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Students' Conceptual Knowledge about Electricity and Magnetism and Its Implications: An Example of Turkish University

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ABSTRACT *The main purpose of this study was to investigate students' conceptual knowledge and structure of thought about electricity and magnetism and its implications on an introductory general physics-2 course. This course is proposed at Balikesir University, Turkey. Maloney, O'Kuma, Hieggelke, and Heuvelen (2001) developed a conceptual test, which contains 32 multiple-choice questions related to electricity and magnetism topics. This Conceptual Survey of Electricity and Magnetism (CSEM) test was administered as a pre- and post-test to all students enrolled in general physics-2 courses at Necatibey Faculty of Education and the Faculty of Science and Liberal Art. A total of 614 and 544 freshmen students were present during the pre- and post-test, respectively. Significant differences were found in both male and female students' pre- and post-CSEM test percentage scores, and there were significant correlation between students' general phsics-2 achievement scores and post-CSEM scores. Further analysis of the CSEM scores revealed a number of difficulties that students usually face in electricity and magnetism, and some tentative solutions are suggested.*

KEY WORDS: *Alternative conceptions, physics achievement, physics education.*

Introduction

Since the last quarter of the twentieth century, research about physics education revealed that, before taking the physics courses, students usually have many preconceived ideas that generally come from interaction with their real physical and social environments. Those kinds of ideas influence their future learning negatively (Thornton & Sokoloff, 1990; Van Heuvelen, 1991; Hestenes, Wells & Swackhamer, 1992; Poon, 1993; Palmer & Flanagan, 1997; McDermott, 1997; Mazur, 1997; Redish, Saul, & Steinberg, 1997; Duit, & Rhöneck, 1997; Mutimucio, 1998; Hake, 1998; Tatlı & Eryılmaz, 2001). To assess students' achievements and conceptual understanding of many physics subjects, many tests have been developed and applied. In mechanics concepts, Mechanics Baseline Test (MBT) and Force and Motion Concepts test (FCI) (Hestenes, Wells & Swackhamer, 1992) are well-known tests. In Electricity and Magnetism subjects, Maloney, O'Kuma, Hieggelke, and Heuvelen (2001) omitted the content of electric circuits and developed Conceptual Survey of Electricity and Magnetism (CSEM) test. The CSEM test consists of 32 multiple-choice questions targeting eleven different concepts related to Electrostatics and Magnetism.

Barrow (2000) "Committee on Undergraduate Science Education" (1997), and some studies identified on web (URL-1, 2004; URL-2, 2004 and URL-3, 2003) suggested that both high school and university students have many preconceived ideas about electrostatics and magnetism in physics. In addition to these studies, Moreira and Dominguez (1986, 1987) have shown that university students had many preconceived ideas about several topics such as current and potential differences. Electricity and Magnetism topics mainly consist of formal and abstract concepts, and the kinds of students' preconceived ideas affect their future achievement (Champagne, Klopfer & Anderson, 1980; Halloun & Hestenes, 1985).

The main aim of this study was to investigate students' conceptual knowledge about electricity and magnetism and their implications on an introductory general physics-2 course in Balıkesir University, Turkey.

Research Questions

1. Are there any statistical differences between male and female students' pre- and post-CSEM (Conceptual Survey of Electricity and Magnetism) mean scores?
2. Is there any correlation between students' Conceptual Survey of Electricity and Magnetism (CSEM) pre- and post-test scores?
3. Is there any relationship between students' general physics 2 achievement scores and Conceptual Survey of Electricity and Magnetism (CSEM) post-test scores?

Methodology

Population and sample

The population of this study consisted of all students enrolled in introductory general physics-2 courses in the Bal_kesir University, Turkey. The subjects of the study were a convenient sample that included the students who were enrolled in introductory general physics-2 courses at Necatibey Faculty of Education and the Faculty of Science and Arts. There were 614 and 544 students in the pre- and the post-test, respectively. Table 1 shows the sample of the study and its distribution in the two departments.

Instrumentation

The Conceptual Survey of Electricity and Magnetism (Maloney et al., 2001) was administered both as a pre- and posttest.

Conceptual Survey of Electricity and Magnetism (CSEM) Test

The Conceptual Survey of Electricity and Magnetism est consists of 32 multiple-choice questions to assess students' eleven different conceptual areas in Electricity and Magnetism. These areas are charge distribution on conductors/insulators, coulomb's force law, electric force and field superposition, force caused by an electric field, work, electric potential, field and force, induced charge and electric field, magnetic force, magnetic field superposition, Faraday's law, and Newton's third law.

