



JOURNAL
OF BALTIC
SCIENCE
EDUCATION

ISSN 1648-3898

COMPARATIVE ANALYSIS OF THE EFFECTIVENESS OF 4MAT TEACHING METHOD IN REMOVING PUPILS' PHYSICS MISCONCEPTIONS OF ELECTRICITY

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Abstract. *The purpose of this study is to determine pupils' misconceptions about the electricity and the effects of 4MAT teaching method on these misconceptions. For this purpose, a non-equivalent pretest-posttest control group design was adopted and a three tier test with a sample of 100 ninth grade pupils was used to detect pupils' misconceptions about the electricity. The analysis of the data showed that pupils have the following misconceptions; local reasoning, attenuation model, empirical rule model, shared current model, current-potential difference confusion, short circuit misconception, current flow as water flow, power supply as a constant current source model and sequential reasoning etc. It was determined that the frequency of most of the misconceptions decreased after the application of the innovation. A greater fall was observed in the experimental group which suggests that the 4MAT teaching method was more effective than the traditional method in reducing misconceptions. Based on the results of this study, investigation of the effects of 4MAT teaching method on other complicated subjects of physics such as magnetism, regular circular momentum is suggested for further studies.*

Key words: *electricity, 4MAT teaching method, misconceptions, ninth grade pupils, physics teaching.*

Introduction

Human beings start asking questions almost as soon as they have the language to do so. Unsurprisingly, some answers they receive are far from scientifically sound. Individuals' daily life experiences with their families, friends, visual and print media may result in the formation of scientifically false models and ideas about concepts. Science educators call these false ideas misconceptions, pre-conceptions, alternative frameworks, children's science, common sense concepts, spontaneous knowledge or naive conceptions (Gilbert, Watts, & Osborne, 1982; Pines & West, 1986). In this study, the 'misconception' term will be used since it has been widely used in recent studies. Misconceptions can block the learning of scientific concepts and Physics understanding will be severely limited unless misconceptions are overcome (Halloun & Hestenes, 1985; McDermott, 1991). Studies also indicate that it is difficult to overcome the misconceptions via traditional teaching methods (Driver & Bell, 1986; Driver, 1989; Gilbert & Watts, 1983).

The models and methods developed in recent years as alternatives for traditional teaching methods are based on constructivist approach. The twentieth century psychologists Piaget and Vygotsky made major contributions to what Phillips (1995) calls 'psychological constructivism'. This constructivist perspective is based on the premises that (i) knowledge is constructed by individuals, and (ii) people construct knowledge influenced by their personal needs. One goal that is widely held is the desire

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to make sense out of one's experience. The constructivist-inclined teacher carries out assessments to determine pupils' current knowledge, understanding and possibly also their confidence in their understanding (Bonello & Scaife, 2009). The teacher's diagnostic assessment reveals pupils' learning needs in relation to the curriculum being followed and informs the design of targeted teaching responses. The teacher knows that just 'delivering' to pupils what is in the curriculum will be liable to result in 'surface learning' of words rather than scientific meanings. To escape formal education process, pupils should be motivated to acquire scientific life experience for their conscious life. Science Education must be rooted within personal as well as societal real life needs and not become formal duty of pupils only to pass their examinations. To promote understanding in learners, the constructivist teacher aims to design tasks and activities that will persuade them to change their minds, decrease misconceptions and replace them with scientifically sound accounts. Although different instructional methods have been ventured to remove misconceptions, the results of these studies have shown that misconceptions cannot be fully removed. This study aims to present a new method of coping with misconceptions with the help of 4 Mode Application Technique (4MAT).

4MAT Teaching Method

4MAT, which was developed on the basis of constructivism, is a teaching method put forward by Bernice McCarthy (1987). The 4MAT teaching method asserts that each student has his/her own learning style and due to this fact the teaching environment should be designed to be able to satisfy those learning styles. For example, some pupils learn science well through 'concrete' activities such as doing experiments, while some prefer learning through abstract mental tasks. Some excel when making individual presentations of a project while others prefer learning in a group. 4MAT is a method which takes pupils' learning styles and brain dominance into account. McCarthy was categorized learning styles under four headings as; imaginative learners, analytic learners, common sense learners and dynamic learners (McCarthy, 1990, 1997, 2000). 4MAT was designed so that different learners from each of the four groups could find suitable time for themselves. The left and right hemispheres of the brain process knowledge and experiences in different manners. Continuously using only a single hemisphere does not pose any advantage so pupils are desired to use both (McCarthy, 2000). In order to complete the activities assigned by 4MAT pupils should use both dominant and also recessive hemispheres. In other words, this method appeals to not only one group of pupils but all of them.

So, it operates with a cyclic learning environment using an 8-step lesson plan that is followed in a prescribed order. Simply, these steps could be named as create an experience, examine, image, define, try, extend, refine and integration (Nikolaou & Koutsouba, 2012). 4MAT teaching method concerns starting lesson with student experiences and making pupils integrate themselves with concepts. Furthermore, discussions about real life experiences offer good opportunities to determine misconceptions. 4MAT teaching method presents activities so as to pupils find answers for questions like "Why?", "What", "How" in pupils' minds. Concept cartoons, worksheets, experiments, preparing and presenting projects are among these activities and they can easily be adapted to the steps of 4MAT. By means of these activities, students continuously research and solve cases connected to the subject (McCarthy, 2000). It is expected that the struggle for removing misconceptions and conceptual understanding are supported as a result of this method. Previous studies confirmed that concept cartoons, worksheets (Atasoy, Küçük, & Akdeniz, 2011) and doing experiments (Demirezen, 2010) had positive effects on removing misconceptions.

