Research Article

Determining Science Teacher Candidates' Academic Knowledge and Misconceptions about Electric Current

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Abstract

The aim of this study is two-fold. Its first aim is to determine science teacher candidates' knowledge (academic success) and misconceptions about electric current and its second aim is to compare these results across participants' year of study and gender. A total of 132 teacher candidates studying in their 2nd, 3rd, and 4th years in Gazi University's Department of Science Education of the Gazi Education Faculty in Turkey participated in this study. Data were collected using the survey model. The Electrical Current Concept Test and semi-structured interview questions were used as data collection tools. The results of the study revealed that while there are no meaningful differences between students' academic success regarding electric current based on their year of study, there are meaningful differences based on the gender of participants, with males scoring more favorably. The findings also revealed that teacher candidates have many misconceptions related especially about to such concepts of current, electric field, generators, supply emf, and potential difference. Furthermore, it was observed that teacher candidates held misconceptions about the function of magnetic fields and energy conversion in electric power-plants, a subject dealt with in the context of alternating current.

Keywords

Science teacher candidates • Electric current • Academic success • Misconception • Grade level • Gender

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Ideas about the natural world are connected with one's previous experiences and daily interactions. Although most people accept statements made by scientists on a specific subject, the conceptions and misconceptions held by the general public regarding a particular subject are the result of either the (mis)conceptions of one's owns teachers or deficiencies in the language one uses. Correcting such misconceptions is rendered difficult due to a number of factors and a correct conceptual structure may only be attained as a result of positive interactions is an expected situation. Science teachers describe the process of education as the replacement of layman's conceptions with those accepted by the scientific community (Wainwright, 2007).

More efficient and persistent learning in science education depends on how efficiently the many factors interact and affect one another. Misconceptions in conflict with scientific realities and ideas (Hewson & Hewson, 1984) may be influenced by a number of factors, including student-teacher relationship, the methods used to assess and evaluate students' knowledge, and the activities, methods, techniques, and strategies used in courses. Considering that communication between the teacher and student has a fundamental role in shaping other factors, improving communication is a necessity not only because teachers and students lack the same conceptual structure, but also because meaningful learning at the desired level depends on student-teacher communication (Karakuyu & Tüysüz, 2011). If quality communication is lacking, students will simply build off of their previous knowledge to form a new set of erroneous knowledge based on their daily experiences and previous erroneous knowledge, leading the student to develop further misconceptions (Driver, 1989; Driver, Squires, Rushworth, & Robinson, 1994; Yılmaz, Tekkaya, Geban, & Özden, 1998). Since it is observed that such misconceptions develop not only in primary education, but also in a university setting, the importance of teachers and their influence on education should be discussed. In correcting misconceptions, teacher candidates' own misconceptions should be revealed and the necessary precautions to be taken should be discussed. According to Pardhan and Bano (2001), many teachers lack scientific knowledge about certain concepts, having misconceptions similar to those of their students. Due to this awareness, misconceptions originating during primary education can be prevented by eliminating the teacher factor that forms the foundation for a student to develop such misconceptions.

Considering teacher candidates' current learning situation, the most important question to be asked is: "How and in what way(s) do student candidates acquire knowledge starting in primary education and continuing into university?" As such, it is necessary to discuss science as discipline, students' misconceptions about physics, and reasons causing these misconceptions.

Misconceptions Related to Physics (Electric Current)

Students experience difficulties learning science related concepts and from the very beginning of primary education, science courses are difficult for students to understand (Özmen, 2004). As a result, students are observed to have acquired many misconceptions related to science.

One of the main reasons for students' misconceptions in this branch is thought to be due to the fact that neither the natural processes nor the concepts affecting these processes are thoroughly taught using scientifically appropriate explanations. For instance, it is stated that students who are unable to conceptualize what processes occur in a simple electric circuit not only have difficulty understanding this subject, but go on to form other misconceptions based on their original misunderstanding (Flynn, 2011). Misunderstanding this physical phenomenon at the very beginning hinders one from understanding the entire subject and the other related concepts, resulting in compounded misconceptions.

In addition to this, the fact that there are many problems and formulae requiring one to perform mathematical operations or use meta-reasoning skills to solve them causes students to regard their science courses negatively. Placing greater emphasis on calculations while teaching science, especially while teaching physics related concepts, will result in students simply learning by rote, rendering it even more difficult to understand concepts.

