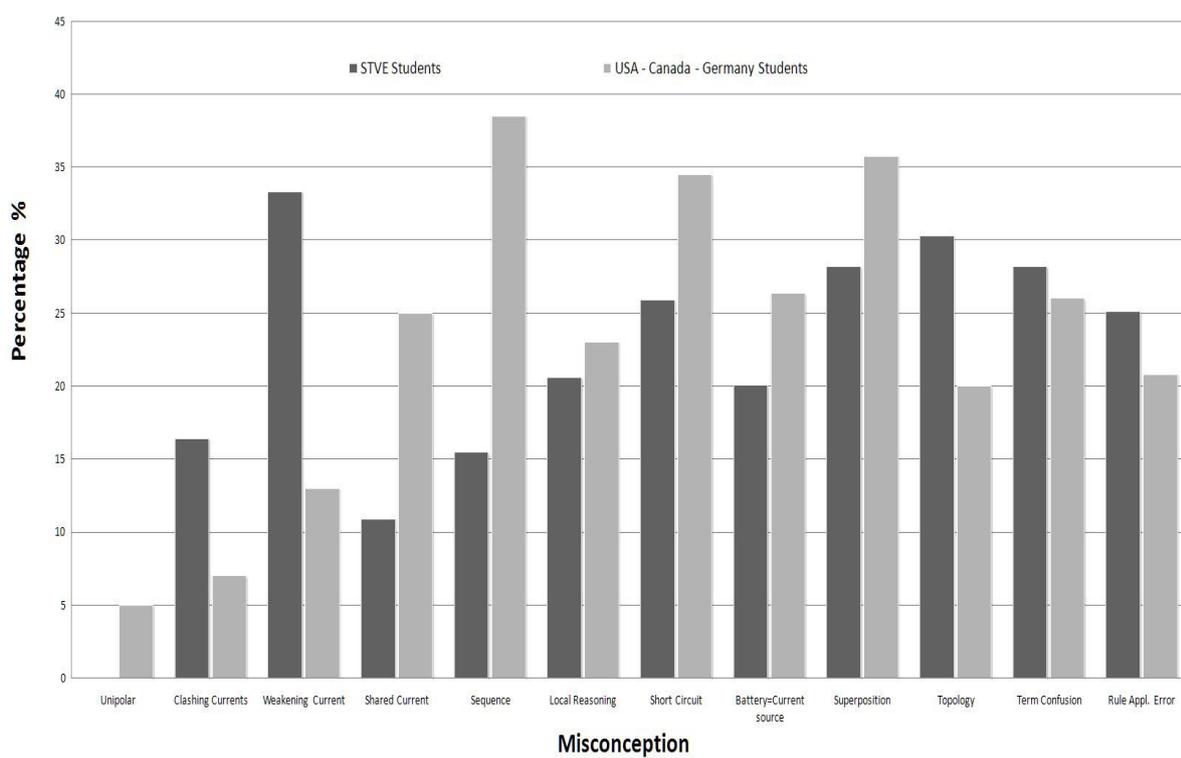


This divergence was expected as it has already been documented in a similar study conducted among Greek students by Koumaras et al. (1990). In that study only 35% of the students answered that the value of electric current remains unaltered when it travels through a light bulb or a resistor. The reason of this divergence is caused by the fact that students learn from their parents, their peers, even from the mass media that what is "consumed" when we turn on an electric device is not electric energy, but electric current (Koumaras et al., 1990; Koltsakis & Pierratos, 2006). This misconception is so widespread, that if we put in Google search engine the exact phrase "κατανάλωση ρεύματος" (current consumption in Greek), it returns about 125.000 results!

In the remainder of the instructional objectives, Cypriot students share their success or failure, with their counterparts from other countries.

Afterwards a frequency analysis of students' misconceptions was performed. This action was deemed necessary in order to make a comparison of the STVE students' rate of misconceptions appearance, with the corresponding rate in the Engelhardt & Beichner's study and find prospective divergences between the two studies. The results are presented in Graph 1 that follows, together with their equivalents obtained from Engelhardt & Beichner's study.

**Graph 1** Mean rate of misconceptions appearance.



What we observe by studying the graph, is that none of the STVE students adopts the unipolar model (see section 1.2), while on the contrary it is adopted by 5% of the students in Engelhardt & Beichner's study. This finding needs to be further investigated at a later time.