Previous studies on 4MAT focused mainly on student achievement (Aktaş, 2011; Mutlu, 2004; Tsai, 2004) but some others stated that it has no significant effect on achievement (Delaney, 2002; Hsieh, 2003; Lee, 2008). In addition, a few studies noted that the method contributes to persistency of learning (Jackson, 2001; Tsai, 2004). In this study, misconceptions of pupils were investigated. The learning styles of pupils were not determined. This fact is a limitation of this study. Whichever learning styles the students have, needs of all students were taken into consideration and removing misconceptions was prioritized in the teaching plans prepared according to 4MAT.



Pupils' Misconceptions about Electricity in Physics

Studies indicate that pupils have a lot of misconceptions in abstract areas of Physics such as heat, temperature (Lewis & Linn, 1994), electricity (Demirezen, 2010; Osborne, 1983), force, speed and motion (Atasoy et al., 2011; Eryilmaz, 2002; Marioni, 1989; Whitaker, 1983), energy (Goldring & Osborne, 1994; Toroslu Cekic, 2011). Aycan and Yumuşak (2002) gave university pupils, who were first graders at physics and chemistry departments and who were taught all physics and chemistry issues in the curricula at secondary school, the name of the all topics in the curriculum and asked them to order them from easy to hard with a 5-choice Likert-type scale. They found that electricity and magnetism were perceived as the most difficult subjects by the pupils. The reasons for this perception were indicated as that the topic was abstract, that the topic was covered with a very theoretical style without any experiments, and that pupils did not have proper pre-knowledge. Electricity issues are perceived as harder to be understood by the pupils than mechanical issues (Parthan & Bano, 2001; Shipstone, 1985). This hardship was explained with the fact that the basic concepts of electricity as the current, potential difference, resistance, power, electrical potential derives from the charge, which is an abstract concept (Küçüközer, 2004).

Although pupils think that electricity unit in physics course is hard, they can use the related concepts consciously or unconsciously whether they have previous training or not. That is because they are quite acquainted with electricity or electrical equipment in daily life conversations around them (Duit & Rhöneck, 1998). The studies on misconceptions in electricity field state that pupils bear wide variety of different opinions about current, potential difference, resistance, short circuit and the properties of the electrical circuits. For example, Osborne (1983) determined that pupils have 4 different models about what is current and how it is generated as: unipolar model, cashing current model, current consumption model, and scientifically true; direct current model. Borgers and Gilbert (1999) were also classified the different opinions pupils have about the current. In addition the misconceptions listed below, there were the misconceptions about the electricity in the related literature; the current is wasted by circuit units particularly by lamps (Shipstone, Rhöneck, Karqvist, Dupin, Johsua, & Licht, 1988; Tsai, Chen, Chou, & Lain, 2007), batteries are constant current generators (Lee & Law, 2001), lamps closer to battery light brighter (Lee & Law, 2001), a change in a circuit is only in that part of the circuit (Cohen, Eylon, & Ganiel, 1983; Demirezen, 2010). There were also misconceptions by confusing basic terms like current and potential difference with each other (Demirezen, 2010; Küçüközer, 2004). In the study with secondary school pupils, electricity technicians, physics teachers and electrical engineers of different age groups, Borgers and Gilbert (1999) found out that the misconceptions mentioned above also existed in all groups. Parthan and Bano (2001) and Heller and Finley (1992) also stated that not only teachers but also pupils had misconceptions about electricity.

In this regard, this research addresses the following objectives:

1. Determining conceptual models of ninth grade pupils about electricity.
2. Determining how much 4MAT teaching method is effective on remedying misconceptions comparing to traditional instruction.

Methodology of Research

A non-equivalent pretest-posttest control group design (Robson, 1998) was adopted in this study. The application was carried out in the second term of 2011-2012 school year for five weeks in two class hours per week.

Sample of Research

The study group was ninth grade pupils in one of the secondary schools in Ankara city. One hundred pupils, aged 14-16, participated in the study, with 50 in each group. Since the socioeconomic and education backgrounds of the sample were similar, the sample was randomly appointed into experimental and control groups. The first researcher had been the physics teacher of the pupils for two terms and had taught the lesson with the same method in the classrooms.



Context of the Study

The physics curriculum in Turkey was changed in 2007. In the new program, the electricity unit is placed into 4th, 5th, 6th, 8th grade curricula as a single unit with the name of "Electricity in our Life". It is given as a single unit called "Electricity and Magnetism" at 9th grade. In this study gains of the new 9th grade curriculum and the misconceptions arising from this curriculum were considered. The new curricula focus scientific process skills deeper and adopt a more constructivist and life-based approach (Toroslu Cekic, 2011). In the wake of teaching electricity which is a part of 9th grade curriculum, it is expected that the pupils will gain the following knowledge and skills:

1. Recalls that potential difference is an indicator of the energy level difference between the two ends of a conductor that can cause the current and explains its role in a simple electrical unit.
2. Tries and discovers the relation between the current passing through a conductor and the potential difference between the ends of the same conductor.
3. Shows the factors affecting the resistance of a conductor with experiment.
4. Tests and shows the relations among the current, resistance and potential difference in series and parallel connected circuits.

Treatment

In control group, "Electricity and Magnetism" unit was instructed with the traditional curriculum such as; lecturing, questioning and problem solving by referencing to the textbook prepared by Ministry of National Education for ninth grades. In the meanwhile, the instruction was distributed via 4MAT teaching method in the experimental group. During the application of the 4MAT, several methods and techniques like; sample case, brainstorming, concept cartoons, group-work, experiment, project assignments, worksheets were used. 4MAT, applied in experimental group by the first researcher was explained below, in detail.