Since quantitative applications are used compulsorily in science classes to instill an understanding of the related concepts, students are more interested in solving quantitative problems to be successful. However, such success in solving quantitative problems is not suitable for evaluating conceptual understanding (Mcdermott & Shaffer, 1992). Reaching sufficient success is just as important in solving qualitative problems as it is in quantitative problems. Students able to answer questions on the main concepts of physics have been found to experience difficulties answering simple qualitative questions, if they could answer them at all (Galili, 1995).

Such a situation indicates that traditional physical applications are not sufficient (Mcdermott & Shaffer, 1992). Qualitative problems, by enabling the student to think in multiple perspectives about a concept, constitute an indicator showing what, how, and to what extent students understand a specific concept and with which other concepts they are associated. For instance, the concept(s) used by a student to explain the question "How does an electrical circuit come into being?" clearly reveals his ideas about this phenomenon. For this reason, qualitatively-oriented applications that enable the student to think extensively on those events comprising abstract concepts should be given more importance.

In his study on university students' conceptual understanding of electricity and magnetism, Planinic (2006) found that qualitative applications, such as open-ended questions, are highly useful in obtaining clearer results while assessing students' ideas on these subjects. At the end of his study, he states that not only did students lack knowledge in how electric and magnetic events occurred; they also had difficulty understanding these two particular subjects in general.

In accordance with the above explanations, it is thought that both the professional competence of teachers and the design of educational curriculum have important roles in teaching a wide variety of concepts, such as DC (Direct Current), potential energy, generator, resistance, electromotive force (emf), AC (Alternating Current), alternating voltage, and energy conversion. As such, the first thing to do is to question what university students know and both how and to what extent they know it. Teacher candidates, whose main objective should be to prepare a scientifically literate future generation, should not only be aware as to whether their content knowledge is sufficient, but also learn the reasons for any insufficiency and what precautions should to be taken to prevent them from passing down any misconceptions to their own students.

Lack of knowledge and insufficiency in solving problems are the two main reasons behind teacher candidates' lack of content knowledge, which in turn leads to the unavoidable development of misconceptions (Yip, Chung, & Mak, 1998). As a result, it is then necessary to determine students' physics related misconceptions since there are many applications that combine theory with practice (Gürel & Acar, 2001). Currently in the literature, there are many similar misconceptions about the issue of electric current that show resistance to change internationally, and that is thought to be caused mainly from one's teachers and textbooks (Duit, Jung, & von Rhöneck, 1985). Some of these studies are: Çıldır and Şen (2006), Çökelez and Yürümezoğlu (2009), Engelhardt and Beichner (2004), Küçüközer and Kocakülah (2007), Lee and Law (2001), Örgün (2002), Pardhan and Bano (2001), Şen and Aykutlu (2008), Yıldırım, Yalçın, Şensoy, and Akçay (2008), and Yürümezoğlu and Çökelez (2010). The common results of these studies demonstrate that there are difficulties in both learning what electric current is and transforming one's knowledge about it to a scientifically sound form. Considering that many of the students' misconceptions are related to how the subjects are taught during one's first years of primary education (Koray, Özdemir, & Tatar, 2005), revealing primary students' misconceptions about electric current is of high importance since these misconceptions can influence further misconceptions later in one's education .

University students graduate with these misconceptions, preventing them from performing as expected and affecting their success in their professional life. If this condition is not remedied, misconceptions acquired during primary education will

continue to compound, causing a vicious cycle of misconceptions to manifest. In this context, universities are endowed with the important task not only of determining teacher candidates' inadequacy and misconceptions in content knowledge, but also of preventing them from passing them on to their own students. As such, studies aiming to achieve these goals are of high importance in revealing teacher candidates' basic knowledge levels.

Electric current is taught under the two subtitles of direct current (DC) and alternating current (AC). Studies aiming to determine misconceptions focus mostly on concepts related to direct current (Cohen, Eylon, & Ganiel, 1983; Çıldır, 2005; Heller & Finley, 1992; Lee & Law, 2001; Psillos, Koumaras, & Tiberghien, 1988; Sencar & Eryılmaz, 2002; Shipstone et al., 1988; Yıldırım et al., 2008). Generally, not only is students' knowledge about current, electrical energy, potential difference, resistance, and a variety of other concepts as well as the relations between these concepts insufficient (Licht, 1991), they also confuse fundamental concepts, using one when another should be used instead (Yürümezoğlu & Çökelez, 2010).

