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Prospective teachers' misconceptions about the atomic structure in the context of electrification by friction and an activity in order to remedy them

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Science educators have generally agreed that understanding the atom concept is the basis of science education. However, the numerous research studies have shown that many students at all educational levels have difficulties understanding this concept. This study was developed under three headings. The first was to identify misconceptions that prospective teachers (PTs) had about atomic structure in the context of electrification by friction (ASCEF). The second was to study the effectiveness of the branch differences (basic sciences, social sciences, physics, chemistry, biology, mathematics) on the levels of their misconceptions. The third, based on students' misconceptions, was to examine the effectiveness of the activity 'Modelling of the Atomic Structure' (MAS). The study was divided into two stages. First, in order to identify the PTs' misconceptions, an Understanding the Nature of Electrification by Friction Test (UNEFT) which could be summarised by the question 'is electrification by friction due to the electron transfer?' was applied to the PTs who attended the Primary School Teacher Education Pedagogical Formation Certificate Program (PSTEPFCP) at a large public university for a five weeks science teaching course followed by an examination after the static electricity topic had been presented. It was found that the PTs from all branches of science held the misconception that electrification by friction was due to the transfer of protons. At the same time the effects of the branch differences on the levels of the PTs' misconceptions was studied and was not significant in groups other than the basic scientists–social scientists pairing. In the second stage, using the students' misconceptions, the effectiveness of the MAS activity was examined in the experimental and control groups and was found to be significant at all levels. From this result, it was found that the models were quite useful in teaching science and that the construction of knowledge would be possible if students played an active role in the learning environment.

Atomic structure, electrification by friction, misconception, modelling, science education

INTRODUCTION

Many students were unable to succeed in learning some concepts of physical science even though they worked very hard (Nakhleh, 1992; Noh and Scharmann, 1997). According to experts, the reason for this was that they had misunderstood the fundamental science concepts. Hence, they were not able to learn other concepts built upon them (Nakhleh, 1992). Piaget (1963 and 1970) was, in fact, aware of this case in the 1920s and 1930s. However, it was neglected by the mid–1960s. Educators needed to know the students well in order to improve the science teaching from that time (for example, Anderson, 1965; Raven, 1967–68). Therefore, teachers interacted with the students by means of interviews and questionnaires. However, in the 1960s and 1970s, the number of studies in the field of science education was relatively few in number.

In one of the early studies on children's ideas concerning natural phenomena taught in science, Anderson (1965) found that the pupils were capable of building mental models when asked to explain selected phenomena. About the same time, Raven (1967–68) conducted a study on the concept of momentum with students aged five to eight years old. In the study, he found that they could understand the concept of momentum without understanding the sub–components of the concept. Doran (1972) investigated elementary school pupils' understandings of the continuity of matter, the movement and the size of particles. He found that they did not have these concepts. Doran's study examined the reaction of some science educators. Swartz (1973) stated that this case was, in the Piagetian stage theory, a normal result for the children at the concrete operational level and that it should not indeed be exaggerated. As a reply to Swartz's comment, Doran (1973) pointed to the fact that Piaget's findings concerning the general cognitive capabilities of young people seemed to suggest the inability of students in the lower grades to operate with abstract concepts and supported his ideas with the results of research by educators (Anderson, 1965; Raven 1967–68) using alternatives to the Piagetian theory. According to the researcher's opinion, a focus on students' misconceptions in the basic sciences was in the interest of other science educators and this discussion is quite useful for science education.

According to the results of research, students often had a concept of science that was different from the one that experts had and tried to present (Driver, Leach, Scott and Wood–Robinson, 1994). Therefore, they might give these concepts different meanings from those generally accepted by the experts. This manner of students' learning has been characterised by terms such as misconceptions, preconceptions, alternative frameworks, intuitive beliefs, children's science, naive beliefs, students' descriptive and explanatory systems, alternative conceptions, misunderstanding and students' conceptions (Cho, Kahle and Nordland, 1985; Garnett, Garnett and Hackling, 1995; Gilbert and Watts, 1983; Griffiths and Preston, 1992; Nakhleh, 1992; Schmidt, 1997; Stepans, Beiswenger and Dyche, 1986). However, one generally used by researchers was the term 'misconception.' Cho, Kahle and Nordland (1985) defined misconception as any idea whose meaning deviated from one commonly accepted by scientific consensus.

Science educators generally agree on the idea that concepts that assist in the understanding of the atom and molecule are the basis of science education because the learning of other concepts such as chemical bonding, ions, states of matter, amount of matter, electricity, chemical reactions, heat, temperature, dilation, light, diffusion, elements, compounds, mixtures, osmosis, dissolving, chemical kinetics, chemical equilibrium, the effects of pressure and temperature on gases are possible only with the comprehension of atomic and molecular concepts (Griffiths and Preston, 1992; Nakhleh, 1992). From this point of view, science educators have particularly focused their research on the concepts that students in pre–university education have about atoms and molecules, in the context of the particulate nature of matter.

A study conducted by Pella and Carey (1967–68) was one of the early studies of the field. They investigated the relative levels of understanding of 16 concepts on the particulate nature of matter in elementary school pupils in the United States. The results showed that the pupils had some difficulties understanding the particulate nature of matter. In recent years, there has been increased interest in the subject. In two studies on the particulate nature of matter, Novick and Nussbaum (1978, 1981) found that over half of students in high school and university only had a primitive idea, which was consonant with the continuous–matter outlook on the physical world, rather than the accepted particulate model of matter. In a study conducted by Gabel and Samuel (1987), to determine prospective elementary teachers' views of the particulate nature of matter, an examination of the individual drawings that they did showed that their conceptions of matter were frequently distorted. The investigators found that prospective elementary teachers had the misconception that there was an enlargement of atoms of a same element as they changed from liquids to gases. A similar study by Ben–Zwi, Eylon and Silberstein (1986) revealed that atoms and molecules had a different size in the phases of the same matter was prevalent in 15–year–old students. Again, the same study showed that the students held the concept that features belonging to the matter such as electrical conductivity, colour, and malleability were also the features of a single atom. In her review of studies concerning atomic and molecular concepts, Driver (1993) showed that many students could not apply the law of conservation of mass to chemical and physical changes. She found that nearly half of the students surveyed suggested that the weight of steel wool would decrease after burning and that the mass would change when dissolving sugar in water. In a study by Sarikaya (2000), it was revealed that prospective science teachers also had the same misconceptions. Griffith and Preston (1992) found 42 misconceptions held by the students in Grade 12 about the fundamental characteristics of atoms and molecules. In a study by Abraham, Williamson and Westbrook (1994) on junior high, high school, and college chemistry students' understanding of the concepts of conservation of mass, it was shown that only 18 per cent of the sample had a sound knowledge about the concept. A recent study by Mulford and Robinson (2002) showed that first semester general chemistry students retained many of their initial concepts about atoms and molecules through the first semester of instruction. A very recent study by Sarikaya (2004) showed that chemistry teachers, prospective chemistry teachers, freshman science students and high school students had some misconceptions about the definitions of the mole and Avogadro's number, which were based on the atom and molecule concepts. More than half of them, instead of using the ^{12}C isotope, defined these concepts as Avogadro's number of particles and 6.022×10^{23}, respectively.

For the last 40 or 45 years, the results of studies had shown that students of all ages held misconceptions about basic science concepts, regardless of where they were on the earth. Educators' work is to teach the truth, and to remedy misconceptions, which the students have. Because educators in universities can not reach each school or class or student, teachers have to do it. The remediation of students' misconceptions is only possible by their teachers, who must be well trained and freed from misconceptions. For this reason, it is important to investigate whether prospective teachers hold misconceptions or not. Also, all prospective teachers need to be trained to correct misconceptions. They need to be aware of both their own and students' misconceptions and learn to remedy and overcome them. An unknown illness can not be cured! However, the studies that focus on prospective teachers' misconceptions are rather rare (Haidar, 1997). From this point of view, this study focuses on prospective teachers' understandings of the atom concept in the context of the nature of electrification by friction.

PURPOSES, OBJECTIVES AND HYPOTHESES

The purposes of this study were considered under three headings. The first was to identify misconceptions that prospective teachers (PTs) had about atomic structure in the context of electrification by friction (ASCEF). The second was to study the effectiveness of the basic sciences, social sciences, physics, chemistry, biology, mathematics on the degree of their misconceptions. The third was to examine the effectiveness of the activity 'Modelling of the Atomic Structure' (MAS) and its effect on students' misconceptions.'

The following objectives guided this study.

(1) The first was to identify the misconceptions that the PTs of the various branches of science had about the ASCEF on an Understanding the Nature of Electrification by Friction Test (UNEFT).

(2) The second was to explore the relationship between the levels of misconceptions that the PTs of the various branches held about the ASCEF on the UNEFT.

(3) The third, using an experimental and a control sample, was to examine the effectiveness of the MAS on their misconceptions.

For the purpose of statistical analysis, objectives were set up as the research hypotheses and assessed against the null hypotheses.

For the first objective, the following seven hypotheses in the research hypothesis form were tested:

(1) H_1: The PTs had misconceptions about the ASCEF.

(2) H_2: The basic scientists (BSs) had misconceptions about the ASCEF.

(3) H_3: The social scientists (SSs) had misconceptions about the ASCEF.

(4) H_4: The physicists (Ps) had misconceptions about the ASCEF.

(5) H_5: The chemists (Cs) had misconceptions about the ASCEF.

(6) H_6: The biologists (Bs) had misconceptions about the ASCEF.

(7) H_7: The mathematicians (Ms) had misconceptions about the ASCEF.