The features and application of the steps of 4MAT teaching method is explained below:

Step 1 (Create and experience): The activities to be chosen for this step should help to reveal alternative opinions of pupils. During the application, the pupils participated in activities individually or in couples. The pupils were asked to exchange ideas about given proper activities such as; sample case, motivational stories, concept cartoons etc. In one lesson instructing 'Electric current', the pupils were given a sample case of 'a student who is afraid of being electrocuted scares to set a simple circuit composed of a light bulb, a battery, and a piece of conductor wire in laboratory'. Then the pupils were asked to write the things they know about conductor, insulator, current, the effect of the battery in the generation of the current. Then they were given a concept cartoon in which four different people discuss about how the light bulb in a simple circuit produces light.

Step 2 (Examine): In this step, the aim is to make pupils share their opinions across the classroom about the activity in Step 1. In this way, the misconceptions that the pupils have will emerge. During this application, the pupils enriched the topic by giving examples other than the activity and associated the topic with daily life more deeply.

Step 3 (Imagine): This step is a step for transformation of personal experience into scientific knowledge. In this step, teacher fosters the cognitive struggle by exposing the pupils with different examples that contradict the explanations of the pupils. In this step lecturing, question- answer, discussion and modeling techniques were used.

Step 4 (Define): In this step, the teacher explained scientific information by being traditional (McCarthy, 2000). Also in this step, lecturing, problem solving, concept maps techniques were used. It was observed that some of the pupils were still insisting on their own ideas. It was realized that some of this information included wrong information while some others were expressions having misconceptions.

Step 5 (Try): The pupils were allowed to work together. In this way, various activities were introduced



in order for them to practice using the knowledge given during the previous step and deal with continuing misconceptions effectively. These activities were like worksheets, concept cartoons, open-ended problems and sample case etc. The pupils were given time to think about the activities done during the lesson and opportunity to make joint decisions. In this inquiry, the pupils were given and expected to answer questions like "If you had sufficient resources to minimize the loss of energy, how would you arrange the properties of the electricity wires coming to our houses? Why?"; "What does running out of a battery mean? Explain."

Step 6 (Extend): The pupils were organized to do experiments in groups after they were given prepared experiment sheets. The pupils were directed to do experiments with instructions like: "What kind of circuit you can form by using circuit items you have learned to light a light bulb?"; "Do the experiment you designed and explain the results."; and "Do an experiment by using batteries, light bulbs, voltmeter, ammeter, switch and wires in various length, thickness and type". Then they were expected to associate the things they learned with the results of the experiments.

Step 7 (Refine): The aim of this stage is to make pupils apply what they have learned in their daily life (McCarthy & McCarthy, 2006). During the application, the teacher assigned the pupils to research by giving open-ended questions, explanations about the situations faced in daily life, performance and project tasks and made them to present the research results. This step anticipates that during their research pupils will be able to overcome the misconceptions they have via facing with their false ideas and realizing the scientific facts again and again. The pupils were assigned tasks like: "Which are the conductors with zero or almost zero resistance? In which field are they used? Why aren't they used in daily life?"; "Stop lights of a car lights when the driver presses on the brakes. How could you explain this?"

Step 8 (Integration): This step is the step pupils teach themselves and their friends (McCarthy & McCarthy, 2006). In this step, the pupils gave presentations and answered the questions from other pupils. The prepared assignments were put on the classroom walls so that they can be available. It was assumed that the pupils learn better when they are teaching their peers. It was also anticipated that the other pupils learn better since their peers would speak 'the same lingo' and that they can comfortably ask questions.

The 4MAT approach embraces both well-established understandings about experiential learning and more contentious inferences from brain accounts of learning. At its core is an urge to be responsive to learners' needs and characteristics and it is this that makes 4MAT compatible with a constructivist perspective on knowing and learning.

Instrument and Procedures

In the literature, 'two tier' and 'three tier' tests have been used in order to explore misconceptions. The tests are structurally similar but three tier tests differ in that in the third step pupils are asked whether they are sure about the answers they chose in the first two steps. A misconception is indicated by a three tier test if (i) a student selects a scientifically unacceptable answer to a question, and (ii) selects or composes a rationale to support this answer, and (iii) expresses confidence that the answer and reasoning are scientifically correct (Peşman, 2005). This three-part specification is intended to bring out more profoundly unscientific thinking and judgment than that which would produce basic factual errors or careless slips. The test used in this study was composed of 18 questions each having three tiers. The reliability and validity of the study was tested with a pilot study sampling 150 pupils. The test used in the pilot study was applied by the researcher to the tenth grade students who were taught the subjects of electricity and magnetism at the beginning of the 2011-2012 school year under the supervision of the their own teachers. Necessary explanations were made to the students and they were given one class hour to answer the test. After analysis of pilot results, six items were omitted and the test was produced in its final form with 12 items. One sample item is presented in Appendix. These 6 items were excluded since their difficulty and discrimination values were in the desire range and they were reducing the reliability. According to Matlock-Hetzel (1997) values of d above 0.40 indicate 'very good items'. The difficulty value (p) and discrimination (d) of each test item in the final form of the Electricity Subject Misconceptions Test (ESMT) are given in Table 1.



Table 1. Item analysis values of ESMT.

Items	1	2	3	4	5	6	7	8	9	10	11	12
(p)*	0.48	0.53	0.79	0.40	0.68	0.52	0.63	0.46	0.50	0.43	0.30	0.37
(d)**	0.37	0.48	0.40	0.35	0.63	0.67	0.52	0.70	0.48	0.63	0.52	0.44

**Difficulty, **Discrimination*

Items 1, 2, 3, 4, and 11 were drawn from the study by Peşman (2005), items 5, 6, 7, and 8 from a study by Shipstone (1985), and items 10 and 12 from a study by Shipstone et al. (1988). Item 9 has been used by many researchers (Küçüközer, 2004). The first step in the three tier test was the question root. In this step, a multiple-choice question was given to pupils. In the second step, they were asked the reason for the answer they chose in the first step. To respond to this, they selected from a multiple-choice set of reasons, or composed a reason in their own words if they were not satisfied with the choices offered. If a student's composed reason corresponded to one of the choices offered, the answer was evaluated as if it had been that choice.