There are only a scare number of studies focusing on the concepts dealt with in this study, namely AC, alternating voltage, transformers, generators, and AC energy conversions (Biswas et al., 1998; Biswas et al., 2001; Demirci & Çirkinoğlu, 2004). Studies focusing on electromagnetic issues, however, are more common due to their higher importance.

The interview technique has been widely used in both national and international studies aiming to reveal misconceptions (Çıldır, 2005; Çıldır & Şen, 2006; Lee & Law, 2001; Özen & Gürel, 2003; Pardhan & Bano, 2001; Raduta, 1998; Sert Çıbık, 2011). This technique is highly effect in providing various and extensive definitions about the related concept, while also allowing the researcher to compare his own findings with those in the literature (Wainwright, 2007). A semi-structured interview technique has been used in this study to obtain more explicit and explanatory information regarding participants' knowledge of concepts related to electric current as well as concepts relationships with each other.

Since sub-concepts related to electricity are frequently used in daily life, individuals enter school with a certain comprehension of these topics. Since in most cases students pre-held conceptions are not the same as how they are used in a scientific context, forming misconceptions is inevitable. Since they negatively affect learning, determining prior misconceptions is of utmost importance in realizing meaningful and permanent learning.

It is clear that, in means of conceptual understanding and practice, not only is teaching knowledge and skills necessary; correcting misconceptions on basic

activities is not easy. Since there are misconceptions about electric current stemming from one's primary education, and even from one's university education, since these misconceptions differ from person to person, and since there are only a limited number of studies attempting to determine students' misconceptions about alternating current, this study will fill in this specific gap in the literature.

Academic Success in Physics

Students' success is very significant in deciding whether education goals have been reached. Academic success is measured by scoring the answers given by students on a measurement tool specifically prepared for the subject in question after having taught the subject using a defined method that includes a variety of activities (Sert Çıbık, 2011). In other words, academic success is a part of learning process and may vary in means of learning. Considering that one learns out of necessity and/or interest, a number of learning difficulties may appear as a result of not instilling in students a love of physics or making them feel that it is necessary to learn physics (Eryılmaz, 2002). Since physics is a course that includes a variety of abstract concepts and is based on solving problems requiring the use of meta-cognitive strategies, students consider physics to be a difficult course (Aycan & Yumuşak, 2003). Furthermore, it is inevitable that misconceptions preventing students from learning will cause them to develop negative attitudes toward the course in which they are struggling. As such, it is essential to know what misconceptions students have at every education level of their physics education as knowing such will influence students' success levels. In the literature, it is remarked that knowing what misconceptions students have is an important factor influencing students' success in physics course (Eryılmaz, 1996). Those teacher candidates training to teach primary students in particular should be aware of their misconceptions related to physics since doing so will allow them to organize their practices in such a way to prevent these misconceptions from being passed on to their future students. This in turn will enable their future students to understand related concepts more easily, to be more successful in class, and to enjoy their physics class.

Educational success is an important concept influencing a student's entire life and may be influenced by biological, social, and cultural variables, among others. These variables influence students' learning conditions which in turn influence students' academic success either positively or negatively (Kan, 2003; Uluğ, 1999). Though these conditions are undoubtedly significant in influencing students' success levels, the amount of change is affected by both gender and grade level. In the study that he performed with his own students, Bursal (2013) indicated that students' academic success in science is significantly reduced as grade level increases and that there is a meaningful difference in the degree of change based on gender.

On the one hand, in studies examining the relationship between academic success in physics and gender, it is generally emphasized that effect of gender on the success becomes clearer as one's age and grade level advances (Çekbaş & Kara, 2009; Engelhardt & Beichner, 2004; Jones, Howe, & Rua, 2000). On the other hand, when the literature is examined, it is seen that there is an insufficient number of studies examining science teacher candidates' misconceptions regarding electric current and how gender and grade level affect their academic success. Furthermore, those studies that do exist have generally been realized with primary and secondary students (Bursal, 2013; Sencar & Eryılmaz, 2004; Yeşilyurt, 2006).