There are two criteria for evaluating a standardized test, validity and reliability. When developing CSEM test, 42 college professors expressed their opinions about

Table 1
The Sample of the Study

Colleges	Departments	Sub Departments	Type of Class	Pretest N	Posttest N
Science and Arts	Mathematics	-	PC	39	30
	Physics	-	PC	29	24
			BC	26	23
	Chemistry	-	PC	47	38
			BC	40	34
Necatibey Faculty of Education	Secondary Education	Physics Education	PC	26	25
		Chemistry Education	PC	30	27
		Computer and Technology Education	PC	37	44
			BC	34	30
		Mathematics Education		46	33
	Elementary Education	Science Education	PC	55	45
			BC	42	38
		Mathematics Education	PC	84	76
			BC	79	77
		Total		614	544

Note: PC: Primary Classes; BC: Bilateral Classes

both the reasonableness and the appropriateness of the test's items. The KR-20 post-test estimates for the CSEM was found around r = 0.75 which is a very reasonable value (Maloney et al., 2001). In addition, the CSEM test was translated (with kind permission of the authors) into Turkish, and then many physics instructors were asked to judge the understandability of the items. The Turkish version of CSEM test was administered to a small group (n=31) of pre-service candidate physics teachers, and the information was used to eliminate or minimize unclear sentences due to translation of the test items. After evaluating their results and getting their opinions, the final test was administered to the sample of this study. Moreover, the reliability of the posttest in this study was found to have an r value of 0.74.

Procedures

After constructing the final translated version of the CSEM test, it was administered to all participants during the second week of spring semester of 2004 as a pre-test, and the last second week of the spring semester of 2004 as a post-test. After the post-test, each class as a whole group has been interviewed with unstructured questions asking them their opinion about electricity and magnetism concepts and in general physics course. Then students' responses were recorded for further analysis.

Results

The result section can be divided into two parts: CSEM test and research questions.

Results Related to the CSEM Test

According to CSEM pre- and post-test results, students' mean score on the pretest was 27.104 % (correct answers/total questions x100) with a standard deviation of 9.849. The mean of post-test score was 53.394% with a standard deviation of 15.811. Participated students' mean scores, standard deviations and normalized gain scores in pre- and post-test according to their enrolled are presented in Table 2.

Table 2
Students' Mean Scores, Standard Deviations and Normalized Gain Scores in Pre- and Post-test According to Their Departments

Students' Enrolled Department		N	%	Mean (%) scores	Standard deviations	Normalized Gain Scores (%)
FEF Mathematics	Pretest	39	6.4	26.795	1.605	30.85
	Posttest	30	5.5	49.394	12.547	
FEF Physics	Pretest	29	4.7	26.379	1.330	49.03
	Posttest	24	4.4	62.474	16.587	
FEF Chemistry	Pretest	47	7.7	20.702	1.172	20.00
	Posttest	38	7.0	36.563	9.955	
NEF Physics Education	Pretest	26	4.2	33.807	1.990	25.60
	Posttest	25	4.6	50.750	9.567	
NEF Chemistry Education	Pretest	30	4.9	24.700	1.424	29.20
	Posttest	27	5.0	46.690	10.422	
NEF Math. Education	Pretest	46	7.5	29.065	1.582	63.58
	Posttest	33	6.1	74.167	8.828	
NEF Computer and Technology Education	Pretest	37	6.0	25.622	2.053	65.89
	Posttest	44	8.1	74.0630	8.109	
NEF Elementary Mathematics Education	Pretest	84	13.7	31.702	0.988	31.74
	Posttest	76	14.0	53.380	13.947	
FEF Physics- BC	Pretest	26	4.2	24.846	1.985	31.95
	Posttest	23	4.2	48.859	17.698	
FEF Chemistry-BC	Pretest	40	6.5	21.875	1.305	25.62
	Posttest	34	6.3	41.893	16.067	
NEF Computer and Technology Education - BC	Pretest	34	5.5	25.500	1.895	51.76
	Posttest	30	5.5	64.062	8.882	
NEF Elementary Math. Education- BC	Pretest	79	12.9	25.734	0.872	34.17
	Posttest	77	14.2	51.112	13.220	
NEF Science Education	Pretest	55	9.0	30.454	1.303	28.40
	Posttest	45	8.3	50.208	9.270	
NEF Science Education-BC	Pretest	42	6.8	28.452	1.287	25.74
	Posttest	38	7.0	46.513	8.600	
Total	**Pretest**	**614**	**100**	**27.104**	**9.849**	**36.07**
	Posttest	**544**	**100**	**53.394**	**15.811**	

Note: $N_{pretest}$ = 614; $N_{posttest}$ = 544; BC: Bilateral Classes; FEF: The Faculty of Science and Liberal Art.; NEF: Necatibey Faculty of Education; Gain Scores ((posttest average scores% - pretest average scores % / (100-pretest average scores %))

The results in Table 2 indicate that the CSEM test was administered to fourteen different classes. While students from the Physics Education department had the highest pre-test mean score of 33.8%, the Chemistry department students' pre-test mean score was the lowest score (20.70%) among the all classes studied. On the other hand, students from Computer and Technology Education department had, on the post-test, the highest scores of 74.63%, and again the Chemistry department's students had the lowest score of 36.56% on the posttest. In addition, these results have given the highest and lowest normalized gain scores for the same departments with 65.89%, and 20%, respectively.