If a student chose an answer corresponding to a misconception in the first step and a scientifically accepted reason in the second step (wrong answer, right reasoning), this situation was called a False Negative. If they chose a scientifically accepted answer in the first step and an answer corresponding to a misconception in the second step (right answer, wrong reasoning), this situation was called a False Positive (Hestenes & Halloun, 1995). Hestenes and Halloun (1995) argue that careful test design can minimize the incidence of False Negatives to below 10%, a level that they consider acceptable. They note, however, that it is inherent in the nature of multiple-choice testing that False Positives will arise, for instance through guesswork.

In the third step, pupils were asked whether or not they were sure about the answers they had given in the first two steps. We took pupils' answers only in the third step to give a 'Lack of Knowledge' value, regardless of their answers in the first two steps. According to pilot study, in Table 2, False Negative, False Positive and Lack of Knowledge values for each item are shown.

Table 2. Percentages of false negatives, false positives and lack of knowledge item.

Variable	1	2	3	4	5	6	7	8	9	10	11	12	Mean	SD
False Negatives	4	8	1	4	0	0	1	0	2	1	1	3	2.08	2.35
False Positives	26	3	2	42	1	27	3	20	7	16	15	0	13.5	13.26
Lack of Knowledge	14	18	14	21	23	24	25	21	19	25	23	27	21.16	4.21

When the percentages of false negatives are checked, it is seen that no question exceeds the 10% level, justifying their inclusion.

Reliability of the test was evaluated using Cronbach's Alpha and found to be 0.69, which is above the 'minimally acceptable level' of 0.65 (DeVellis, 1991, p. 85). In ESMT, if a student marked the choice corresponding to the misconception in the first step, the choice corresponding to the same misconception in the second step again, and the choice 'I am sure' in the third step, the case was called a misconception. If a student marked the choice 'I am not sure' in the third step, this was not called a misconception even if the choices of the student in the first and second steps were misconceptions. Furthermore, in order to accept a question as correct, it was required that the student marked the correct choice in the first two steps and the choice 'I am sure' in the third step. In ESMT, a total of nine misconceptions are evaluated. Table 3 presents the distribution of these misconceptions with respect to items.



Table 3. Alternative sets indicating a misconception according to items.

Misconceptions	Explanation	Item no
Local reasoning	If a modification is done in a part of an electrical circuit pupils try to analyze this local part and they ignore global changes (Shipstone et al., 1988).	1, 11
Attenuation model	The electric current, which travels round an electrical circuit in one direction, is assumed to decrease gradually because of consumption of it by the resistors within the circuit (McDermott & Shaffer, 1992).	2, 9
Empirical rule model	Pupils believe that the further away the bulb is from the battery, the dimmer the bulb (Heller & Finley, 1992).	2, 3, 9, 11
Shared current model	Electrical current is assumed to be shared equally by electrical devices (Shipstone et al., 1988).	2
Current-potential difference confusion	In these misconceptions pupils confuse and use the concepts of current and potential difference with each other (Demirezen, 2010).	10, 12
Short circuit misconception	As pupils analyze the circuit, they wires without any electrical devices are ignored (Chambers & Andre, 1997).	4, 11
Power supply as a constant current source model	Pupils regard a battery as a constant electrical current source rather than electrical energy source, whatever the circuit is flowed (McDermott & Shaffer, 1992).	5, 6, 7, 8
Sequential reasoning	It is assumed a change at a point in the circuit to affect forward in the direction of the electric current, not backward (McDermott & Shaffer, 1992).	6, 8
Current flow as water flow	Current is seen as something flowing through the circuit, from the battery to the bulb very much like water in a hydraulic circuit (Borgers & Gilbert, 1999).	3

As seen in Table 3, some misconceptions are detected by more than one item. In the graphs about these misconceptions the numbers of pupils bearing these misconceptions was given in average.

Data Analysis

Since the aim of the study is to determine the change in the number of pupils who have misconceptions only the responses with misconceptions were considered. The answers given by the students were evaluated separately according to the first tier, the first two tiers and the first three tiers of the items. According to only first tier, first two tiers and first three tiers if a student's response is correspond to misconception, it was coded as "1", otherwise it was coded as "0". Since the data set showed non-normal distribution, Mann Whitney U test was applied to test whether the difference between pre and posttest of control and experimental group.

Results of Research

In this section, the descriptive examples of the data obtained from ESMT were given. In the charts below the numbers of pupils who had misconceptions according to the first step, the first two steps and the first three steps of each item for the pre and posttest are shown. Figure 1 shows the numbers of pupils who indicated the 'local reasoning' misconception in the first step, the first two steps and the first three steps, for the experimental group and the control group.



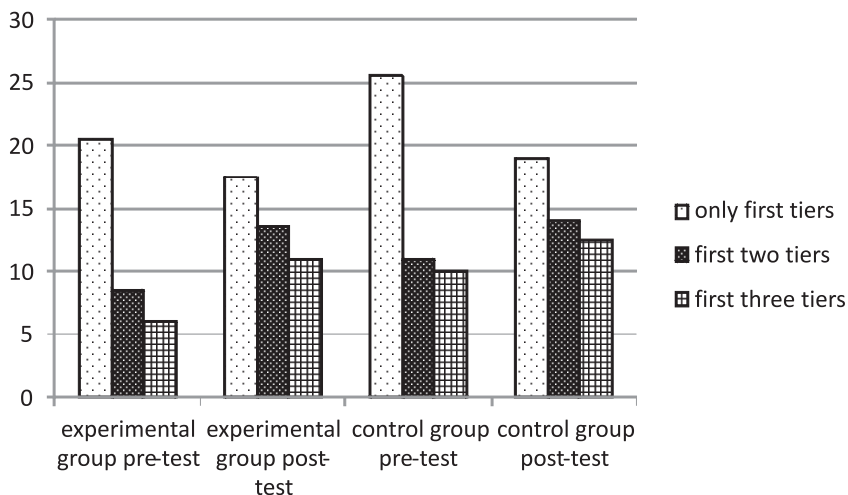


Figure 1: The number of pupils having 'local reasoning' misconception.