A significant divergence in the appearance rate of the clashing currents and the weakening current models that were mentioned in section 1.2. is also observed, a fact which we have previously pointed out in this section. This could be caused by the erroneous way that students receive information related with electric phenomena from their social

environment. Expressions commonly used in Cyprus such as "he was knocked out by current" or "don't waste current", contribute to the development of erroneous perceptions, that are difficult to be eliminated with formal teaching (Koumaras *et al.*, 1990).

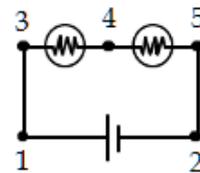
An interesting fact that will be further investigated is the ascertainment that the percentage of appearance of the shared currents and the sequence models among STVE students is much smaller than that of their counterparts from other countries.

Another finding that also requires further investigation is the reasoning with which STVE students responded in question 6 (Figure 10).

**Figure 10** Question 6

6) Rank the potential difference between points 1 and 2, points 3 and 4, and points 4 and 5 in the circuit shown below from HIGHEST to LOWEST.

- (A) 1 and 2; 3 and 4; 4 and 5
- (B) 1 and 2; 4 and 5; 3 and 4
- (C) 3 and 4; 4 and 5; 1 and 2
- (D) 3 and 4 = 4 and 5; 1 and 2
- (E) 1 and 2; 3 and 4 = 4 and 5



In this question 47,3% of students selected the answers (C) and (D). That means that STVE students consider that the potential difference between the points located above the battery is higher than the potential difference between the poles of the battery.

An assumption was that perhaps did STVE students confuse the term "πτώση τάσης" (voltage fall) that is synonym to *potential difference* in Greek language. So maybe they perceive that in order to have "voltage fall", the potential difference between points 3 and 4 should be the highest because point 3 is located in the top left corner and point 4 follows. So as we travel further in the direction of current flow the potential difference will gradually "fall".

## 6. CONCLUSION AND SUGGESTIONS

After performing a detailed analysis of the results we came to the following conclusions:

- ✓ The perceptions of Cypriot STVE students about electric current and simple electric circuits does not appear to differ considerably from those of students from other countries (Engelhardt & Beichner, 2004) and previous years (Koumaras *et al.*, 1990), a fact that proves their universality and diachronicity.
- ✓ STVE students adopt to a great extent the clashing currents and weakening current models, while on the contrary they don't seem to use the unipolar, the sequence and the shared current models.
- ✓ The majority of the students seem to ignore where the contacts of a bulb are placed.
- ✓ Social environment plays an important role in the appearance of misconceptions resistant to formal teaching.
- ✓ Students in a percentage that reaches 30% do not use mathematic equations in order to compute physical quantities such as equivalent resistance and power but

they use the superposition model instead.

- ✓ Also about 30% of STVE students seem to confuse common terms that occur in simple electric circuits.

As Paraskeyas & Alimisis (2007) pointed out, the learning process does not take place in a social void. The existing curriculum and textbooks have been proved insufficient at helping students abandon their preconceptions and adopt the scientifically accepted ideas and perceptions (Educational Reform Committee, 2004).

That's why the new Physics curriculum and the accompanying textbooks, must be developed in a way that they will connect the concepts of electric current and simple electric circuits with situations that occur in everyday life.

We must not however, overlook the important role that the teacher will play, because it is them that will be asked to implement these new ideas and methods.

According to Kokkotas (2007) a reform will be condemned to failure if the necessary conditions under which the teachers can and should teach in a better and more effective way are not ensured. For this reason, the experiential training of teachers is more than essential, in order to achieve the long-sought objective of the replacement of students' misconceptions with scientifically acceptable ones.

## 7. LIMITATIONS

The present study is subject to limitations that have been pointed out for studies that use tests as data collection instruments. These limitations are related with issues such as: (Cohen *et al.*, 2000):

- a) The level of students' comprehension of the terms appeared in test items.
- b) The insufficiency of the educational level and the limited ability of the use of language ability by functionally illiterate or foreign students.

Apart from the above, due to financial limitations and time restrictions the participants of the study were chosen from only one Technical School, so someone could argue that the results can't be generalized from the sample to population, because of the inability of the results comparison of the participants with those that didn't participate.

Also the present study -like all the studies that rely on tests- couldn't avoid the divergences that are owed to the fact that some students (intentionally or not) didn't give the necessary attention during test completion. It should however be pointed out that during test administration and data analysis the researcher made every effort to reduce this phenomenon as much as possible.

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