In general, from the CSEM pre and posttest results, while the most correct answer was given the third question with 82.4%, the least correct answer is given the fifteen questions with 5.2% in pretest. On the other hand, the only six questions (question number 15, 20, 23, 25, 29 and 31) were correctly answered with less than ten percent. In addition to this, students' correct answer percentage lessens when go over the further questions (for example while third, fourth and fifth questions are answered more than 90 percent, 29th and 30th questions were answered about 50 percent by the participants). In the posttest while the most correct answer was given the third question with 94.7 %, the least correct answer was given the 32nd question with 6.4 %. In the posttest, the three questions (27th, 29th, and 32nd questions) were correctly answered with less than ten percent that was dropped from six questions to three questions from the pretest to posttest.

Students' detail CSEM test results according to conceptual areas and related questions are given in Tables 3-9.

Conductors and Insulators

Students' CSEM pre and posttest results for the concepts of "conductors and insulators" are given in Table 3.

Table 3
Participants' pre- posttest results for the concepts of "conductors and insulators".

Questions		N	A (%)	B (%)	C (%)	D (%)	E (%)	Correct Answer
1	Pretest	587	1.5	59.8	20.27	6.8	6.8	B
	Posttest	540	2.2	17.8	10.1	2.0	6.3	
2	Pretest	521	28.3	17.8	12.1	8.5	16	A
	Posttest	514	58.3	11.9	9.7	6.4	8.1	
13	Pretest	503	39.1	18.9	2.0	2.8	19.2	E
	Posttest	502	22.2	24.4	2.9	2.4	40.3	

Students have some confusion how charges are distributed on conductors and insulators. There is a clear difference in how the students respond to the question one and two. For the question one about conductors the majority of the students distribute the charges over the sphere (choices B and C). In contrast, the answer distribution on the question two is essentially random, which is what it would be expected if the students had not have any strong initial ideas. Students' responses to the question one about charge distribution on conductors show a definite improvement from pre- to posttest (60% to 78). However, at posttest a substantial number of students responded that the charge was distributed over both the inner and outer surfaces of the metal sphere (28% to 58%). It appears that a substantial number of students seem not to be able to distinguish between conductors and insulators or fully understand what happens to the charge at all. Based on results, students' knowledge of the shielding effect of conductors seems rather weak. The contrast between about 40 % correct on the question thirteen and about 12 % correct on the question fourteen may be seen odd. However, part of the explanation is that about less than half of the students chose the correct response on the question thirteen for the wrong reason. For the question fourteen, there is an apparent pattern in the pretest choices and more than 50% of the students still chose answer A for the question fourteen on the posttest, which seems to indicate a misuse of Newton's third law.

Coulomb's Law

Students' CSEM pre and posttest results for the concepts of "Coulomb's law" are given in Table 4.

Table 4

Participants' pre- posttest results for the concepts of "Coulomb's law".

Questions		N	A (%)	B (%)	C (%)	D (%)	E (%)	Correct Answer
3	Pretest	599	3.9	82.4	4.6	2.6	4.1	B
	Posttest	537	1.3	94.7	1.7	1.7	0.7	
4	Pretest	590	2.3	58.6	24.9	7.5	2.8	B
	Posttest	542	1.5	80.1	12.5	4.0	1.5	
5	Pretest	590	22	4.7	59.8	4.7	4.9	C
	Posttest	541	12.1	1.7	79.2	4.4	2.0	

The third question, which was a straightforward application of Coulomb's law, having the best pretest and posttest correct answer percentages, is the easiest item overall. However, when it is turned to the question four, which looks at the force on the other charge, many fewer correct responses was found (about 15% less). The favored alternative C may indicate that many students could not apply Newton's third law correctly. The question five shows an additional small reduction in correct responses and indicates confusion on both the effect of the magnitude of the charges and the distance separation.

Force and Field Superposition

Students' CSEM pre and posttest results for the concepts of "force and field superposition" are given in Table 5.

Table 5

Participants' pre- posttest results for the concepts of "Force and field superposition"

Questions		N	A (%)	B (%)	C (%)	D (%)	E(%)	Correct Answer
6	Pretest	598	5.5	8.3	13.7	1.5	68.6	E
	Posttest	544	5.0	4.0	8.5	0.9	81.6	
8	Pretest	570	1.3	61.9	6.0	8.5	15.1	B
	Posttest	535	1.3	80.1	5.0	3.3	8.6	
9	Pretest	487	4.7	42.8	10.3	13.5	8.0	B
	Posttest	515	3.5	68.4	8.3	8.8	5.7	
23	Pretest	367	6.5	18.9	18.1	3.9	12.4	A
	Posttest	487	39.0	15.6	11.9	9.6	13.4	
26	Pretest	397	12.2	18.2	6.8	21.	6.1	A
	Posttest	488	49.1	11.8	7.7	17.6	3.5	
28	Pretest	437	4.9	14.8	15.1	5.4	30.9	C
	Posttest	491	11.9	7.5	38.4	4.6	27.8	