As seen in Figure 1, the number of pupils who marked the misconception choice for the first question decreases from the first step to the third step. This is because the pupils who had marked the misconception choice in the first step might choose the correct answer, an incorrect answer or another misconception in the second step as the explanation of the first step. In both the experimental and control groups, the pupils' local reasoning misconception continued after teaching. Figure 2 shows the numbers of pupils who indicated 'the attenuation model' misconception in the various steps.

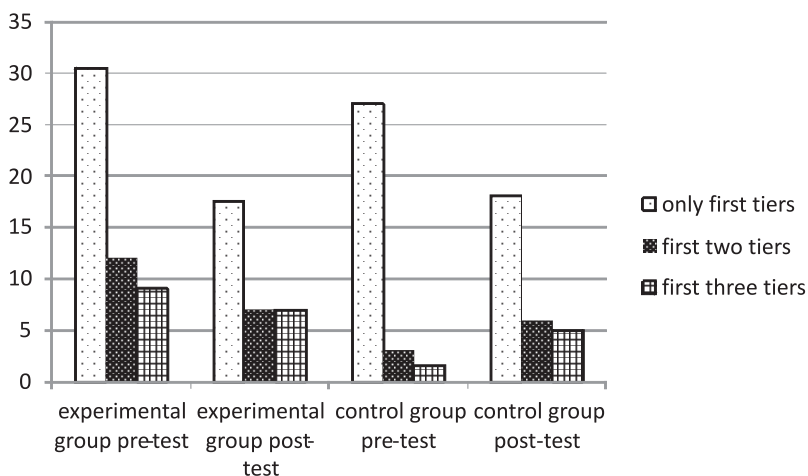


Figure 2: The number of pupils having 'attenuation model' misconception.

As seen in Figure 2, pupils in the experimental group had higher incidence of having this misconception. According to the pre-test and post-test results, there was a slight decrease in the number of pupils who had this misconception for the experimental group. The percentage of having this misconception was low among the pupils in the control group. Despite this, there was an increase in the number of pupils who had this misconception according to the pre-test and post-test results. The results related to the empirical rule model misconception are summarized in Figure 3.



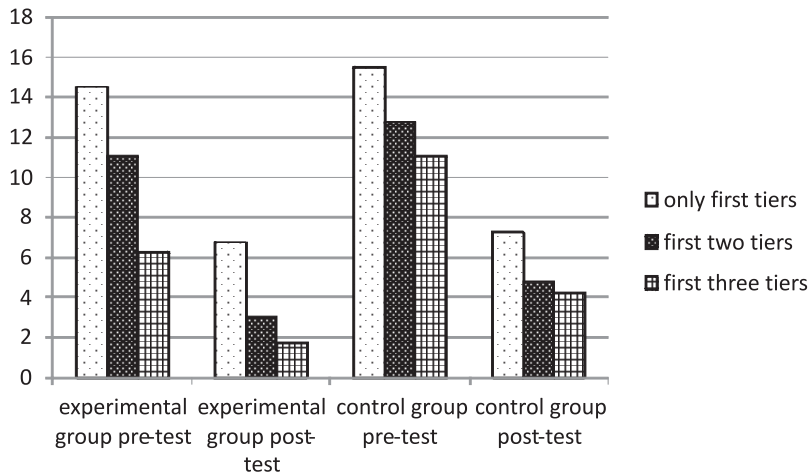


Figure 3: The number of pupils having the 'empirical rule model' misconception.

As seen in Figure 3, while the number of the student having this misconception in control group was greater, there were similar decreases in both groups after the implementation. Figure 4 shows the numbers of pupils who indicated the 'shared current model' misconception in various steps.

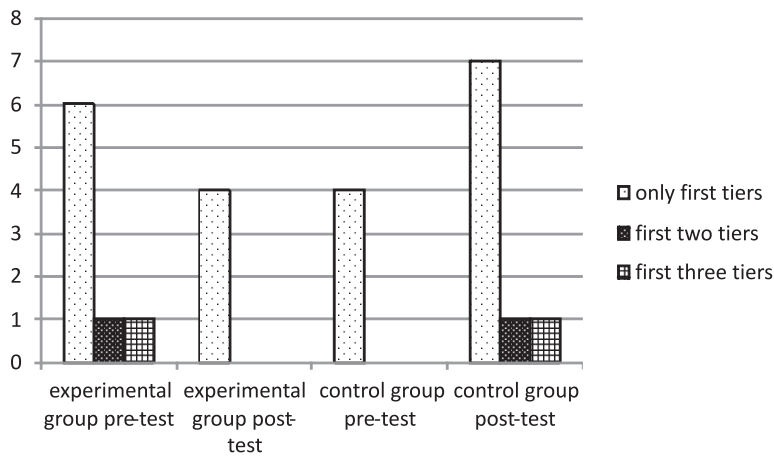


Figure 4: The number of pupils having the 'shared current model' misconception.

Figure 4 shows that almost no pupils had 'shared current model' misconception. In only first tier section, there was a slight decrease in experimental group whereas there was an increase in control group. The results related to the current-potential difference confusion misconception are summarized in Figure 5.