This study is significant in that it will determine misconceptions related to alternating current and will compare findings on academic success according to grade level and gender. It is thought that the findings obtained from this study will contribute to the field of education, to an increase in teacher candidates' academic success in physics, and to future research that will be conducted in other teacher education programs.

Aim

The aim of this study is two-fold. The first aim is to determine how well 2nd, 3rd, and 4th year university students studying in a Department of Science Education in Turkey understood electric current and its related concepts and what misconceptions they had regarding it, while the second aim is to compare the results obtained according to grade level and gender. Teacher candidates' academic success in this subject was determined using the Electric Current Concept Test (ECCT) developed by Sert Çıbık (2011), and their misconceptions were determined by conducting semi-structured interviews with them. To achieve the study's aims, answers to the following questions were solicited:

1. *Do the academic success scores obtained by the science teacher candidates on the ECCT show any meaningful differences according to their year of study and/ or gender?*

2. *What are the science teacher candidates' misconceptions about electric current?*

Method

The survey model was used in this study. In this model, a situation that either currently exists now or has previously existed is described in its current form (Cohen, Manion, & Morrison, 2000, p. 169; Karasar, 2004, p. 77). A general statement about the target population is sought so that descriptions can be made either for a sample group taken from the larger target population or for a sample of related units and variables (Karasar, 2004, p. 79).

Study Group

The sample of the study is composed of a total of 132 teacher candidates in their 2nd, 3rd, and 4th years in the Gazi University's Department of Science Education within the Gazi Education Faculty during the spring term of the 2011-2012 academic year.

One of the main reasons that the study was conducted with this sample group was to contact and attain the desired sample easily. In addition, the group was chosen using simple random sampling, and 1st year students were not included in the study because electric current is part of the General Physics-II course.

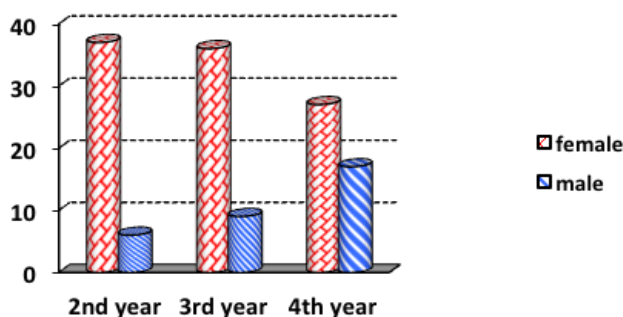The distribution of teacher candidates' year of study according to gender is shown in Figure 1.

Figure 1. Teacher candidates' year of study according to gender.

As seen in Figure 1, 37 (28.0%) of the candidates studying in their 2nd year are female and 6 (4.5%) are male, 36 (27.3%) of the candidates studying in their 3rd year are female and 9 (6.8%) are male, and 27 (20.5%) of the candidates studying in their 4th year are female and 17 (12.9%) are male.

Instruments

Electric Current Concept Test (ECCT). The ECCT was used to collect data on teacher candidates' academic success regarding electric current. The ECCT was developed by a researcher in light of Treagust's (1988) study in which he offers ten steps to follow when developing a concept test. The questions on the test were prepared in two parts according to the curriculum followed in General Physics-II (Sert Çıbık, 2011). Since the test aimed to determine teacher candidates' academic success in this subject, the data obtained from the first part of the test were analyzed and the results were evaluated during scoring.

Validity and Reliability Analyses of the ECCT. The 35-question draft version of the concept test was analyzed by three physics education experts for clarity and consistency with scientific knowledge. After the analyses, the test was brought to its

final form either by using a different scientific concept or by making changes in how questions were expressed. Afterwards, the test was applied to the 2nd year teacher candidates to test its reliability.

When conducting statement analyses, those statements whose distinguishing index values are less than .20 are deemed to be dissimilar to the other statements included in the test in terms of aim and content. Such statements also negatively affect the internal consistency of the test. As such, a total of 10 statements (5, 8, 10, 15, 17, 21, 30, 33, 34, and 35) were excluded from the test due to their low distinguishing values, leaving 25 questions to carry out analyses. The results of the 25-question test were analyzed with each correct answer being worth 1 point, and both wrong and blank answers were worth 0 points. According to this calculation, the maximum score possible was a score of 25. The results of the analysis are given in Table 1.