The question six has a good success rate for pre and posttest. The questions eight and nine are a more subtle application of superposition coupled with force and field ideas. Students performed about 12 % less well on the posttest for the question nine than six and eight questions. A noticeable percentage of students seem to be confused how a new charge affects the direction of the force or field. The question twenty-three was designed to be a straightforward application for the magnetic field around a long, straight wire and superposition. Although students might not have known this idea on the pretest, it can be assumed they may have known it fairly on the posttest. The question twenty-six provides some insight into the "depth" of student understanding of the magnetic field created by a current carrying wire and superposition of these fields. This straightforward question does have a fair success rate as a posttest item with 49%. This question shows a clear non-random response pattern on the pretest. Answer D was an attractive distracter for both pre and posttest students. This may indicate that students think the current coming out of the page is a positive charge (electrical analog). The question twenty-eight is another superposition question. Students show a fairly strong understanding of superposition by choosing answer C. Answer E, a strong distracter, may be another electrical analog with two like charges and the point in between them having no net field.

Force, Field, Work, and Electric Potential

Students' CSEM pre and posttest results for the concepts of "force, field, work and electric potential" are given in Table 6.

Table 6

Participants' pre- posttest results for the concepts of "Force, field, work, and electric potential"

Questions		N	A (%)	B (%)	C (%)	D (%)	E(%)	Correct Answer
10	Pretest	502	2.0	14.2	27.4	12.9	25.4	C
	Posttest	526	1.5	16.5	50.4	11.4	16.9	
11	Pretest	434	29.5	12.1	12.1	8.6	8.5	E
	Posttest	501	25.7	7.5	21.5	6.1	31.3	
12	Pretest	496	15.1	6.4	5.9	47.7	5.5	D
	Posttest	519	12.1	18.2	5.5	56.3	3.3	
14	Pretest	515	30.6	4.4	5.7	10.7	32.4	D
	Posttest	495	51.3	5.1	5.3	12.3	16.9	
15	Pretest	454	5.2	21.7	17.4	18.4	11.2	A
	Posttest	499	22.4	34.2	14.9	12.1	8.1	
16	Pretest	439	6.4	12.4	9.8	5.9	37.1	E
	Posttest	493	9.0	14.5	13.8	8.6	44.7	
17	Pretest	432	2.6	13.0	24.9	4.2	25.6	E
	Posttest	513	2.4	9.0	21.1	7.0	54.8	
18	Pretest	408	0.8	6.4	9.8	30.3	19.2	D
	Posttest	494	2.2	3.7	9.7	33.8	41.4	
19	Pretest	306	11.6	11.6	10.6	9.9	6.2	A
	Posttest	453	37.7	19.9	10.1	8.1	7.5	
20	Pretest	358	15.8	10.4	14.3	9.1	8.6	D
	Posttest	474	18.8	22.1	25.2	14.3	6.8	

Influence of residual conceptual problems from the first semester can provide some answers for the weak performance on the question ten. Post instruction, one would expect that students should have little problem thinking through the steps from a uniform field to a uniform force and to a uniform acceleration. Indication that the first step in this reasoning is straightforward was shown by the success rate (56 %) on the question twelve. The fact that about 16 % of the students' choice of B was on the question ten indicates that these students may still be associating a constant velocity with a constant force. Choice E on the question ten indicate that these students are working with an idea about an "equilibrium" situation in a uniform field. This inference is strengthened by the fact that about 26 % of the students chose A on the question eleven. Students do not seem to be able to distinguish the direction of the electric field from a change in potential. Students confuse whether an increase or a decrease in potential determines direction. The most incorrect answer was given in the pretest to the question fifteen with 5.2 % correct rate. The correct answer slightly changes in the posttest to 22.4 % indicating that students have many problems even after the instruction connecting the electric field lines and electrical charges. On the question twenty, almost 40 % chose answers A and B, however only about 38 % on the question nineteen, opted answer B. A little more than 5 % chose an increase, answers D, on the question twenty, and also about 16 % on the question nineteen, answered A. Around 20 % of the students chose an answer on the question nineteen (C and D). The field strength seems to be still confusing for many students. Answers A and C on the question twenty seem to indicate that students are associating large distances between equipotential lines with stronger field. It seems that this distance separation had affected student responses on the question seventeen as well.

Magnetic force

Students' CSEM pre and posttest results for the concepts of "magnetic force" are given in Table 7.

Table 7
Participants' pre- posttest results for the concepts of "Magnetic force".