For the second objective, the following two hypotheses in the null hypothesis form were tested:

(8) H_0: There was no a statistically significant difference between the BSs' and SSs' mean misconception scores (μ) on the UNEFT.

$$H_0 : \mu_{BSs\,(UNEFT)} = \mu_{SSs\,(UNEFT)}$$

(9) H_0: There were no statistically significant differences among the Ps', Cs', Bs', Ms' and SSs' mean misconception scores on the UNEFT.

$$H_0 : \mu_{Ps\,(UNEFT)} = \mu_{Cs\,(UNEFT)} = \mu_{Bs\,(UNEFT)} = \mu_{Ms\,(UNEFT)} = \mu_{SSs\,(UNEFT)}$$

For the third objective, the following null hypothesis was tested:

(10) H_0: There was no statistically significant difference between the experimental (Exp) and control (Con) groups' mean misconception scores on the UNEFT.

$$H_0 : \mu_{Exp\,(UNEFT)} = \mu_{Con\,(UNEFT)}$$

METHOD

The Study Context

The present study is related to the topics of both chemistry and physics in the context of atomic structure and electricity. In the Turkish educational system, the first chemistry and physics teaching begins with a brief introduction to physical and chemical changes, as a part of the science curriculum at the age of 10–11 years in Grade 4. The topics of atomic structure and electricity are first given in Grades 4 and 5, respectively. These topics are again taught to students aged between 12 and 14 years in Grades 6, 7 and 8. The topics are taught again at an advanced level in secondary education at ages 15 to 17 years in Grade 9, 10 and 11 (Calik and Ayas, 2005; MEB Tebligler Dergisi, 2000). Accordingly, the knowledge content of this study is at the pre–university level of education.

Instrumentation

In order to identify the misconceptions that the prospective teachers (PTs) have about the ASCEF, we compare the levels of the groups' mean misconception scores and examine the effectiveness of the MAS on students' probable misconceptions about the ASCEF and the UNEFT that have been developed by the researcher. The UNEFT is a paper and pencil reading test and it has two multiple–choice items with four questions in each part. In addition, each of the four options has true or false questions. The UNEFT takes a total testing time of 15 minutes. In order to understand the nature of electrification by friction, both of the items have to be correctly answered because they are directly related. If one of the items is true and other is false, the Cronbach alpha reliability coefficient of the instrument cannot be computed. However, a group of science educators checked the test for validity. The test items considered in this study and the structure of questionnaire are shown in Table 1.

Table 1. Test items used in the study and the structure of questionnaire

Name and Surname:

Note: All of eight points in two statements below may be true or false. Please tick (√)True or False for each of eight points.

Matter is made up of atoms, the atom consists of protons, electrons and neutrons, the proton and the electron have the positive and negative charge, respectively, and the neutron is uncharged. In electrically neutral matter, the total number of electrons is equal to that of protons.

Item 1:

Statement 1. If an ebonite rod (or plastic comb or plastic balloon) is rubbed against a woollen cloth, the ebonite and the cloth are charged with negative and positive electricity, respectively. Because:

(a) Both electrons and protons pass from the wool to the ebonite. However, the number of electrons passing to the ebonite is more than that of protons. The ebonite is negatively charged since the negative charge transferred to it is greater than the positive charge. The negative charge, which the wool loses is more than the positive charge, therefore, the wool is positively charged. True:…, False:…

(b) Both electrons and protons pass from the ebonite to the wool. However, the number of protons passing to the wool is greater than the number of electrons. The ebonite is negatively charged since it loses more the positively charged particles than negatively charged ones. The positive charge that the wool gains is more than the negative one and therefore, it is has a net the positive charge. True:..., False:...

(c) Only the electrons are transferred from the wool to the ebonite. True:..., False:...

(d) Only the protons are transferred from the ebonite to the wool. True:..., False:...

Item 2:

Statement 2. If a glass rod (or glass tube or glass bottle) is rubbed against a silken cloth, the glass and the silk are charged positively and negatively charged , respectively. Because:

(a) Only the protons pass from the silk to the glass. True:…, False:...

(b) Only the electrons pass from the glass to the silk. True:..., False:...

(c) Both the protons and the electrons pass from the glass to the silk. However, the number of electrons transferred from the glass to the silk is more than that of the protons. The glass is positively charged since it loses more negative charge than positive. The negative charge that the silk gains is more than the positive charge and therefore, with the silk is negatively charged. True:..., False:...

(d) Both protons and electrons pass from the silk to the glass. However, the number of protons transferred from the silk to the glass is greater than the number of electrons. The glass is positively charged because it gains more the positive charge than negative. The positive charge that the silk loses is more than the negative one and therefore, it is negatively charged. True:..., False:...

For the test, correct answers have to be similar to the following one: The statement 1: (a) True:…, False: √; (b) True:…, False: √; (c) True: √, False:…; (d) True:…, False: √; the statement 2: (a) True:…, False: √; (b) True: √, False:…; (c) True:…, False: √; (d) True:…, False: √.

The incorrect or correct answers were assigned a score of 1 or 0, respectively and measured a participant's score that was his or her misconception score on the UNEFT.

Pilot Study

In Turkey, although there were enough teachers in secondary and high schools, there were teacher shortages in primary schools until a few years ago. For this reason, in the middle of 1990s, the Ministry of National Education declared that the graduates of faculties of arts and sciences, and education should go on to become primary school teachers after completing a two or three semester pedagogical foundation course. The faculty of education began the Primary School Teacher Education Pedagogical Formation Certificate Programme (PSTEPFCP) for this purpose and graduates as well as fourth year students of faculties mentioned were admitted to the PSTEPFCP. The midterm examination results of 206 prospective teachers (PTs), who were not included in the study, but in the two academic years of the PSTEPFCP at a large public university, were evaluated in the context of a pilot study. The administration of the pilot study questionnaire took about 15 minutes. The pilot study revealed that the statements on the test on electrification by friction were quite understandable and clear to all the PTs.

The Sample

The sample under investigation was comprised of 345 students in the three academic years of the PSTEPFCP. The students (PTs) in the PSTEPFCP were divided into two groups: Basic scientists, the (BSs) (people in physics, (Ps), chemistry, (Cs), biology, (Bs) and mathematics, (Ms) and social scientists, the (SSs) (people in history, geography, Turkish, English, French, German, sociology, psychology, philosophy, physical education and education sciences). During the university education, the Ms studied basic physics and other BSs learn physics and chemistry and biology courses, but the SSs did not study any courses in the basic sciences. However, all students had taken a five–year science course in elementary and secondary school and studied physics, chemistry and biology for three years during their high school education.

The research included two samples and was administered in two stages. The first stage included 177 PTs (103 BSs: 17 Ps, 21 Cs, 36 Bs and 29 Ms, and 74 SSs). The first group in which misconceptions were identified was called the ‘identification group.’ The second stage included 169 PTs, and in this stage, the misconceptions concerning the effectiveness of the MAS were examined in two groups: experimental and control groups. The experimental and control groups included 85 PTs (48 BSs: 8 Ps, 8 Cs, 16 Bs and 16 Ms, and 37 SSs) and (47 BSs: 10 Ps, 8 Cs, 18 Bs and 11 Ms, and 37 SSs), respectively. The groups were formed by the directors of the PSTEPFCP and each of them was randomly chosen as either the experimental or the control group by the researcher.

Variables

This study had one dependent variable and three independent variables, one independent variable for each of the conditions. The dependent variable was the PTs’ (the total, the BSs, the SSs, Ps, Cs, Bs and Ms) misconception scores on the UNEFT. The independent variables were as follows:

(a) the PTs (the total, the BSs, the SSs, Ps, Cs, Bs and Ms) in the PSTEPFCP;

(b) the PTs’ areas of study (basic sciences, social sciences, physics, chemistry, biology and mathematics);

(c) the group or treatment condition (experimental and control groups, the subgroups and the sub–subgroups).

Data Collection Procedure

The researcher taught the science teaching method course in the PSTEPFCP at a large public university. The course involved three class periods of 50 minutes per week and it was taught in a 14 week semester. Classes consisted of 50 to 90 students. The course had eleven topics selected from science textbooks at the Grade 4 and 5 levels, and in the course, both science content knowledge and methods of science teaching in primary schools were taught.

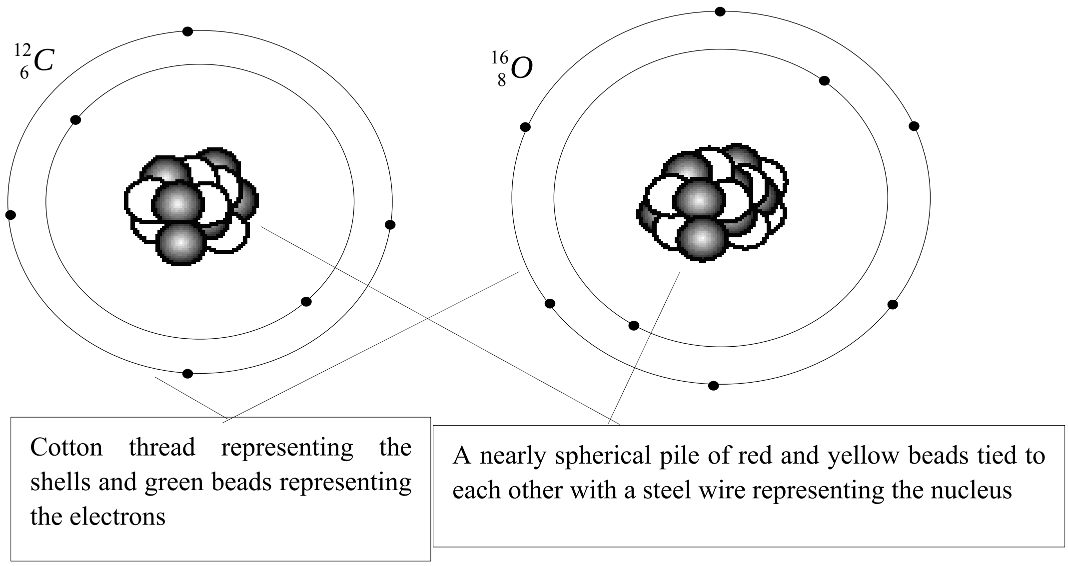
The course was planned in the first week. In the plan, a class was randomly divided into ten groups of five to nine people and 10 of the 11 topics were given to a group. In the second week, the lecturer (that is, the researcher) presented the remaining topic as a sample lesson. From the third week, the first seven groups presented their topics. At the end of the ninth week, the students took the midterm examination. In the tenth week, the lecturer and the students discussed the questions on the midterm examination. In the eleventh, and twelfth, and thirteenth weeks, the remaining groups presented the final three topics. In the fourteenth week, the course was evaluated as a whole. At the end of fourteenth week, the PTs took the final examination. The data in this article consisted of the PTs' misconception scores on the midterm examinations in the topic electrification by friction.