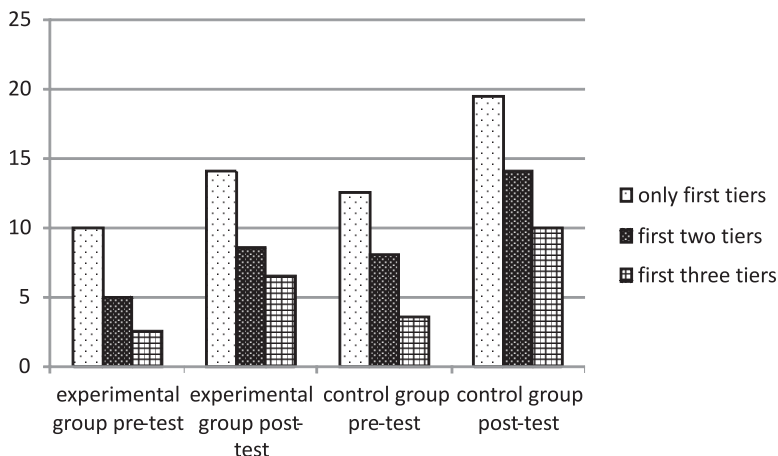


Figure 5: The number of pupils having the 'current-potential difference confusion' misconception.

The number of pupils who had this misconception in the pre-test and the post-test increased in both groups, though more sharply in the control group, namely from about three to seven pupils in the experimental group and from four to ten pupils in the control group. The results on the 'short circuit' misconception are shown in Figure 6.

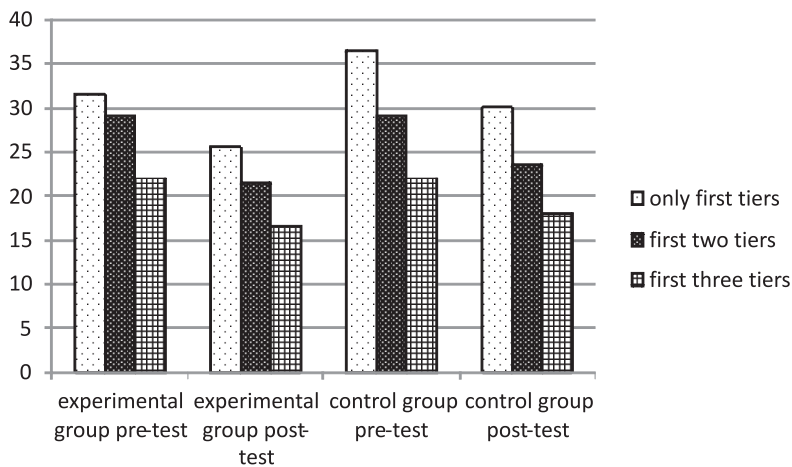


Figure 6: The number of pupils having the 'short circuit' misconception.

As seen in Figure 6, the number of pupils having this misconception was markedly higher than in other cases. There was a similar improvement in both experimental and control groups. The results on the 'power supply as a constant current source model' misconception are shown in Figure 7.



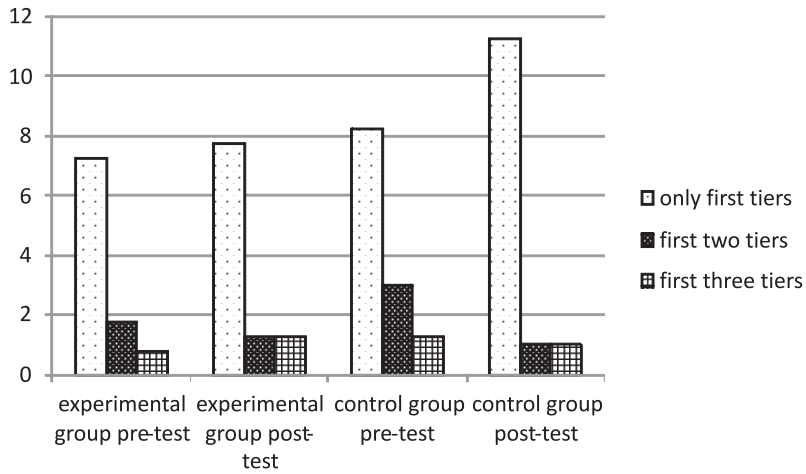


Figure 7: The number of pupils having the 'power supply as a constant current source model' misconception.

The numbers indicating this misconception were small. There was no considerable change in the experimental group however there was an increase only in wrong answers given for the first part of the item in the control group. The results related to the sequential reasoning misconception are summarized in Figure 8.

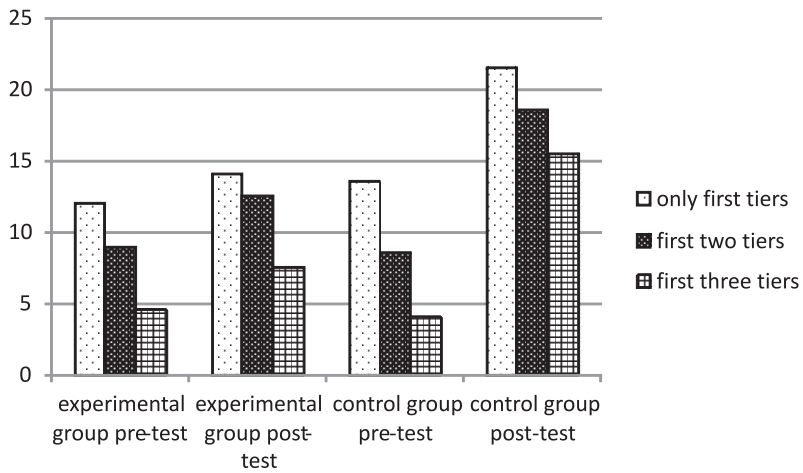


Figure 8: The number of pupils having the 'sequential reasoning' misconception.