Questions		N	A (%)	B (%)	C (%)	D (%)	E (%)	Correct Answer
21	Pretest	434	14.2	22.3	11.1	11.4	11.7	E
	Posttest	493	18.4	24.3	20.0	14.9	12.5	
22	Pretest	436	16.6	10.3	12.4	16.6	15.1	D
	Posttest	505	15.8	18.6	28.7	23.7	6.1	
25	Pretest	417	8.8	25.7	18.7	6.5	8.1	D
	Posttest	496	11.2	23.2	16.7	31.3	8.8	
27	Pretest	463	13.4	30.0	7.8	17.1	7.2	E
	Posttest	467	16.7	27.4	9.6	25.0	7.2	

It is known by many experienced physicists that students expect a magnetic force whenever an electric charge is placed in a magnetic field. Getting students to first check to make sure the charge has a velocity with at least a component perpendicular to the field direction is quite difficult. Choices of A, C, and D in the question twenty-one all were related to the same interest. Choice E is the only answer but not often chosen, which was the correct answer (the charge actually were to experience a magnetic force). There is a variety of ways that students seem to be interpreting the effect of a magnetic field on a moving charged particle. On the question of twenty-two, less then 30 % of the students chose answer C and D. There is a strong sign that students confuse the electric force and magnetic force. The correct answer percentage in the question twenty-seven remained unchanged from pre to posttest (7.2 %). That is the most interesting result of all items. Again, students had confused the electric force and magnetic force vice versa. One accepts that if the electric force and magnetic force were the same, they have to choose most probably the choice of B. In addition, the most incorrect answer, which is the choice of B, also slightly changed. On the question twenty-five, a strong alternative answer was C and could indicate fluid flow interpretations of the effect of the magnetic field on the moving charged particle.

Faraday's law

Students' CSEM pre and posttest results for the concepts of "Faraday's law" are given in Table 8.

Table 8
Participants' pre- posttest results for the concepts of "Faraday' law".

Questions		N	A (%)	B (%)	C (%)	D (%)	E (%)	Correct Answer
29	Pretest	312	10.9	12.1	6.7	15.5	5.7	C
	Posttest	426	15.1	27.0	8.8	23.3	4.0	
30	Pretest	302	14.5	6.0	12.2	9.1	7.3	A
	Posttest	424	34.2	5.9	20.2	11.4	6.3	
31	Pretest	359	12.1	17.1	18.2	5.0	6.0	E
	Posttest	438	9.6	19.7	15.4	13.2	22.4	
32	Pretest	378	25.4	10.7	8.8	12.2	4.4	D
	Posttest	470	56.3	10.7	6.3	6.4	6.8	

Questions 29 through 32 deal with Faraday's law and magnetic induction. Answers A, B, and C of the question 29 imply that the students know that a moving magnetic field (due to the moving magnet) or a moving bulb in a stationary magnetic field creates an induced current (lighting the bulb). Answers B and D, a powerful distracter, could indicate that students think this is the "only" way to get the bulb to light. Answer A, a powerful distracter as well, indicates that students believe a rotation is the "movement" necessary to induce a current (as well as moving of the magnetic field source). Answer D, is bewildering since it implies that a moving bulb creates an induced current but not case I. Overall, 50% of the students chose answers that used the idea that "motion" from either the loop or the magnet is necessary to create an induced current. Students could not see the collapsing loop as changing the magnetic flux or the rotating loops as not changing the magnetic flux. The question thirty approaches the induced current/voltage issue from a different direction. Cases I and II are correct (answer A with 34 % for posttest) but are contained in part in answers A–D. Answers A, B, and D include case I and answers A, C, and D contain case II. Case III is included in answers B, C, and D. It appears that students understand that the current-carrying wire is generates a magnetic field. Students were not sure of what loop motion induces a current. Case III seems to give them trouble determining whether it has an induced current or not.

The question 31, answers D and E could indicate students think that there is an induced "emf" that causes charges to move to the top (or bottom) of the metal bar. Unfortunately, these answers account for only 35 % on the posttest. Answers B and C are strong distracters, possibly indicating those students again think of the electrical effects instead of the magnetic effects. This interpretation would account for 35 % on the posttest. Answer A also remains a strong distracter and may indicate that students think that there is no effect or that there are no charges available to move.

The question 32 investigates an induced voltage experiment. Answer A, which is the most incorrect answer was given by the students with 56 %. A strong distracter, which is the same as the ammeter reading versus time graph, indicating the student might believe that the induced voltage is graphically the same as the original current. Answer B, is a strong distracter too. Students may be thinking the "negative" idea (like the question 29). Answer C, a distracter, is more like the "opposite" slopes—if current is changing, voltage is not and vice versa.

Newton's Third Law

Students' CSEM pre and posttest results for the concepts of "Newton's third law" are given in Table 9.

Table 9
Participants' pre- posttest results for the concepts of "Newton' third law".