Treatment

Treatment 1: Presentation of the topic* 'electrification by friction' *to the identification and control groups: Static electricity was presented in the fourth week. In order to present the topic, members of the PTs group brought a piece of woollen cloth (a sweater or a sock), an ebonite rod (or a plastic comb or balloon), a glass rod (or a glass bottle or tube) and a piece of silk cloth (a scarf or a tie). Additionally, they used a simple electroscope they had made themselves. In the presentation of the topic, the group first explained that matter is composed of atoms, and that the atom consists of protons and neutrons and electrons, that a proton has positive charge, an electron has equal negative charge, a neutron has no charge, and that a neutral object has an equal amount of positive and negative charge from the protons and the electrons. They drew a model of an atom on the board. On the model, they showed that the atomic nucleus was formed of protons and neutrons, and that the electrons revolve round the nucleus. They emphasised that the nucleus was robust and compact, and that the electrons, especially the outer ones, were weakly bound to the atom. The presenters first rubbed the ebonite rod with the wool and the glass rod with the silk and they showed that the ebonite rod and the glass rod were charged with a simple electroscope they had made. They explained that the charging of the ebonite rod and glass rod was due to the electron transfer between objects, which were rubbed against each other. They emphasised that the friction could not cause any proton transfer. They stated that scientists had shown that electrons moved from the silk to the glass rod and to the ebonite rod from the wool. Further, they explained that when the ebonite rod was rubbed with the wool, it became negative because electrons left the wool and stuck on the surface of the ebonite, and that when the glass rod was rubbed with the silk it became positive because electrons left the glass rod and stuck to the surface of the silk. In order to explain in a visual way the transferring of electrons, they drew the figures of the ebonite–wool and the glass–silk pairs on the board and showed the movement of electrons between the pairs with arrows. Then, they showed the kind of charges on the figures using (+) or (-) signs. In addition, from time to time, there was discussion between the presenters and the listeners (other PTs).

Treatment 2: Presentation of the topic 'electrification by friction' in the experimental group: examining the effectiveness of the modelling atomic structure activity (MAS): The topic of static electricity was also presented to the experimental group in the way it was presented to the identification and the control groups. In addition, the experimental group performed the MAS activity.

In the application of the activity to the experimental group, this procedure was followed: The PTs were divided into ten groups. Each group was given red, yellow and green beads with a hole in the centre, a steel wire and a cotton thread. The radii of the red and yellow beads were about 3.0 mm and that of the green beads was about 1.5 mm. The steel wire had a radius of 0.5 mm and a length of 30 cm. The cotton thread was as thick as sewing thread. Some of the groups were given eight and the other groups were given six beads of each kind. The groups lined the red and yellow beads up on steel wire and tied the end of the wire. The red and yellow beads represented the protons and the neutrons, respectively. The spherical piles, which consisted of red and yellow beads, corresponded to the nuclei of ${}^{12}_{6}C$ (Carbon) and ${}^{16}_{8}O$ (Oxygen) atoms. The nucleus models were placed on a desk. There were two green beads, which represented the electrons that were fixed on the cotton thread. Then the thread was tied at the end and it was put around the nucleus model in a circular form. Because there could be only two electrons in the outer or n = 1 shell, the first circular orbit representing the n = 1 shell included two green beads that modelled the electrons for both the atoms. The orbital circles with increasing size were placed around the nucleus models. The second circular orbit represented the inner or n = 2 shell and included four and six green beads in the models of and atoms, respectively. The design of the models of $^{12}_{6}C$ and $^{16}_{8}O$ atoms is shown in Figure 1.



(a) (b)

Figure 1. (a): Model of the (Carbon) $^{12}_{6}\mathbf{C}$ atom, (b): Model of the (Oxygen) $^{16}_{8}\mathbf{O}$ atom

The students tried to transfer one red bead representing the proton from one atom model to the other. However, this was impossible because red and yellow beads were tied to each other with a steel wire. They then tried to transfer one green bead representing the electron from one atom model to the other. They broke the thread easily and took one green bead from the outermost circular orbit of the model of $^{12}_{6}C$ atom and placed it on the outermost circular orbit of the model of $^{16}_{8}O$ atom. The procedure carried out is illustrated in Figure 2.

In the second case, the model of $^{12}_{6}C$ atom consists of six red beads (representing the protons) and five green beads (representing the electrons). The resulting $^{12}_{6}C$ atomic ion is positively charged, (+1) since the proton and the electron are the positive and the negative in the charge, respectively. The $^{16}_{8}O$ atomic ion has a negative charge, (−1) because its new model contains eight red (proton) and nine green (electron) beads.

This activity showed the students that there could be no proton transfer from an atom to another. The modelling with the steel wire showed that binding in the nucleus was very strong, and the protons were tightly packed in the atom.

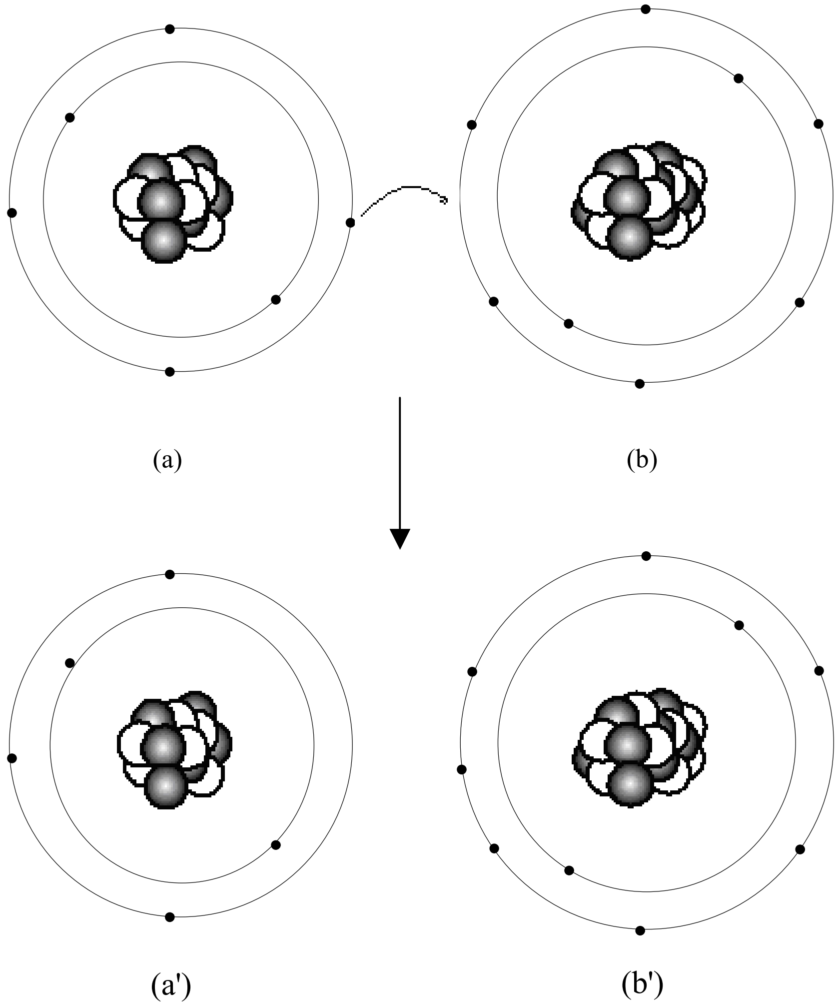


Figure 2. Modelling of electron transfer from the $^{12}_{6}\mathbf{C}$ atom to the $^{16}_{8}\mathbf{O}$ atom, (a): Model of the $^{12}_{6}\mathbf{C}$ atom, (b): Model of the $^{16}_{8}\mathbf{O}$ atom, (a'): Model of the $^{12}_{6}\mathbf{C}^{+}$ ion, (b'): Model of the $^{16}_{8}\mathbf{O}^{-}$ ion

Data Analysis

Data were analysed using the SPSS 10.0 for Windows (Statistical Software Package for the Social Sciences). Frequencies, means, and standard deviations were used to summarise and analyse the data. Data from only two groups were compared using a one–way analysis of variance (one–way ANOVA). Comparisons of means from more than two groups were analysed using a one–way ANOVA followed by the Fisher's Least Significant Difference (LSD) multiple–comparison post–hoc test. The significance level was set at 0.05. In other words, the probability of rejecting the true null hypothesis (probability of making Type I error) was set to 0.05 a priori to hypotheses testing. A univariate analysis of variance was used to estimate the effect size in the eta–squared, η^2 and the power. In order to interpret the eta–squared, Green, Salkind and Akey's (2000) eta–squared scale as cited by Brashears, Akers and Smith (2005), which the eta–squared values of 0.01, 0.06, and 0.14 and over represent small, medium and large effect sizes, respectively, was used. In the SPSS program, graphs that depicted the groups' mean misconception scores on the Understanding the Nature of Electrification by Friction Test (UNEFT) were produced.

RESULTS

Hypotheses 1, 2, 3, 4, 5, 6 and 7: The first seven hypotheses, were that the PTs had the misconceptions about Atomic Structure in the Context of Electrification by Friction (ASCEF), in (1) the total group, and (2) the BSs, and (3) the SSs, and (4) the Ps, and (5) the Cs, and (6) the Bs and (7) the Ms. According to Table 2, (1) the PTs in total, (2) the BSs, (3) the SSs, (4) the Ps, (5) the Cs, (6) the Bs and (7) the Ms had mean misconception scores of 0.54, 0.48, 0.64, 0.41, 0.48, 0.53 and 0.45 on the UNEFT, respectively. In a clearer expression, 54.2, 47.8, 63.5, 41.2, 47.6, 52.8 and 44.8 per cent of them said that the UNEFT as electrification by friction occurred as a result of the proton transfer. For knowledge gained at the primary education level, these were high values. Accordingly, none of the first seven hypotheses were rejected: The PTs had misconceptions about the ASCEF, in (1) the total group, and (2) the BSs, and (3) the SSs, and (4) the Ps, and (5) the Cs, and (6) the Bs and (7) the Ms.