Table 1
Item-Total Correlation of the Test and KR-20 Reliability Results

Item analysis operations	Part of test	Questions removed from the test	Total number of questions	KR-20
Item-Total correlation	First part	5, 8, 10, 15, 17, 21, 30, 33, 34, 35	25	.74

Semi-structured Interview Questions. Semi-structured interviews employ previously prepared questions while also allowing for some flexibility on the necessary parts according to interviewers and physical conditions. Semi-structured interviews are often used in the literature as they prevent specific pitfalls that other interview techniques limit (Büyüköztürk, Kılıç Çakmak, Akgün, Karadeniz, & Demirel, 2014, p. 152; Karasar, 2004, p. 168). Therefore, semi-structured interviews were used in this study to reveal science teacher candidates' misconceptions about electric current.

To gain a comprehensive perspective and to determine possible misconceptions, semi-structured interviews on electric current were conducted with teacher candidates. During the selection process of the interview sample group, teacher candidates' scores on the ECCT were taken into account, resulting in the sample group being divided in three subgroups: (i) lower, (ii) middle, and (iii) upper. Semi-structured interviews were conducted with three teacher candidates from each grade on the voluntary basis, resulting in a total of 9 teacher candidates being interviewed.

While preparing interview questions, both misconceptions found during the literature review and those related to teacher candidates' General Physics-II course in the first year of their Science Education Bachelor's Degree Program during the spring term were taken into consideration. Interview questions were prepared under three main titles; namely, direct current, measurement means, and alternating current. A total of 13 questions were prepared by dividing each main subject into subtitles.

In terms of validity, researchers must gather data, report their process of analyzing and discussing the data that they have obtained, and explain how they reached their conclusions (Büyüköztürk et al., 2014, p. 168; Cansız Aktaş, 2015, p. 351; Yıldırım & Şimşek, 2016, p. 270). For reliability, it is important to define as clearly as possible the research process and data obtained so that other researchers can easily benefit from them (Yıldırım & Şimşek, 2016, p. 285). To ensure the validity of interview questions, the opinions of two physics education experts and one science education expert were solicited while preparing the questions. To test the understandability and appropriateness of the final version of the questions, a pilot application was carried out on four people. After these applications, it has been decided that these questions were appropriate for use in this study. To ensure reliability, voice recorders were used and answers were saved in computers in written form. In order to define whether an answer was right or wrong, an extended content based answer key was prepared. To define wrong answers, recordings were listened to several times, which also served to ensure the assessment's consistency. Lastly, without making any additions or corrections, candidates' wrong answers were offered to the views of two physics experts, and misconceptions about the questions were finalized after discussions with them. The questions used during semi-structured interviews have been given in Table 2.

Table 2
Questions used during Semi-Structured Interviews Conducted with Teacher Candidates

	1. Basic Concept: Direct Current Questions	
Sub-concepts	Direct current	1. How is current produced in a direct current circuit? 2. What are the circuit components in a direct current circuit?
	Potential difference	3. What is potential difference? Explain the function of potential difference in a direct current circuit.
	Generator/emf supply	4. Explain the relationship between the generator, emf supply, and potential difference.
	DC energy conversions	5. Explain the energy conversions that take place in a direct current circuit.
	2. Basic Concept: Measurement Means	
Sub-concepts	Ammeter	6. How is the ammeter connected to the circuit? Explain the role of resistance in the connection pattern.
	Voltmeter	7. How is the voltmeter connected to the circuit? Explain the role of resistance in the connection pattern.
	3. Basic Concept: Alternating Current	
Sub-concepts	Alternating current	8. How is current produced in an alternating circuit? 9. What are the circuit components in an alternating circuit?
	Alternating voltage	10. What is alternating voltage? Explain the function of voltage in an alternating current circuit.
	Transformer	11. How do transformers work? Why are they used?
	Generator	12. How do alternating current generators work?
	AC energy conversions	13. Explain energy conversions in electric power-plants. (thermic, hydraulic, nuclear).

Data Analysis

To determine the change in teacher candidates' correct understanding of electric current (academic success) according to their year of study, a one-factor ANOVA, one of the analysis techniques in the SPSS-17 program, was used and the independent group's t-Test was used to determine the change in correct understanding according to gender. The results were interpreted assuming a significance level of .05. A value of N in the tables indicates the total number of candidates.