Questions		N	A (%)	B (%)	C (%)	D (%)	E (%)	Correct Answer
4	Pretest	590	2.3	58.6	24.9	7.5	2.8	B
	Posttest	542	1.5	80.1	12.5	4.0	1.5	
5	Pretest	590	22	4.7	59.8	4.7	4.9	C
	Posttest	541	12.1	1.7	79.2	4.4	2.0	
7	Pretest	596	13.2	45.3	31.8	4.4	2.4	B
	Posttest	542	5.1	70.0	20.4	2.8	1.1	
24	Pretest	437	5.9	30.9	10.4	14.2	10.1	C
	Posttest	489	5.5	31.4	26.3	20.4	6.3	

The failure to believe that Newton's third law extends to electric and magnetic situations is shown by the responses on questions 7 and 24. On question 7, on the posttest 70 %, overall, chose the response consistent with Newton's third law. A few numbers of students responded that the larger magnitude charge exerts the larger force. A lesser distracter was the smaller magnitude charge exerts the larger force, answer A. When it is turned from electrical force to magnetic interactions, it is found the same difficulties about the Newton's third law (it is because of the correct answer percentages of the questions 4 and 5 were about 80 %). On the question 24, 26.3 % of the students applied Newton's third law correctly to the situation. It means that the majority of students are not properly use the third law.

Results devoted to research questions

To answer the question *"Are there any statistical differences between male and female students' Conceptual Survey of Electricity and Magnetism (CSEM) pre and posttest mean scores?"* the t-test performed for pretest and posttest separately for gender variable.

The t-test results are given in Table 10 for pretest and in Table 11 for posttest.

Table 10
CSEM pretest t-test result summary table for gender

Variable	df	t	p
Gender (difference of mean percent scores)	612	3.761	.000*

*$\underline{p}$. < 0.05

According to data obtained from this study, male and female students' pretest CSEM mean percent scores ($\bar{X}_{male}$= 28.88, $\bar{X}_{female}$= 25.64) are statistically significant in favor of male students (t_{612}= 3.761, $\underline{p}$.< 0.05).

Table 11
CSEM posttest t-test result summary table for gender

Variable	df	t	p
Gender (difference of mean percent scores)	542	3.024	.003*

*$\underline{p}$. < 0.05

According to data obtained from this study, male and female students' posttest CSEM mean percent scores ($\bar{X}_{male}$= 54.38, $\bar{X}_{female}$= 50.18) are statistically significant in favor of male students (t_{542}= 3.024; $\underline{p}$.< 0.05).

To answer *"Is there any correlation between students' Conceptual Survey of Electricity and Magnetism (CSEM) pre and posttest percent scores?"* question, Pearson correlation analysis was done between pre and post CSEM test scores. The summary result of this analysis is given in Table 12.

Table 12
The interaction summary table between CSEM pre and posttest percent scores

	Interaction coefficient (r)	N	t	p
pretest-posttest percent scores	0,32	468	2.14	.033*

*$\underline{p}$. < 0.05

According to data obtained from this study; there is a statistically significant interaction between CSEM pre and posttest percent scores (t_{466}= 2.14, $\underline{p}$.< 0.05).

To answer "*Is there any relationship between students' general physics-2 achievement scores and Conceptual Survey of Electricity and Magnetism (CSEM) posttest percent scores?" question*, Pearson correlation analysis was done between students' general physics-2 achievement scores and post CSEM test percent scores. The summary result of this analysis is given in Table 13.

Table 13
*The interaction summary table between CSEM posttest percent scores and students' general physics-*2 achievement scores

	Interaction coefficient (r)	N	t	p
Posttest-general physics-2 achievement scores	0,3	544	2.06	.036*

*$\underline{p}$. < 0.05

According to data obtained from this study; there is a statistically significant interaction between students' general physics-2 achievement scores and post CSEM test percent scores (t_{544}= 2.06, p.< 0.05).

Discussion

When it is looked at pretest and posttest CSEM answers, students had mostly made a mistake in the following concepts: magnetic force and field caused by current, magnetic field superposition and Faraday's law. The CSEM test results obtained from this study, female students have gotten lower scores than male students from both pre and posttest and these results were statistically significant. In the literature, there was not any result about the achievement of electricity and magnetism concepts for significance of gender differences. Whereas, Weinburgh's (1995) meta-analysis of the research suggests that there is only a moderate correlation between attitude towards science and achievement, Beaton et al. (1996) have found a consistent relationship between attitude and physics achievement. Similar findings have appeared in the major study conducted by Simpson and Oliver (1990), by Jovanic and King (1998) and by Osborne and Collins (2000). Under-representation and underachievement of female students in physics were also reported in many other recent studies in countries such as Ireland (O'Brien and Porter 1994), England and Wales (Stewart 1998, Smail 2000), Switzerland (Labudde et al. 2000) and Turkey (Tatlı and Eryılmaz, 2001; Demirci, 2004a, and 2004b).