Table 2. Descriptive statistics for the PTs' misconception scores

Groups	N	Misconception Level			SD Standard Deviation
		M Misconception Score	f_a Absolute Frequency	f_r Relative Frequency	
Ps	17	0.41	7	41	0.51
Cs	21	0.48	10	48	0.51
Bs	36	0.53	19	53	0.51
Ms	29	0.45	13	45	0.51
BSs	103	0.48	49	48	0.50
SSs	74	0.64	47	64	0.48
Total	177	0.54	96	54	0.50

Thus after testing hypothesis 1, two types of misconceptions were identified by the UNEFT: The first was directly identified and the second was identified by implication. A list of the misconceptions is presented in Table 3.

Table 3. The PTs' misconceptions as identified from the UNEFT

The first misconception:
Electrification by friction is due to a proton transfer.
The second misconception:
1. The atomic number can be changed by rubbing objects together.
2. Any element can be made from another element by rubbing objects together.
3. The nuclear energy can be generated by rubbing objects together.
4. The nuclear binding energies are sufficiently low to split the nuclei.
5. The atomic nuclei can be split by rubbing objects together.
6. The smallest units of matter are the protons and the electrons rather than the atoms or the molecules.
7. An atom consists of a sphere of positive electricity with negative electrons doted inside it.

Hypothesis 8: Hypothesis 8 concerned the group differences between the BSs and SSs in the mean misconception scores on the UNEFT. It was tested by a one–way ANOVA and the results were reported in Tables 2 and 4.

Table 4. One–Way ANOVA of the BSs and SSs' mean misconception scores

Source of Variation	Sum of Squares	df	Mean Square	F	p	η^2	Power
Between Groups	1.09	1	1.09	4.47	0.04	0.02	0.56
Within Groups	42.84	175	0.24				
Total	43.93	176					

The ANOVA procedures revealed a significant difference between the BSs' and SSs' mean misconception scores [$F_{(1, 175)} = 4.47$, $p = 0.04 < 0.05$, $\eta^2 = 0.03$, power = 0.56]. In addition, the univariate analysis of variance calculated a power of 0.56, with an effect size of 0.03. Since the ANOVA procedures revealed a significant difference between the groups' scores, hypothesis 8 was rejected: There was a statistically significant difference between the BSs' and SSs' mean misconception scores on the UNEFT. According to Table 2, the SSs' mean misconception score

(M = 0.64) was significantly higher than that of the BSs (M = 0.48): $H_r : \mu_{BSs\,(UNEFT)} < \mu_{SSs\,(UNEFT)}$. This result demonstrated that a university science education was effective in correcting the PTs' misconceptions.

In addition, the BSs' and SSs' mean misconception scores were also compared visually by the graph in Figure 3.

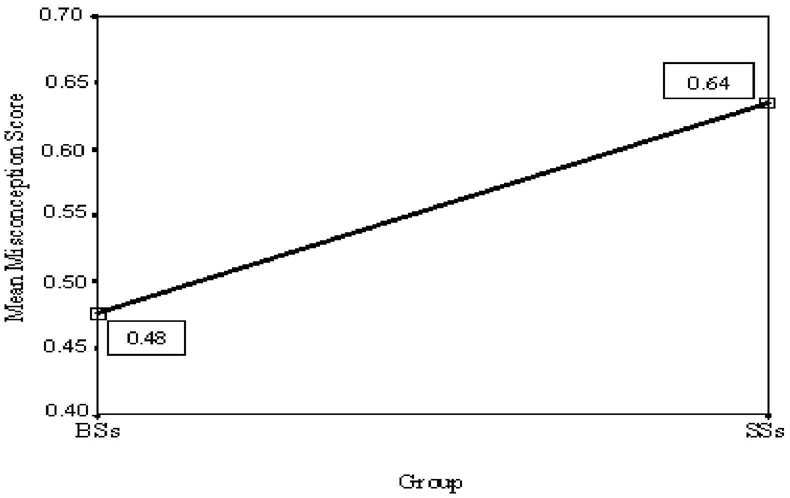


Figure 3. Plot of the misconception scores by the BSs and SSs groups

Hypothesis 9: Hypothesis 9 examined the group differences between the Ps, Cs, Bs, Ms and SSs in the mean misconception scores on the UNEFT, as did hypothesis 8.It was tested by a one–way ANOVA and the results were reported in Tables 2 and 5.

Table 5. One–Way ANOVA of the Ps', Cs', Bs', Ms' and SSs' mean misconception scores

Source of Variation	Sum of Squares	df	Mean Square	F	p	η^2	Power
Between Groups	1.28	4	0.32	1.29	0.27	0.03	0.40
Within Groups	42.65	172	0.25				
Total	43.93	176					

The ANOVA procedures revealed that there was no significant difference [$F_{(4,\ 172)} = 1.29$, $p = 0.27 > 0.05$, $\eta^2 = 0.03$, power = 0.40]. In addition, the univariate analysis of variance calculated the power of 0.40, with an effect size of 0.03. Since the ANOVA procedures revealed that there was no statistically significant difference between the means of the five groups, it was not necessary to compare their means by a one–way ANOVA followed by the Fisher's LSD test. Therefore, the null hypothesis stating that there was no statistically significant difference among the Ps', Cs', Bs', Ms' and SSs' mean misconception scores on the UNEFT was not rejected: $H_0 : \mu_{Ps\,(UNEFT)} = \mu_{Cs\,(UNEFT)} = \mu_{Bs\,(UNEFT)} = \mu_{Ms\,(UNEFT)} = \mu_{SSs\,(UNEFT)}$.

In addition, the Ps, Cs, Bs, Bs, Ms and SSs groups' mean misconception scores on the UNEFT were also compared visually by the graph in Figure 4.

Hypothesis 10: Hypothesis 10 examined the difference between experimental and control groups' mean misconception scores on the UNEFT. It was tested by a one–way ANOVA and the results are reported in Tables 6 and 7.

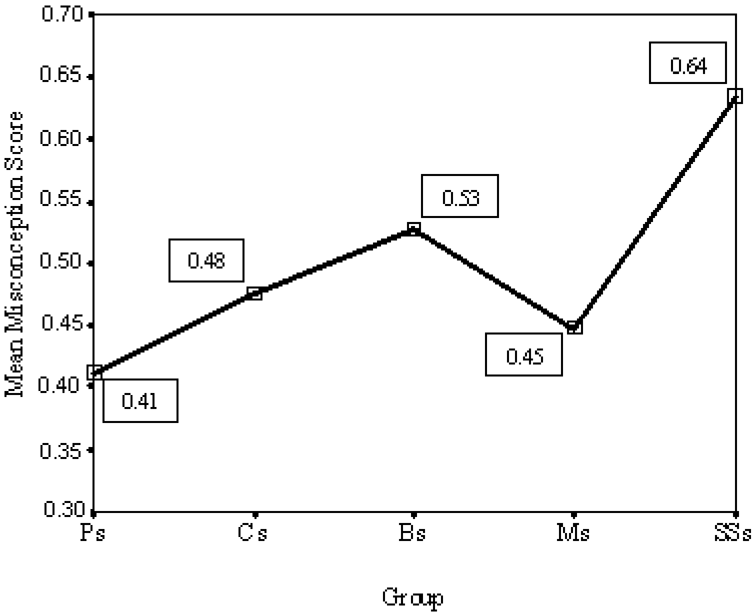


Figure 4. Plot of mean misconception scores by the Ps, Cs, Bs, Ms and SSs groups

Table 6. Descriptive statistics for the experimental and control groups' misconception scores

Groups	N	Misconception Level			SD
		M Misconception Score	f_a Absolute Frequency	f_r Relative Frequency	Standard Deviation
Experimental	85	0.16	14	16	0.37
Control	84	0.52	44	52	0.50
Total	169	0.34	58	34	0.48

As can be seen in Table 7, the ANOVA procedures reveal a statistical significant difference between the experimental and control groups' mean misconception scores [$F_{(1,\ 167)} = 27.87$, $p = 0.00 < 0.05$, $\eta^2 = 0.14$, power = 1.00]. In addition, the univariate analysis of variance calculated the power of 1.00, with an effect size of 0.14. Since the ANOVA procedures revealed a significant difference between the groups' scores, hypothesis 10 was rejected in favour of the research hypothesis: that there is a statistically significant difference between the experimental and control groups' mean misconception scores on the UNEFT. According to Table 6, the control group's mean misconception score (M = 0.52) is significantly higher than that of the experimental group (M = 0.16):

$H_r : \mu_{Exp\,(UNEFT)} < \mu_{Con\,(UNEFT)}$. These results indicate a Treatment two effect on the experimental–control pair.

Table 7. One–Way ANOVA of the experimental and control groups' mean misconception scores

Source of Variation	Sum of Squares	df	Mean Square	F	p	η^2	Power
Between Groups	5.45	1	5.45	27.87	0.00	0.14	1.00
Within Groups	32.65	167	0.20				
Total	38.10	168					

In addition, the experimental and control groups' mean misconception scores on the UNEFT were also once more compared visually by the graph in Figure 5.

As mentioned above, the research population consisted of the BSs (Ps, Cs, Bs and Ms) and SSs. Although they were not listed separately as hypotheses of the study, and in hypothesis 10, in order to compare the BSs and SSs subgroups in the experimental and control groups, a post–hoc comparison test was carried out. The comparison was analysed using a one–way ANOVA followed by the Fisher's LSD test. The results are reported in Tables 8, 9 and 10. The abbreviations EBSs, ESSs, CBSs and CSSs for the group names in Table 8 represent the experimental basic scientists (EBSs), and social scientists (ESSs) groups, and the control basic scientists (CBSs) and social scientists (CSSs) groups, respectively.