As seen in Figure 8, the number of pupils who had this misconception increased in both groups. This increase was more obvious in the control group. The results on the 'current flow as water flow' misconception are shown in Figure 9.



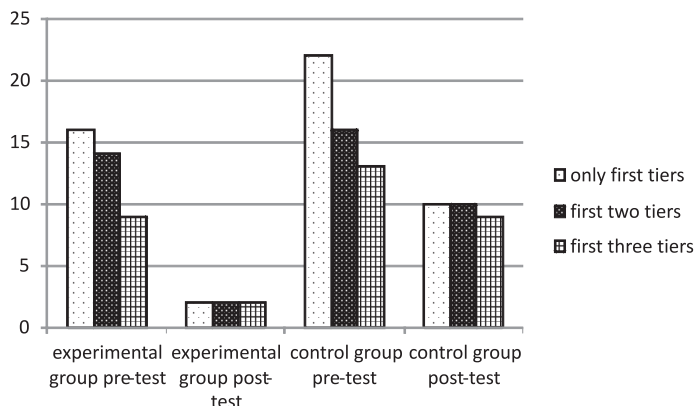


Figure 9: The number of pupils having the 'current flow as water flow' misconception.

As can be seen in Figure 9, while there was a considerable decrease in the number of pupils bearing 'current flow as water flow' in the experimental group, the improvement in the control group was weaker.

As a summary, based on the pupils responses given to first level, first two levels and first 3 levels, there was an increase in the local reasoning, current-potential difference confusion and sequential reasoning misconceptions and considerable decrease in the rest of the misconceptions of the pupils in the experimental group. There was not a big change in 'Power supply as a constant current source model' misconception. A similar case was also valid for the control group. However, there was a greater increase in wrong ideas in the control group than the experimental group and the decrease in misconceptions was smaller in the control group. This comment is restricted to what the graphs showed us. Certain statistics are given below to make more precise comparison.

In order to determine whether there was a difference between the pre-test scores of pupils in the experimental and control groups in terms of the misconceptions they had, a Mann Whitney-U test was applied because the pre-test scores did not fit a normal distribution. The results are summarized in Table 4.

Table 4. Pre-test data for the experimental and control groups for the ESMT using the Mann Whitney U-Test.

Group	N	Mean Rank	Sum of Ranks	U	p
Experimental	50	47.48	2374.00	1099	0.289
Control	50	53.52	2676.00		

As seen in Table 4 there is no significant difference between the experimental group and the control group pupils in terms of the misconceptions they had before the application ($U=1099$; $p>0.05$). The corresponding analysis of post-test data is summarized in Table 5.

Table 5. The Post-test data for the experimental and control groups for the ESMT using the Mann Whitney U-Test.

Group	N	Mean Rank	Sum of Ranks	U	p
Experimental	50	56.50	2825.00	950	0.036
Control	50	44.50	2225.00		



As seen in the Table 5, there is a significant difference between the experimental group and the control group pupils in terms of the misconceptions they had after the application ($U=950$; $p<0.05$). This difference is in favor of the experimental group. In other words, there is a significant decrease in the indicated misconceptions on the part of the experimental group pupils compared with the control group pupils.

Discussion

The studies on misconceptions related to electricity show that students have many misconceptions regarding this subject. Some of these misconceptions are as follows; unipolar model, clashing current model, current consumption model, (Osborne, 1983; Borgers & Gilbert, 1999), local reasoning (Shipstone et al., 1988), attenuation model (McDermott & Shaffer, 1992), empirical rule model (Heller & Finley, 1992), shared current model (Shipstone et al., 1988), current-potential difference confusion (Demirezen, 2010), short circuit misconception (Chambers & Andre, 1997), power supply as a constant current source model (McDermott & Shaffer, 1992), sequential reasoning (McDermott & Shaffer, 1992), current flow as water flow (Borgers & Gilbert, 1999). In addition, it was found that the students thought batteries as a source of constant current and confused the concepts of current and potential difference (Cohen et al., 1983; Shipstone et al., 1988; McDermott & Schiefer, 1992; Borgers & Gilbert, 1999; Lee & Law, 2001; Sencar, Yilmaz, & Eryilmaz, 2001). In this study, the misconceptions summarized in Table 3 were examined. It is observed that students have various misconceptions about electricity. Possible reasons may be that teachers give instruction without taking students' previous knowledge into account or they do not support subjects with visual material sufficiently. It is very difficult for students to picture this kind of abstract subjects in their minds and construct them correctly on their own without help. It has been shown that constructivist learning approach is effective in decreasing students' misconceptions about electricity in terms of not only taking students' previous knowledge into account but also presenting activities that help them construct knowledge in their minds correctly (Psillous, Koumaras, & Tiverhien, 1988; Cosgrove, 1995; Lee & Law, 2001; Küçüközer, 2004; Demirezen, 2010).

Henceforth, the effects of 4MAT teaching method on misconceptions were analyzed. It can be concluded that 4MAT method of instruction is more effective than the traditional method of instruction in coping with misconceptions through giving the pupils the opportunity to question their knowledge via intensive conceptual discussions, assignments and projects, face with the scientific facts continuously and discover the scientific aspects of events. When we consider that misconceptions are the results of the previous life experiences, it can be argued that one of the strengths of 4MAT is being sensitive to learner needs by presenting various activities like sample cases, concept cartoons, experiments and worksheets to enrich the learning environment. 4MAT monitors this diversity by means of instructional plans developed by considering differences arising from learning styles and dominant brain hemispheres of pupils (Ergin, 2011). Although the traditional curriculum also presents similar activities, 4MAT is better in terms of presenting concept teaching activities in these instructional plans in a well-organized way.