After the post-test, students were interviewed with un-structured questions as a whole asking each classroom to their opinion about CSEM test and physics course. In general, students' thoughts could be summarized as follows:

- "The electricity and magnetism topics mainly consist of abstract concepts. Therefore, it is needed to have more concrete explanations using different kinds of instructions or media or aids."
- "Physics is not useful for their further life or further education—especially this idea comes from none physics or none science major students– therefore they could not motivate themselves to physics instructions and CSEM test."
- "Their instructions were mainly calculus based however the CSEM test consists of conceptual based questions; therefore, they thought they did not do well on the test."
- Some said, "Contents of physics topics are very broad and they had some difficulties with following and pursuing the instructions", and "they did not know which topics or concepts to start with" or "pacing their time to which concept to study."
- Some of them said, "They had heard at the beginning of the secondary high school that "The physics was very difficult subject", these kinds of expressions influence their approaches to physics courses."

Those kinds of problems and ideas influenced their physics achievement and understanding of electricity and magnetism concepts. To reduce those kinds of negative effects on physics course, the physics instructors has to be careful about their instructions and have many responsibilities to deal with. It can be implied also that the changes have to be made on traditional physics instructions and new approaches and new instructional techniques are needed.

In general, several characteristics of the traditional introductory Electricity and Magnetism course pose special difficulties:

- Traditional approach to Electricity and Magnetism is often highly formal. Conceptual reasoning is not taught explicitly.
- Many layers of abstract concepts are introduced in a short time so quickly that most of the students could not digest and distinguish among them.
- Many students are not familiar with the basic phenomena studied in the Electricity and Magnetism course.

The significant interaction between percentage mean score of pretest and posttest; and between posttest and general physics-2 achievement scores show and imply that there is correlation between pretest and posttest and general physics-2 achievement scores. If one gets higher percentage score on pretest, he/she most probably gets also higher percentage score on posttest and also gets higher general physics-2 achievement scores or vice versa.

Conclusions and Recommendations

As a summary, in this study students' knowledge and structure of thoughts about electricity and magnetism concepts were investigated. For this purpose, all students enrolled general physics-2 courses in the spring semester of 2004 at Bal_kesir University, the department of Science and Art and Necatibey Faculty of Education were chosen as a sample of this study. The CSEM test was applied as a pretest at the beginning of the spring semester of 2004, and as posttest at the end of same semester. In the pretest there were a total 614 (318 were male (51.8 %), 296 were female (48.2 %)), in the posttest there were a total 544 (273 were male (50.2 %), and 271 were female (49.8 %)) students. Students' mean percentage score of pretest was 27.104 and the mean percentage scores for posttest 53.394 were found. The male students have obtained higher mean score for both pre and post CSEM test than female students, and that results were statistically significant. In addition to this, it is found that there were significant correlations between both the result of CSEM pretest and posttest; and CSEM posttest and general physics-2 achievement percentage scores. It is found that even after the instruction students had many problems about electricity and magnetism concepts especially in magnetism parts.

Recommendations

According to the result of this study, the following recommendations can be made:

- In both result of pre and post CSEM test finding showed that there is a gender differences between male and female students percentage score that should be important finding to look forward it. Male and female students' attitudes toward CSEM test and physics could influence the results. Therefore, the parents, science instructors and science book publishers should be very careful and have to encourage female students from primary school to universities to reduce gender differences in physics.
- The physics professors or instructors in universities especially in pre-service

science or physics teacher's institutions should prepare and develop new instructional materials and methods to teach better understanding of all physics concepts as well as electricity and magnetism concepts. To acquire new instructional materials physics instructors should attend seminars, conferences or these kinds of activities and pursue up-to-date researches. Nowadays the Internet offers many opportunities to obtain new information and new possibilities that might be helpful for all those interested.

References

BARROW, L. (2000). Do elementary science methods texts book facilities the understanding of the magnet concepts? *Journal of Science Education and Technology, 9,* 199-205.

BEATON, A., MARTIN, M. O., MULLIS, I., GONZALEZ, E. J., SMITH, T. A., & KELLEY, D. L. (1996). *Science achievement in the middle school years: IEA's Third International Mathematics and Science Study.* Chestnut Hill, MA: Boston College.

CHAMPAGNE, A. B., KLOPFER, L. E., & ANDERSON, J. H. (1980). Factor influencing the learning of classical mechanics. *American Journal of Physics, 48* (12), 1074-1079.

COMMITTEE ON UNDERGRADUATE SCIENCE EDUCATION (1997). *Misconceptions as barriers to understanding science.* National Academy of Science, Science teaching reconsidered (Chapter 4). Washington D.C. National Academy Press. Available at: http://bob.nap.edu/readingroom/books/str/4.html

DEMIRCI, N. (2004a). A study on students' misconceptions and achievement in force and motion concepts using web based physics program.. *Science and Education, 29* (186), 20-29. (In Turkish)

DEMIRCI, N. (2004b). Students' attitudes toward introductory physics courses. *Hacettepe Faculty of Education, 26,* 40-47 (in Turkish).