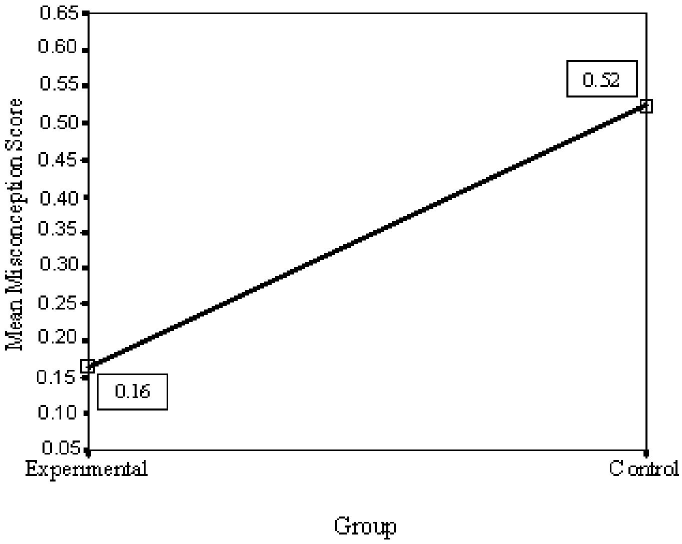


Figure 5. Plot of mean misconception scores by the experimental and control groups

Table 8. A description of the statistics of misconception scores of the subgroups of the experimental and control groups

Groups	N	Misconception Level			SD
		M Misconception Score	f_a Absolute Frequency	f_r Relative Frequency	Standard Deviation
EBSs	48	0.12	6	12	0.33
ESSs	37	0.22	8	22	0.42
CBSs	47	0.45	21	45	0.50
CSSs	37	0.62	23	62	0.49
Total	169	0.34	58	34	0.48

As can be seen in Table 9, the ANOVA procedures reveal a statistically significant difference between at least one pair's mean misconception scores [$F_{(3,\ 165)}$ = 10.80, p = 0.00 < 0.05, η^2 = 0.16, power = 1.00]. In addition, the univariate analysis of variance calculated the power of 1.00, with an effect size of 0.16. These results indicate a treatment two effect in at least one pair of the subgroups.

Table 9. One–Way ANOVA of mean misconception scores of the BSs and SSs subgroups in the experimental and control groups

Source of Variation	Sum of Squares	df	Mean Square	F	p	η^2	Power
Between Groups	6.26	3	2.08	10.80	0.00	0.16	1.00
Within Groups	31.84	165	0.19				
Total	38.10	168					

The Fischer's LSD test results in Table 10 indicate that there are significant differences between the mean misconception scores of EBSs–CBSs, EBSs–CSSs, ESSs–CBSs and ESSs–CSSs pairs (p < 0.05), and that there are no significant differences between the mean misconception scores of EBSs–ESSs and CBSs–CSSs pairs (p > 0.05).

In summary, the pairs that have significant differences among the subgroups' mean misconception scores are noted in Table 10 and marked by the (*) symbol on the p values.

In addition, the subgroups' mean misconception scores in the experimental and control groups are also compared visually by the graph in Figure 6.

Table 10. LSD multiple–comparison of the experimental and control subgroups' mean misconception scores

Pairs I	J	Mean Difference (I-J)	Standard Error	p
EBSs	CBSs	-0.32	9.01E-02	0.00*
EBSs	CSSs	-0.50	9.61E-02	0.00*
ESSs	CBSs	-0.23	9.66E-02	0.02*
ESSs	CSSs	-0.40	0.10	0.00*
EBSs	ESSs	-0.10	9.61E-02	0.34
CBSs	CSSs	-0.18	9.66E-02	0.07

* = significant

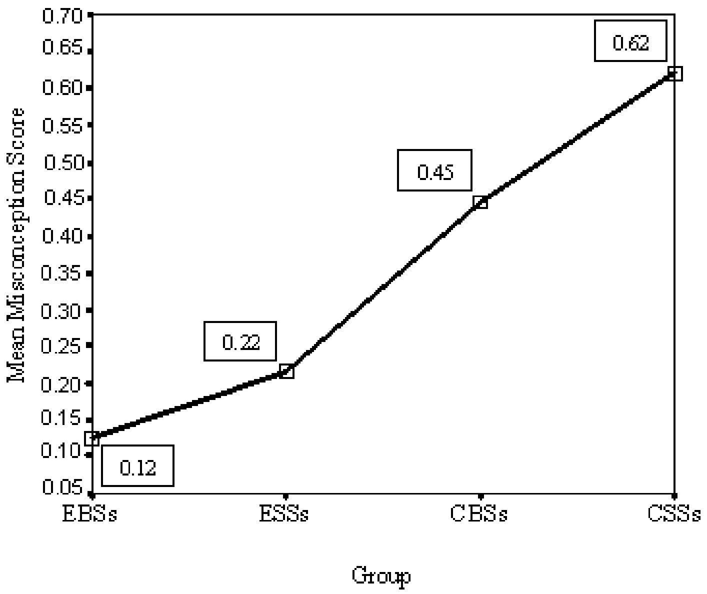


Figure 6. Plot of mean misconception scores by the subgroups of the experimental and control groups

Again in hypothesis 10, the particular pairs of the sub–subgroups (Ps, Cs, Bs, Ms and SSs) in the experimental and control groups are compared using a one–way ANOVA followed by the Fisher's LSD test and the results are reported in Table 11, 12 and 13. By way of explanation, the abbreviations EPs, ECs, EBs, EMs, ESSs, CPs, CCs, CBs, CMs and CSSs are used as group names in Table 11. They represent the experimental physicists, chemists, biologists, mathematicians and social scientists groups, and the control physicists, chemists, biologists, mathematicians and social scientists groups, respectively.

Table 11. Descriptive statistics of misconception scores of the sub–subgroups of the experimental and control groups

Groups	N	Misconception Level M Misconception Score	f_a Absolute Frequency	f_r Relative Frequency	SD Standard Deviation
EPs	8	0.12	1	12	0.35
ECs	8	0.12	1	12	0.35
EBs	16	0.12	2	12	0.34
EMs	16	0.12	2	12	0.34
ESSs	37	0.22	8	22	0.42
CPs	10	0.40	4	40	0.52
CCs	8	0.50	4	50	0.54
CBs	18	0.50	9	50	0.51
CMs	11	0.36	4	36	0.50
CSSs	37	0.62	23	62	0.49
Total	169	0.34	58	34	0.46

As can be seen in Table 12, the ANOVA procedures reveal a statistically significant difference between at least one pair's mean misconception scores [$F_{(9, 159)} = 3.58$, $p = 0.00 < 0.05$, $\eta^2 = 0.39$, power = 1.00]. In addition, the univariate analysis of variance calculated the power of 1.00, with an effect size of 0.39. These results indicate a treatment 2 effect in at least one pair of the sub–subgroups.

Table 12. One–Way ANOVA of mean misconception scores of the sub–subgroups in the experimental and control groups

Source of Variation	Sum of Squares	df	Mean Square	F	p	η^2	Power
Between Groups	6.43	9	0.71	3.58	0.00	0.39	1.00
Within Groups	31.67	159	0.20				
Total	38.10	168					

The Fischer's LSD test results in Table 13 indicate that there are significant differences between the mean misconception scores of ten sub–subgroup pairs marked by the (*) symbol on the p values ($p \leq 0.05$), and that there are no significant differences among the mean misconception scores of the remaining 25 sub–subgroup pairs ($p > 0.05$).

Table 13. LSD multiple–comparison of mean misconception scores of the sub–subgroups in the experimental and control groups

Pairs				
I	J	Mean Difference (I-J)	Standard Error	p
EPs	ECs	0.00	0.22	1.00
EPs	EBs	0.00	0.19	1.00
EPs	EMs	0.00	0.19	1.00
EPs	ESSs	-0.10	0.17	0.60
EPs	CPs	-0.28	0.21	0.20
EPs	CCs	-0.38	0.22	0.10
EPs	CBs	-0.38	0.19	0.05*
EPs	CMs	-0.24	0.21	0.25
EPs	CSSs	-0.50	0.17	0.00*
ECs	EBs	0.00	0.19	1.00
ECs	EMs	0.00	0.19	1.00
ECs	ESSs	0.10	0.17	0.60
ECs	CPs	-0.28	0.21	0.20
ECs	CCs	-0.38	0.22	0.10
ECs	CBs	-0.38	0.19	0.05*
ECs	CMs	-0.24	0.21	0.25
ECs	CSSs	-0.50	0.17	0.00*
EBs	EMs	0.00	0.16	1.00
EBs	ESSs	-0.10	0.13	0.50
EBs	CPs	-0.28	0.18	0.13
EBs	CCs	-0.38	0.19	0.05
EBs	CBs	-0.38	0.15	0.02*
EBs	CMs	-0.24	0.18	0.17
EBs	CSSs	-0.50	0.13	0.00*
EMs	ESSs	-0.10	0.13	0.50
EMs	CPs	-0.28	0.18	0.13
EMs	CCs	-0.38	0.19	0.05
EMs	CBs	-0.38	0.15	0.02*
EMs	CMs	-0.24	0.18	0.17
EMs	CSSs	-0.50	0.13	0.00*
ESSs	CPs	-0.18	0.16	0.25
ESSs	CCs	-0.28	0.17	0.10
ESSs	CBs	-0.28	0.13	0.03*
ESSs	CMs	-0.15	0.15	0.34
ESSs	CSSs	-0.40	0.10	0.00*

* = significant

The sub–subgroups' mean misconception scores in the experimental and control groups are also compared visually by the graph in Figure 7.

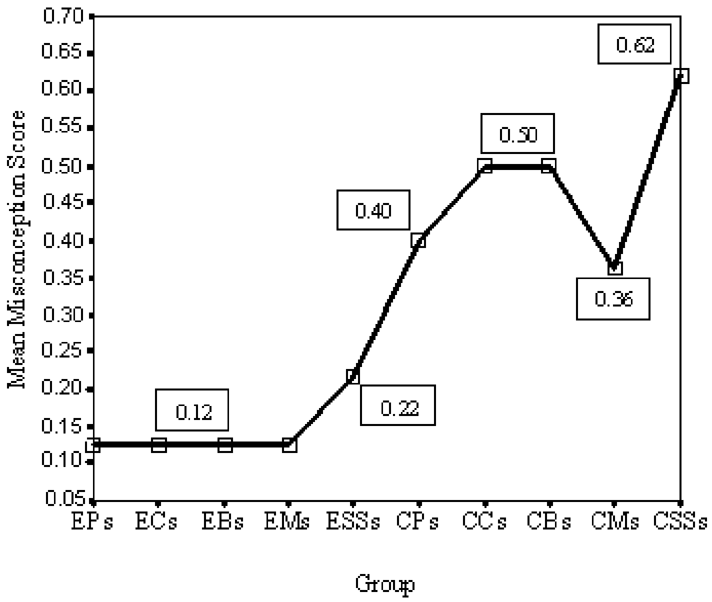


Figure 7. Plot of mean misconception scores by the sub–subgroups of the experimental and control groups

DISCUSSION

According to the results of testing the first seven hypotheses, it was found that the PTs from all the levels in the sample held the misconceptions on the UNEFT presented in the Table 3. Table 2 shows that 54.2 per cent of 177 PTs thought that there was proton transfer between objects rubbed together. The proportions in the BSs, SSs, Ps, Cs, Bs and Ms were 47.6, 63.5, 41.2, 47.6, 52.8 and 44.8 per cent, respectively.