After the application, there was no change in "power supply as a constant current source model" misconception while there were increases in misconceptions about 'local reasoning', 'current-potential difference confusion' and 'sequential reasoning'. McDermott and Shafer (1992) and Ateş and Polat (2005) applied constructivist teaching methods in order to remove the misconceptions about the electricity. Consequently, they found out that some of the misconceptions still existed. This fact shows the difficulty in overcoming the misconceptions. One of the reasons for 4MAT's failing to remove some misconceptions may be the difficulty of applying eight-step instructional plans. Teachers should both plan the activities along with the content and apply the plan in the correct order (McCarthy, 2000). Following 4MAT steps synchronously with the content is a hard and tiring process for teachers. According to 4MAT, at least one or more steps should appeal to dominant brain hemisphere of each pupil and pupils should be fully engaged in that step. This means that some pupils feel themselves alone in some steps and others take the role of supporter or try to improve themselves. This fact made some steps unpopular because of individual differences and sometimes caused some pupils to drift away from the lesson, get bored



and perceive the lesson as a waste of time (Aktaş, 2011). Therefore during the steps, teachers should encourage pupils to engage activities while presenting alternative activities for pupils with different needs. Since the instructional process is so condensed, teachers may miss incomplete knowledge and wrong conceptions of pupils at times.

There may be other reasons for the increase in incidence of misconceptions which it may be possible to address. In the first stages of the 4MAT teaching, pupils were asked to answer questions orally and on paper using concept cartoons, case studies and storytelling techniques. After that, pupils were given the opportunity to share their views in the class. For this purpose, brainstorming, in-class discussion or debate techniques were used. While pupils were sharing their views, they were also explaining their misconceptions with their reasons. We suggest that one of the reasons for the increased incidence of misconceptions in some areas might be that pupils who did not have these misconceptions adopted them from their peers in this step. In the following steps, the teacher dealt with the views one by one and compared them with the scientifically accepted positions. However, these explanations and examples might have been unsatisfactory to pupils who had more fundamental misconceptions about electricity concepts. We suggest that it may have been useful for the teacher to spend more time on specific misconceptions and use examples in order to generate cognitive conflict in the pupils who held those misconceptions. In the later stages of teaching, pupils did experiments, tackled worksheets, drew analogies and solved problems. One of the reasons why there was still not a decrease in misconceptions might be that pupils could solve the problems successfully with their own 'alternative' concepts.

Peer influences may also have arisen from small group work. Pupils in Turkey who are accustomed to traditional teaching methods are unfamiliar with group work. In the 4MAT teaching method, group work is used. The pupils in our study were encouraged to participate in the group work but participation was not forthcoming at a desired level. There was a tendency for one or two pupils in most groups to participate actively while the rest were passive. A possible reason for the increased incidence of misconceptions in the experimental group is that, in the course of group work, some pupils' expressed misconceptions were not challenged and they were adopted by others. Another factor contributing to the increase may be that some pupils who selected a misconception in the first two steps but were not included in the category of misconceptions because they selected 'I am not sure' may, after the teaching, have chosen 'I am sure' in the third step. Arguably, this may be connected with examination anxiety, leading to pupils' becoming result-oriented rather than understanding-oriented and thus not feeling a need to change their misconceptions if they reach correct answers with them. A related consideration is that pupils have a tendency in Physics classes to wait for instructions for solving test questions rather than actively taking responsibility for managing their learning. Based on the results of this study, investigation of the effects of 4MAT teaching method on other complicated subjects of physics such as magnetism, regular circular momentum is suggested for further studies.

Conclusions

In this study, the effect of the 4MAT teaching method on changing misconceptions about electricity was examined and compared with the effect of a traditional teaching approach. It was determined that secondary school pupils have misconceptions listed in Table 3.

After the application there were decreases in misconceptions about 'attenuation model', 'empirical rule model', 'shared current model' and 'short circuit' misconceptions. This improvement in misconceptions may be the result of the fact that 4MAT method, which is based on the constructivist learning approach, gives the opportunity to cope with misconceptions by planning the activities to be performed step by step.

There was a greater decrease in the experimental group than the control. This difference may be explained by the ways of instruction. In the control group, most of the class time was spent on solving numerical multiple choice questions while the same time was spent on assignments and projects, conceptual questions, concept cartoons and intensive conceptual debates about the related concepts. It is



understood that 4MAT provides a wide variety of activities by giving importance to all students' needs and prioritizing their individual differences.

After the application, there was no change in one misconception while there were increases in misconceptions about 'local reasoning', 'current-potential difference confusion' and 'sequential reasoning'. The reason for the increase in misconceptions despite 4MAT may be the spread of misconceptions among students during the conceptual discussions. Sometimes, another reason may be that the students think they can explain events with their own ideas, which include misconceptions, more easily.

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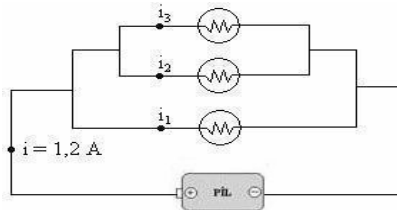


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Appendix: Excerpt from the ESMT



Şekil 2

1.1. The current at the main branch is 1.2 A. What are the magnitudes of currents i_1 , i_2 , and i_3 ?

a) 0.6/0.3/0.3

b) 0.4/0.4/0.4

1.2. Which one of the followings is the reason for your answer to the previous question?

a) After the current is divided evenly on the first junction, it is again divided evenly on the second junction.

b) Because the identical bulbs are in parallel, currents with the same magnitude pass through the bulbs.

c)

Are you sure about your answers given to the previous two questions?

a) Sure.

b) Not sure.

Received: June 08, 2013

Accepted: August 23, 2013

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