DUIT, R., & RHÖNECK, V. C. (1997). *Learning and understanding key concepts of electricity* in A. Tiberghien, E. Josses and J. Barajas (Eds.) Connecting Research in Physics Education with Teacher Education (http://www.physics.ohio-state.edu/~jossem/ ICPE/C1.html).

HAKE, R. (1998). Active-engagement vs. traditional methods: A six thousand-student study of mechanics test data for introductory physics course. *American journal of Physics, 66* (1), 64-74.

HESTENES, D., WELLS, M., & SWACKHAMER, G. (1992). Force concept inventory. *The Physics Teacher, 30* (3), 141-153.

JOVANOVICH, J. & KING, S. S. (1998). Boys and girls in the performance-based science classroom: who is doing the performing? *American Educational Research Journal, 35,* 477–496.

LABUDDE, P., HERZOG, W., & NEVENSCHWANDER, M. P. (2000) Girls and physics teaching and learning strategies tested by classroom interventions in grade 11. International *Journal of Science Education,* 22, 143–157.

MAZUR, E. (1997). *Peer Instruction.* Prentice-Hall, Upper Saddle River (N.J.), & Toronto.

MCDERMOTT, L. (1997). Students' conceptions and problem solving in mechanic, in A. Tiberghien, E. Jossem and J. Barojas (Eds.) *Connecting Research in Physics*

Education with Teacher Education (http://www.physics.ohio-state.edu/~jossem/ICPE/C1.html).

MALONEY, D. P. (1984). Rule-governed approaches to physics-Newton's third law. *Physics Education, 19,* 37-42.

MALONEY, D., O'KUMA, T., HIEGGELKE, C., & HEUVELEN, A. V. (2001). Surveying students' conceptual knowledge of electricity and magnetism. *American Journal of Physics, 69* (7), 12-19. Physics Education Research Supplement.

MOREIRA, M. A., & DOMINGUEZ, M. E. (1986). Misconceptions in electricity among college students. *Ciencia e Cultura.*

MOREIRA, M. A., & DOMINGUEZ, M. E. (1987). Stability of misconceptions on electric current among college students. Paper presented at the interamerican conference on physics education, Oaxtepec, Mexico, July 20-24.

MUTIMUCUIO, I. V. (1998). Improving Students' Understanding of Energy, Druk: VU Huisdrukkerij, Amsterdam, Lay out: René Almekinders.

O'BRIEN, J., & PORTER, G. C. (1994) Girls and physical science: the impact of scheme of intervention projects on girls' attitudes to physics. *International Journal of Science Education, 16,* 327–341.

OSBORNE, J. F., & COLLINS, S. (2000). Pupils and parents' views of the school science curriculum (London: King's College London).

PALMER, D. H., & FLANAGAN, R. B. (1997). Readiness to change the conception that 'Motion-implies-force': A comparison of 12- year-old and 16-year-old students. *Science Education, 81* (3), p317-31.

POON, C. H. (1993). A Multicultural study of student misconceptions of force in mechanics. Reports on the use of the Force Concept Inventory.

REDISH, E., SAUL, J., & STEINBERG, R. (1997). On the effectiveness of active engagement microcomputer-based laboratories. *American Journal of Physics,* 65, 45-54.

SIMPSON, R. D., & OLIVER, J. S. (1990). A summary of the major influences on attitude toward and achievement in science among adolescent students. *Science Education,* 74, 1–18.

SMAIL, B. (2000). Has the mountain moved? The girls into science and technology project 1979–83. In K. Meyers (Ed.), *Whatever Happened to Equal Opportunities in Schools?* (pp. 143–155). Buckingham and Philadelphia: Open University Press.

STEWART, M. (1998) Gender issues in physics education. *Educational Research, 40,* 282-293.

TATLI, A., & ERYILMAZ, A. (2001). The effect of traditional lecturing on METU students' misconceptions in mechanics course. *Education and Science, 26* (122), 72-77 (in Turkish).

THORNTON, R., & SKOLOFF, D. (1990). Learning motion concepts using real time microcomputer- base laboratory tools. American Journal of Physics, *58* (9), 857-867.

URL-1, Misconceptions about electricity and magnetism. http://www.huntel.net/rsweetland/ science/misconceptions/elect magnet.html (Retrieved on June 8, 2004).

URL-2, Misconceptions about electricity and magnetism. Available at:

http://www.phy.uct.ac.za/courses/phy205h/altconcem.htm (Retrieved on June 8, 2004).

URL-3, Students' alternative conceptions in introductory physics in helping students learn physics better. Available at: http://phys.udallas.edu/altconcept. (Retrieved on June 8, 2004).

Van Heuvelen, A. (1991). Learning to think a physicist: A review of research-based instructional strategies. *American Journal of Physics, 59* (10), 891-897.

Weinburgh, M. (1995). Gender differences in student attitudes toward science: a meta-analysis of the literature from 1970 to 1991. *Journal of Research in Science Teaching, 32,* 387–398.