The results of the testing the first nine hypotheses show that the PTs' concepts of atoms, elements and atomic number, which are basic concepts in science, are not at a high enough level. If a proton transfer had occurred between the rubbed objects together, then there would have been a transfer from one nucleus to another because a proton could not exist as an independent particle in matter. This misconception implies a change in atomic number. Proton number also has the same meaning for any atom just as DNA and fingerprints are determinants for living things and people, respectively. If the atomic number of any atom changes, it means that its identity also changes. That is, this thought was as wrong as the alchemists' idea that gold could be made from copper. In fact, the PTs know that a new atom is not produced by rubbing. They can see the fact that the glass and the ebonite in their hands do not change. However, the prospective teachers seem unable to transfer their knowledge of atoms to explain the nature of electrification by rubbing. The students are not able to link up their knowledge on other topics; it is as though their knowledge of science is packaged separately. The results indicate that even the BSs do not completely understand nuclear reactions, nuclear energy and nuclear binding energy concepts. The fact that any atom loses or gains proton(s) means that a nuclear reaction is occurring. If a proton is transferred between the objects rubbed together, nuclear energy must be generated. Such uncontrollable nuclear energy can be the end of life. However, when we comb our hair, take our sweater off, static electricity is usually produced and life does not end. Therefore, it is clear that there is no proton transfer. When the PTs are asked about the origin of nuclear energy, all of the BSs and more than half of the SSs know that it is related to the nucleus. However, they cannot use their knowledge to explain the nature of static electricity. The SSs do not know the meaning of the nuclear binding energy; which is normal because they have not learned this knowledge. Only a few of the Bs and Ms are aware of it. All of the Ps and Cs have some information on the subject. At least, the Ps and Cs have an understanding that the nuclear binding energy is a measure of the nucleus strength. However, they do not see any objection to splitting the atom. An answer to the question do all atoms split is 'no'. When they are asked the question, does the transfer of the proton mean that the atom split, they are perplexed. Again, these results show that the PTs can not synthesise knowledge from different units.

In addition, these results highlight the fact that the PTs imagined that the smallest units of matter were the protons and the electrons rather than the atoms or the molecules, as if these particles had been independent of each other in matter. It seemed as though this was a similar idea to that of Lord Kelvin's atom model in their minds. Kelvin's idea as taken up by Sir J.J. Thomson, an atom might consist of a sphere of positive electricity with negative electrons dotted inside it (Abbott, 1987). His model was known as 'the cake with raisins model of the atom' in the literature. This result supported the view there was a contribution of ideas of past leaders in the field to students' misconceptions known in the science education literature (Griffiths and Preston, 1992). In fact, the PTs drew figures for a single atom: a nucleus in the centre and the electrons around the nucleus. However, they showed the positive and negative charges (protons and electrons) as small spheres signed with (+) and (-) and scattered together. The positive and negative charges in the matter were shown in the same way in their textbooks (for example, Serway, 1990; Wellner, 1991). This result supported the idea that textbooks were responsible for students' misconceptions, a perception identified by Cho, Kahle and Nordland (1985). Textbook writers were aware of the fact that the proton could not be isolated from an atom. However, students misunderstood the spheres signed with (+) and (-) (the models), which experts used in order to teach static electricity. In fact, their textbooks noted that the fact was not correct, but, like all people, students were interested in the figures that they saw first; they chose one that was easiest to understand, rather than read about written ones. For this reason, these kinds of figures, which led students to incorrect ideas, should be avoided. Or, when the topic of electrification by friction was presented using these figures, the fact that they did not actually occur in this way should have been emphasised by the textbooks writers and in classrooms by teachers, lecturers, and instructors.

The misconception that there was the proton transfer between objects rubbed together was also pointed out in the literature (Hanuscin, 2006; Hapkiewicz, 1992). In addition, a study by Hummer (1997) showed that the students had difficulty understanding the electrification by friction in a science class. These results indicated that the misconceptions related to the subject were generally widespread among the students of different countries.

As seen in Table 4, in the context of the hypothesis 8, the ANOVA found a significant difference between the BSs' and SSs's mean misconception scores that indicated a weak university science education effect on the PTs' misconceptions. However, this effect was at a level of an eta–squared of 0.03 and it was a value with a very small effect according to Green, Salkind and Akey's (2000) eta–squared scale. In a clearer expression, the group independent variable in the BSs and SSs explained only 2.5 per cent of the variance in the mean scores in the dependent variable on the UNEFT. Moreover, the power for the hypothesis 8 was 0.56. In other words, the probability of failing to reject the false hypothesis 8 in the null form (the probability of making Type II error) was 0.44 (that is, 1.00 - 0.56) that was also a high probability. As a result of the testing of hypothesis 8, although there was a statistical significant difference between the BSs' and SSs's mean misconception scores, the university science education had little effect on their misconceptions.

As can be seen in Table 2, in the context of the hypothesis 9, in the Ps, Cs, Bs and Ms groups, the ratios were in the range of about 40–50 per cent and were generally close to each other. This result showed that the PTs in the various disciplines of the basic sciences had nearly the same level of knowledge on the subject. Essentially, as seen in Table 5, the ANOVA also revealed that there were no significant differences among the Ps, Cs, Bs, Ms and SSs groups' mean misconception scores. The most important concept was that there was not a significant difference between the SSs' mean and the mean of each of the Ps, Cs, Bs and Ms. This result demonstrated that a university science education generally did not have an effect in eliminating the Ps, Cs, Bs and Ms groups' misconceptions since their mean misconception scores were nearly at the same level as that of the SSs. The magnitude of the eta–squared had already indicated this result. The group effect on the misconception score was an eta–squared of 0.03 and it was a value very near a small effect. In a clearer expression, the group independent variable in the Ps, Cs, Bs, Ms and SSs explained only 2.9 per cent of the variance in the dependent variable of the misconception scores on the UNEFT. Moreover, the power for the hypothesis 9 was 0.40. In other words, the probability of failing to reject the false hypothesis 9 (probability of making Type II error) was 0.60 (that is, 1.00 - 0.40) and was also highly probable.

In spite of the fact that there were no statistically significant differences between the mean misconception scores of the five groups of students, it was also clear that their mean misconception scores increased in the following order: Ps, Ms, Cs, Bs and SSs. The electrification by friction was a physics topic and it was expected that the Ps would know the most about it. Since the SSs students only studied it during their pre–university education, it would be expected that their mean misconception scores would be the highest. In addition, for students beginning a branch of the basic sciences at university after a high school education in Turkey, scores, on an average, would increase in the following order: biology, chemistry, physics and mathematics. When all these explanations were considered together, this distribution of the misconception scores was, in fact, an expected result. In fact, chemistry was nearer to physics as a basic science discipline than to the other two. However, the Ms' misconception scores were lower than those of the Cs. This contradiction might be explained by the fact that the Ms' points were higher than those of the Cs on entrance to university.

In the hypothesis 8 the BSs' and SSs' mean misconception scores were compared and the ANOVA statistics found a significant difference between them. The BSs' misconception scores in the hypothesis 8 were consistent with those of the Ps, Cs, Bs and Ms in hypothesis 9. In fact, it was expected that the ANOVA would find a significant difference between the SSs' mean misconception score and that of at least one of the Ps, Cs, Bs and Ms groups. The fact that there was not a significant difference between the mean misconception scores in each of the pairs SSs–Ps, SSs–Cs, SSs–Bs and SSs–Ms might again appear to be a contradiction. In fact, it was not. Although in the hypothesis 8 the compared groups (BSs, N = 103, and SSs, N = 74) were sufficiently large to yield statistically significant differences between the groups' means, in the hypothesis 9 all the groups (Ps, N = 17, Cs, N = 21, Bs, N = 36, Ms, N = 29) except the SSs (N = 74) were not statistically different. However, in order to compare the means, the groups should have an optimal size (Mcmaster, Fuchs, Fuchs and Compton, 2005).

When viewed from another perspective, the BSs' mean misconception score was 25 per cent lower than of that of the SSs. This meant that the advanced science education undertaken at a university contributed only 25 per cent to the PTs' knowledge in the pre–university science education topic. It was rather a low ratio. It was interesting that nearly half the students who studied physics or chemistry in their undergraduate years could not even comprehend a basic science topic in the elementary curriculum for children aged 10 years. In fact, it was expected that all of them, the BSs and SSs, would answer questions on the UNEFT in a basic science topic correctly. It was clear that the instruction that they received was not sufficiently effective and that their teachers also could not recognise this fact. In spite of studying advanced science, the problem was not solved for the BSs either.

In the context of the hypothesis 10, in order to see the treatment effect, data were examined to see if there was a significant difference between the experimental and control groups' mean misconception scores. In addition, in the experimental and control groups, the subgroups' mean misconception scores, and the sub–subgroups' mean misconception scores were also compared.