On the other hand, semi-structured interviews were conducted to determine science teacher candidates' misconceptions about electric current. The findings obtained from the interviews were evaluated and interpreted using the descriptive-interpretative analysis technique. Only those data that have been commented on and that fit the study's aim are described in this type of analysis. Here, the main aim is to indicate the real problem (Sönmez & Alacapınar, 2011, p. 159). Possible misconceptions were determined after reviewing teacher candidates' answers to the interview questions. Answers were categorized as being either *right* or *wrong*, with wrong answers being defined as those answers that either do not meet the desired response in any aspect or answers that contain incorrect statements. Wrong answers given by teacher candidates were evaluated as misconceptions. Blank answers were not considered for evaluation (see Table 5). In order to define and analyze the findings in a more effective manner, direct quotations from the answers of several candidates have been given (Yıldırım & Şimşek, 2016, p. 270). Finally, when comparing misconceptions based on gender, percentages were calculated.

Findings

In this study, the changes in science teacher candidates' misconceptions and correct understanding (academic success) of electric current according to their year of study and gender are examined. Furthermore, participants' misconceptions are presented. The findings obtained from the sub problems of this research are given below.

1. *Do the academic success scores obtained by the science teacher candidates on the ECCT show any meaningful differences according to their year of study and/ or gender?*

Descriptive statistical distributions of the science teacher candidates according to their year of study and gender are shown in Table 3. A t-Test was conducted on the independent group to ascertain whether candidates' ECCT scores are meaningful in terms of gender or not and a one-factor ANOVA was conducted to compare participants' ECCT scores according to their year of study in university. The results are given in Table 4.

Table 3
Results of Descriptive Statistics According to Year of Study and Gender

Gender	2nd Year		3rd Year		4th Year		Total	
	N	%	N	%	N	%	N	%
Female	37	28.0	36	27.3	27	20.5	100	75.8
Male	6	4.5	9	6.8	17	12.9	32	24.2
Total	43	32.5	45	34.1	44	33.4	132	100

Table 4
Results of the t-Test and One-Factor ANOVA of Science Teacher Candidates' ECCT Scores According to Year of Study and Gender

	ECCT Scores					
Gender	N	$\overline{x}$	sd	df	F	*p*
Female	100	10.58	3.016	130	.455	.017*
Male	32	12.06	3.015			
Year of Study	N	$\overline{x}$	sd	df	F	*p*
2nd Year	43	10.86	3.075	2	.042	.959
3rd Year	45	10.91	3.051			
4th Year	44	11.05	3.155			

*$p < .05$.

When Table 4 is examined, it is seen that the ECCT scores of the male and female candidates are different from each other. Specifically, whereas the arithmetic mean for females is $\overline{x} = 10.58$ with a standard deviation of sd = 3.016, the arithmetic mean for males is $\overline{x} = 12.06$ with a standard deviation of sd = 3.015. When ECCT scores were tested at a .05 significance level to ascertain whether there existed any meaningful differences in the ECCT scores based on gender, a meaningful difference was observed in favor of male candidates [$F_{(100-32)} = .455$, $p < .05$]. This finding demonstrates that males have a better understanding of electric current than do females. With this being said however, no statistically meaningful difference was observed in candidates' scores *t* according to their year of study [$F_{(132)} = .042$, $p > .05$]. As a result, teacher candidates' average academic success rates concerning electric current indicates not only that they are close to each other in terms of knowledge, but that differences in their academic success in this particular subject are not affected by teacher candidates' year of study.

2. What are the science teacher candidates' misconceptions about electric current?

Of the nine total candidates who had taken part in the semi-structured interviews, two females and one male were studying in their 2nd year, two females and one male were in their 4th year, and three females were in their 3rd.

According to the results of the descriptive-interpretative analysis, the results of 11 sub-concepts (DC, potential difference, generator/emf supply, DC energy conversions, ammeters, voltmeters, AC, alternating voltage, transformers, generators, and AC energy conversions) were shown in the study's findings. After the semi-structured interviews were conducted with the teacher candidates, various misconceptions

about these concepts came into sight. The distribution of candidates' misconceptions according to their year of study and gender is presented in Table 5.