As seen in Table 6, 16.5 per cent of the experimental group and 52.4 per cent of the control group said that there was a proton transfer between the objects rubbed together. This result showed that the modelling atomic structure activity (MAS) provided a misconception remediation in a proportion of about 36 per cent of the students. In other words, the experimental and control groups' mean misconception scores were 0.17 and 0.52, respectively, and according to Table 7, the ANOVA procedures found that there was a significant difference between them. If there was a need to discuss the problem in greater detail, the eta–squared for the interaction between the experimental and control groups was 0.14, which according to Green, Salkind and Akey's (2000) scale was a large effect and therefore, provided confirmatory evidence of the effects noted. In a clearer expression, the group independent variable in the experimental and control explained 14.3 per cent of the variance in the mean scores in the dependent variable on the UNEFT. Moreover, the power for the hypothesis 10 was 1.00. In other words, the probability of failing to reject the false hypothesis 10 in the null form (probability of making Type II error) was 0.00 (that is, 1.00 - 1.00) which was a low probability. As a result of testing hypothesis 10, the findings indicated that the MAS activity could be an effective learning tool for understanding the nature of electrification by friction.

In the context of hypothesis 10, Table 8 demonstrates that the EBSs' and ESSs' ratios of misconception were 12.5 and 21.6 per cent, and that those of the CBSs and CSSs were 44.7 and 62.2 per cent, respectively. These results showed that the MAS activity provided a misconception remediation in proportions of about 32 and 40 per cent in the BSs and SSs groups, respectively. As can be seen in Table 9, the ANOVA procedures reveal a statistically significant difference between at least one pair's mean misconception scores. Additionally, the eta–squared was 0.16, which was a large effect. In a clearer expression, the subgroup independent variable explained 16.4 per cent of the variance in the mean scores in the dependent variable on the UNEFT. Moreover, the power was 1.00. In other words, in order to reveal significant differences between the subgroups' mean misconception scores, the probability of making Type II error was 0.00 (that is, 1.00 - 1.00). It was also a very low value for the probability. These results showed that this procedure was a successful model to remedy misconceptions.

In addition, as seen in Table 10, although the ANOVA followed by the Fisher's LSD test found a significant difference between the mean misconception scores in each of the pairs EBSs–CBSs, EBSs–CSSs, ESSs–CBSs and ESSs–CSSs, it did not show a difference in each of the pairs EBSs–ESSs and CBSs–CSSs. The fact that there was no significant difference between the EBSs–ESSs pair's mean misconception scores showed that the treatment two effect was about the same level in both the subgroups of the experimental group. Following the same thinking, the treatment one effect was about the same level in both the CBSs and CSSs subgroups. Therefore, it could be said that teaching of the topic electrification by friction supported by the MAS activity had a decidedly affirmative effect on the BSs and SSs subgroups' misconceptions.

As is seen in Table 11, the EPs', ECs', EBs' and EMs' proportions of misconception were 12.5 per cent for all students and those of the CPs, CCs, CBs and CMs were 40, 40, 50 and 36.4 per cent, respectively. These results showed that the MAS activity provided a misconception remediation in the range of 28–38 per cent in the sub–subgroups EPs, ECs, EBs and EMs. As may be seen in Table 12, the ANOVA procedures reveal a statistically significant difference between at least one pair's mean misconception scores. Additionally, the eta–squared for the interaction between the sub–subgroups was 0.39, which was a large effect. In a clearer expression, the group independent variable explained 39.2 per cent of the variance in the mean scores in the dependent variable on the UNEFT. Additionally, the power was 1.00. In other words, in order to reveal significant differences between the sub–subgroups' mean misconception scores, the probability of making Type II error was 0.00 (that is, 1.00 - 1.00). It was also good to rely on the model. As the result, teaching of the topic electrification by friction supported by the MAS activity had a positive effect on the misconceptions that the sub–subgroups had about the Atomic Structure in the Context of Electrification by Friction (ASCEF).

According to Table 13, the fact that there is not a significant difference between the mean misconception scores in each of the pairs EPs–CPs, EPs–CCs, EPs–CMs, ECs–CPs, ECs–CCs, ECs–CMs, EBs–CPs, EBs–CCs, EBs–CMs, EMs–CPs, EMs–CCs, EMs–CMs, ESS–CPs, ESSs–CCs and ESS–CMs was interesting. The reason for this, as in the hypothesis 8, might be that compared to the other groups, except for the ESSs and CSSs groups, EPs, N = 8, ECs, N = 8, EBs, N = 16, EMs, N = 16, ESSs, N = 37, CPs, N = 10, CCs, N = 8, CBs, N = 18, CMs, N = 11 and CSSs, N = 37, the numbers were not sufficiently large to yield statistically significant between–group differences that might have existed. This limitation might not permit the detailed analyses needed to produce significant differences. However, for some, poor data or results might sometimes be better than no data or results. Additionally, the fact that there was not a significant difference between the mean misconception scores in each of the pairs EPs–ECs, EPs–EBs, EPs–EMs, EPs–ESSs, ECs–EBs, ECs–EMs, ECs–ESSs, EBs–EMs, EBs–ESSs, EMs–ESSs was an indication that the treatment two effect was at about the same level in each of the experimental sub–subgroups. As the result, these findings indicated the treatment two had an effect in at least ten sub–subgroups pairs' mean misconception scores.

When the PTs from the experimental group who correctly answered the UNEFT were interviewed, it was found that they remembered the MAS activity, in which colourful beads had been used, in the examination period. Both the explanations of the PTs and the examination results of the control and experimental groups showed that the activity had positive effects on the students' misconceptions.

In the experimental and control groups, and the subgroups, and the sub–subgroups, the effect sizes had the eta–squared values of 0.14, 0.16 and 0.39, and all of the power values were 1.00. Although the powers were the same values, the eta–squared value in the sub–subgroups was two times greater than of the other two values. That is, when the number of compared groups increased, the effect size also increased. This result indicated that the best of the three models in an experimental versus a control comparison was the third model in which the Ps, Cs, Bs, Ms and SSs groups were included. The reason for this might be that while in the first and second models, one and two small numbers (mean misconception scores) were compared to one and two large numbers, respectively, in the third model, five small numbers were compared to five large numbers. Accordingly, significant differences were more evident.

The message of this statistical finding was quite interesting. As expressed above, in treatment two, the PTs in the experimental group were divided into ten working groups and there was at least one or two person(s) from each of the sub–subgroups EPs, ECs, EBs, EMs and ESSs. When the mean misconception scores of the sub–subgroups Ps, Cs, Bs, Ms and SSs in the identification group were considered, each working group in the experimental group had a heterogeneous structure in academic achievement. In spite of this heterogeneous structure, all of the EPs, ECs, EBs and EMs groups had the same level of a low mean misconception score (M = 0.13). In addition, the ESSs' mean misconception score (M = 0.22) was also quite low. It was understood that the group members contributed to each others' understanding. These findings indicated the importance of group work, for example, cooperative and constructivist learning in classes an addition to the prior research results (for example, Brooks and Brooks, 1993; Humphreys, Johnson and Johnson, 1982). Additionally, this result warned school managements to form heterogeneous or mixed ability classes instead of homogeneous classes.

As a result of testing hypothesis 10, the importance of modelling activities in science teaching was indicated in the present study to be an addition to the prior research (Battino, 1983; Bent, 1984; Cherif, Adams and Cannon, 1997; Erduran, 2001; Harrison and Treagust, 1996 and 1998;

Streitberger, 1994) in the literature. Also, as emphasised by the constructivist learning theories (Bodner, 1986; Driver, 1989; Osborne and Wittrock, 1983; White, 1993; Yager, 1991), this study showed that deep learning was possible only by actually experiencing learning. In other words, the results of this study indicated the fact that the learning had to be an active process.

One of the most important aspects of science education research is the measurement tool chosen because all data are collected by means of it and all results are produced from these data. The UNEFT in this study is an original measurement tool and it is unusual in its presentation style. For a person who does not have sound knowledge about the nature of static electricity, the probability of finding the correct answer by an arbitrary ticking is $1/2^4$ for the ebonite–wool combination. The same one goes for the glass–silk combination. The probability for both together is $1/2^8$. In other words, the chance of finding the correct answer is only one in 4000. Therefore, for an individual who does not know the topic in detail, it is almost impossible to give the correct answer in an arbitrary way. Because the PTs have to pass an examination to get their certificate, they are naturally anxious to answer the questions correctly and use their knowledge on the topic. Each student responds to the UNEFT questions from in his or her own knowledge during the examination; they do not receive any help or information from other examinees. As seen in the data presented in Tables 2, 6, 8 and 11, there is a consistency between the examination results in the identification and control groups. Therefore, the results are considered to be reliable. One limitation of the measurement tool is the fact that it consists of only one question. This feature produces the result that a participant may receive one or zero points. It means that the points in any sample are distributed in a narrow range (a range of 0–1) and that they will be all close to the mean. The small values (closer to zero) of standard deviations in Tables 2, 6, 8 and 11 demonstrate these facts.

When considered from the point of view of the traditional rules of an experimental–control groups design, the weakest point in this study was the fact that the UNEFT was not employed as a pre–test to see if the control and experimental groups were equivalent in previous learning about static electricity. However, there might also have been some disadvantages in using a pre–test. For example, as stated above, some of students in the groups might have disagreed with the test and started to study after the pre–test. Furthermore, because the measurement tool used in the present study consisted of only one question, the PTs were able to remember the question easily and might have studied the material related to the UNEFT after the pre–test. This artificial increase in their success on the post–test might seem to be a successful outcome of the MAS activity. Additionally, the PTs' scores were important when deciding whether they could pass or fail the course. Thus, in order to eliminate the undesirable effects of a pre–test, the previous learning of the control and experimental groups was assumed to be at about the same level as that of the identification group. In addition, the classes in the control and experimental groups were formed from the students with the same qualifications by the manipulation of the program and each of the groups was randomly chosen. Moreover, in the educational research literature, it is possible to read studies which are based on a treatment versus control, rather than a pre–test versus post–test design (for example, Ivanov and Geake, 2003). Further, some studies with a treatment group had no control group (for example, Hessert, Gugliucci and Pierce, 2005). Other possible limitations were that the identification group (N = 177) and the identification subgroups (N = 103 and 74) and the identification sub–subgroups (N = 17–36) were small groups. Finally, the experimental and control groups were relatively large groups (N = 85 and 84) compared with the experimental and control sub–subgroups (N = 8–18) that were much smaller groups. In cases of an experimental versus a control, very large and very small sample sizes might negatively affect the reliability of the results. The controlling of large groups might be difficult; and small groups might not yield statistically significant differences. Nevertheless, in the research literature, it can be seen that even treatment groups with the sample size of 17 may be found to produce significant results (for example, Hessert, Gugliucci and Pierce, 2005).

As a result, in the teaching of science, the modelling technique is very useful and the misconceptions may be corrected in a learning environment in which the learner plays an active role.

CONCLUSIONS

This study led to the identification of the prospective teachers (PTs') (or students) misconceptions concerning the ASCEF, the development of the UNEFT to clarify the PTs' understanding of this topic and the development of the MAS activity to remedy the PTs' misconceptions related to the topic.

The results of this study provided further evidence to support the findings and indicated that students held misconceptions on a variety of science concepts. This study also highlighted the value that modelling was quite useful in the teaching of science, and that students' misconceptions could be remedied through the use of models. Science teaching supported by practical activities could therefore provide alternatives to traditional and other complementary methods to remedy misconceptions. This study called teachers and instructors' attention to the fact that students who studied physics and chemistry at the undergraduate level generally could not comprehend even basic science topics in the elementary curriculum. Other important results of this research were that classes in schools should be formed from a mixture of students with different academic ability, and that group work in classes could increase student achievement. The most important outcome was that the teaching was possible in an academic environment in which learners played an active role.

The remediation of students' misconceptions is only possible with teachers, who are well trained and free from misconceptions. All prospective teachers need to be trained as experts who are aware of possible misconceptions. Prospective teachers, their teachers and instructors or lecturers need to be aware of students' prior knowledge and misconceptions, and they need to understand why these misconceptions occur. A successful teacher is a person who is aware of his or her students' misconceptions and knows how to overcome them. Additionally, teachers need also to be informed about the importance of the modelling, and they need to be able to produce instructional models in science topics.

REFERENCES

Abbott, A. F. (1987). *Physics*. London: Heinemann.

Abraham, M., Williamson, V. and Westbrook, S. (1994). A cross age study of the understanding of five chemistry concepts. *Journal of Research in Science Teaching*, *31* (2), 147–165.

Anderson, R. D. (1965). Children's ability to formulate mental models to explain natural phenomena. *Journal of Research in Science Teaching*, *3*, 326–332.

Battino, R. (1983). Giant atomic and molecular models and other lecture demonstration devices designed for concrete operational students. *Journal of Chemical Education*, *60* (6), 485–487.

Bent, H. A. (1984). Uses (and abuses) of models in teaching chemistry. *Journal of Chemical Education*, *61* (9), 774–777.

Ben–Zwi, R., Eylon, B–S. and Silberstein, J. (1986). Is an atom of copper malleable? *Journal of Chemical Education*, *63* (1), 64–66.

Bodner, G. M. (1986). Constructivism: A theory of knowledge. *Journal of Chemical Education*, *63* (10), 873–878.

Brashears, T., Akers, C. and Smith, J. (2005). The effects of multimedia cues on student cognition in an electronically delivered high school unit of instruction. *Journal of Southern Agricultural Education Research*, *55* (1), 5–18.

Brooks, J. G. and Brooks, M. G. (1993). *In search of understanding: the case for constructivist classrooms*. Alexandria VA: Association for Supervision and Curriculum Development.

Calik, M. and Ayas, A. (2005). A cross–age study on the understanding of chemical solutions and their components. *International Education Journal*, *6* (1), 30–41.

Cherif, A. A., Adams, G. E. and Cannon, C. E. (1997). Non-conventional methods in teaching matter, atoms, molecules and the periodic table for non-major students. *The American Biology Teacher*, *59* (7), 428–438.

Cho, H–H., Kahle, J. B. and Nordland, F. H. (1985). An investigation of high school biology textbooks as sources of misconceptions and difficulties in genetics and some suggestions for teaching genetics. *Science Education*, *69* (5), 707–719.

Doran, R. L. (1972). Misconceptions of selected science concept held by elementary school students. *Journal of Research in Science Teaching*, *9* (2), 127–137.

Doran, R. L. (1973). Author's reply. *Journal of Research in Science Teaching*, *10* (4), 384–385.

Driver, R. (1989). Students' conceptions and the learning of science. *International Journal of Science Education*, *11* (5), 481–490.

Driver, R. (1993). Beyond appearances: The conservation of matter under physical and chemical transformations. In R. Driver, E. Guesne and A. Tiberghien (Eds.). *Children's ideas in science,* (pp. 145–169). London: Open University Press.

Driver, R., Leach, J., Scott, P. and Wood–Robinson, C. (1994). Young people's understanding of science concepts: implications of cross–age studies for curriculum planning. *Studies in Science Education*, *24*, 75–100.

Erduran, S. (2001). Philosophy of chemistry: An emerging field with implications for chemistry education. *Science and Education*, *10* (6), 581–593.

Gabel, D. L. and Samuel, K. V. (1987). Understanding the particulate nature of matter. *Journal of Chemical Education*, *64* (8), 695–697.

Garnett, P. J., Garnett, P. J. and Hackling, M. W. (1995). Students' alternative conceptions in chemistry: A review of research and implications for teaching and learning. *Studies in Science Education*, *25*, 69–95.

Gilbert, J. K. and Watts, M. (1983). Concepts, misconceptions and alternative conceptions: Changing perspectives in science education. *Studies in Science Education*, *19*, 61–98.

Green, S. B., Salkind, N. and Akey, T. (2000). Using SPSS for windows: Analyzing and understanding data (2nd edition). Boston: Prentice–Hall.

Griffiths, A. K. and Preston, K. R. (1992). Grade–12 students' misconceptions relating to fundamental characteristics of atoms and molecules. *Journal of Research in Science Teaching*, *29* (6), 611–628.

Haidar, A. H. (1997). Prospective chemistry teachers' conceptions of the conservation of matter and related concepts. *Journal of Research in Science Teaching*, *34* (2), 181–197.

Hanuscin, D. (2001). Misconceptions in Science. (retrieved on 15 May 2006) http://www.indiana.edu/~w505a/studwork/deborah/.

Hapkiewicz, A. (1992). Finding a list of science misconceptions. *MSTA Newsletter*, *38* (Winteri92), 11–14.

Harrison, A. G. and Treagust, D. F. (1996). Secondary students' mental models of atoms and molecules: Implications for teaching chemistry. *Science Education*, *80* (5), 509–534.

Harrison, A. G. and Treagust, D. F. (1998). Modelling in science lessons: Are there better ways to learn with models? *School Science and Mathematics*, *98* (8), 420–429.

Hessert, M. J., Gugliucci, M. R. and Pierce, H. R. (2005). Functional fitness: Maintaining or improving function for elders with chronic diseases. *Family Medicine*, *37* (7), 472–476.

Hammer, D. (1997). Discovery learning and discovery teaching. *Cognition and Instruction*, *15* (4), 485–529.

Humphreys, B., Johnson, R. T. and Johnson, D. W. (1982). Effects of cooperative, competitive, and individualistic learning on students' achievement in science class. *Journal of Research in Science Teaching*, *19* (5), 351–356.

Ivanov, V. K. and Geake, J. G. (2003). The Mozart effect and primary school children. *Psychology of Music*, *31* (4), 405–413.

Mcmaster, K. L., Fuchs, D., Fuchs, L. S. and Compton, D. L. (2005). Responding to non-responders: An experimental field trial of identification and intervention methods. *Exceptional Children*, *71* (4), 445–463.

MEB Tebligler Dergisi (2000). *Fen Bilgisi Dersi Ogretim Programi*, Sayi No: 2518, Ankara.

Mulford, D. R. and Robinson, W. R. (2002). An Inventory for Alternate Conceptions among First–Semester General Chemistry Students. *Journal of Chemical Education*, *79* (6), 739–744.

Nakhleh, M. B. (1992). Why some students don't learn chemistry? *Journal of Chemical Education*, *69* (3), 191–196.

Noh, T. and Scharmann, L. C. (1997). Instructional influence of a molecular–level pictorial presentation of matter on students' conceptions and problem–solving ability. *Journal of Research in Science Teaching*, *34* (2), 199–217.

Novick, S. and Nussbaum, J. (1978). Junior high school pupils' understanding of the particulate nature of matter: An interview study. *Science Education*, *62* (3), 273–281.

Novick, S. and Nussbaum, J. (1981). Pupils' understanding of the particulate nature of matter: A cross–age study. *Science Education*, *65* (2), 187–196.

Osborne, R. J. and Wittrock, M. C. (1983). Learning science: A generative process. *Science Education*, *67* (4), 489–508.

Pella, M. O. and Carey, R. L. (1967–68). Levels of maturity and levels of understanding for selected concepts of the particle nature of matter. *Journal of Research in Science Teaching*, *5,* 202–215

Piaget, J. (1963). *The child's conception of the world*. New Jersey: Littlefield, Adams

Piaget, J. (1970). The child's conception of physical causality. London: Redwood.

Raven, R. J. (1967–68). The development of the concepts of momentum in primary school children. *Journal of Research in Science Teaching*, *5*, 216–223.

Sarikaya, M. (2000). Turkish prospective teachers' views about the physical and chemical changes. Unpublished Manuscript, Ankara, Turkey: Faculty of Education, Gazi University.

Sarikaya, M. (2004). The application of an activity relating to the determination of Avogadro's number in a class of first–year science students. *The Chemical Educator*, *9* (1), 17–19.

Schmidt, H.–J. (1997). Students' misconceptions–Looking for a pattern. *Science Education*, *81* (2), 123–135.

Serway, R. A. (1990) *Physics: Electricity and magnetism*. London: Saunders.

Stepans, J. I., Beiswenger, R. E. and Dyche, S. (1986). Misconceptions die hard. *The Science Teacher*, *53* (6), 65–69

Streitberger, H. E. (1994) Modelling molecules. *The Science Teacher*, *61* (9), 46–48.

Swartz, C. E. (1973). Comment on "misconceptions of selected science concepts held by elementary school students." *Journal of Research in Science Teaching*, *10* (4), 383–384.

Wellner, M. (1991) *Elements of Physics*. New York: Plenum.

White, R. T. (1993). *Learning Science*. Oxford: Blackwell.

Yager, R. E. (1991). The constructivist learning model: Towards real reform in science education. *The Science Teacher*, *58* (6), 52–57.

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