Table 5

Distribution of Teacher Candidates with Misconceptions According to their Year of Study and Gender

Sub-concepts/Question Items	2nd Year N		3rd Year N		4th Year N	
	F*	M*	F*	M*	F*	M*
Direct Current/1-2	-	1	4	-	2	1
Potential Difference/3	2	-	2	-	1	1
Generator/Emf Supply/4	2	1	3	-	2	1
DC Energy Conversions/5	1	-	3	-	-	-
Ammeters/6	-	-	-	-	-	-
Voltmeters/7	-	-	1	-	2	-
Alternating Current/8-9	2	1	3	-	2	1
Alternating Voltage/10	2	-	3	-	1	1
Transformers/11	1	1	1	-	2	-
Generators/12	2	1	2	-	-	-
AC Energy Conversions/13	2	1	2	-	2	-
Total Number of Misconceptions	14	6	24	-	14	5

N: three teacher candidates, F*: Female, M*: Male

When Table 5 is examined, teacher candidates were observed to have many misconceptions about the 11 sub-concepts related to electric current. When the distribution of these misconceptions is analyzed according to teacher candidates' year of study, 20 misconceptions were observed for candidates in their 2nd year, 24 for those in their 3rd year, and 19 for those in their 4th year. It is observed that 3rd year teacher candidates had more misconceptions than the others. When the university curriculum Yüksek Öğretim Kurulu (2007) is analyzed, it is observed that there is an excessively high number of verbal and application-based lessons and that other major aspects related to electric current are absent during this year of the curriculum. As such, it might be that 3rd year students are distanced from the main area courses, causing them to have difficulty remembering the knowledge they had gained during their 1st year. In addition to this, when the results according to the gender are analyzed, 2nd, 3rd, and 4th year female students were observed to have a total of 14, 24, and 14 (57.14%) misconceptions, respectively and that 2nd and 4th year males have a total of 6 and 5 (42.30%) misconceptions, respectively. That females had more misconceptions than males is noteworthy, and can be explained by the fact that females are more successful in subjects that pertain to daily life, such as the human body, health, and biology, whereas males are more successful in physics concepts involving such subjects as the computers, electricity, and technology. It is possible to come across studies supporting this finding (Greenfield, 1997; Spelke, 2005).

Below is a detailed analysis of teacher candidates' misconceptions about the sub-concepts of electric current based on their answers to the interview questions (S#: stands for the candidate's number and I: stands for the interviewer).

Findings and Comments about DC

For the first question, teacher candidates stated that electric current is formed because voltage is present in the circuit, because both potential and kinetic energy move the electrons, because potential power influences the electrons, and because the generator produces current. The candidates were then asked to explain what an electric field is in order to translate their knowledge into a practical example, and it was determined that they explained this concept using concepts related to magnetism. Consequently, misconceptions were observed in participants' understanding of how electric current is formed. A sample statement from interview is given below:

> S3: Energy passes into the circuit as a result of kinetic energy being converted into electric energy, which brings the current into existence.

Most of the teacher candidates answered the second question correctly using such terms as *ammeter, voltmeter, generator, resistance, conducting wire, switch,* and *lamp* in their responses. Different from these answers were candidates who stated that "a coil is a component in a DC circuit."

Findings and Comments about Potential Difference

The potential difference is a phenomena formed by the current and it has a role in producing electric energy by basing these two concepts on the formula: [$V = I.R$].

It was also observed that some teacher candidates associated electric fields with magnetic fields, causing them to have wrong beliefs in the aspect of that electric field is a transformation of the energy between two plates. A sample statement from the interviews is given below:

> S2: It is produced by the current. I: What is the function of potential difference? S2: Its function is to provide the necessary energy to use various devices.

Findings and Comments about Generators/Supply Emf

The fourth question solicited teacher candidates' knowledge about generators, supply emf, potential difference, and the relations between these concepts. All of the teacher candidates were found to have various misconceptions. While they generally had a correct understanding of generators and potential difference, teacher candidates had a number of misconceptions about supply emf. The following exemplify their misconceptions:

i.   Supply emf is a component of circuits; because it makes other components work, it is the electron and has a current.

ii. Potential difference is calculated thanks to supply emf.

iii.   It is created by establishing either a reverse or a correct connection to the circuit while generating voltage.

iv.   As well as the generator is a general name, supply emf is created as a result of the difference between the generator's poles and the potential difference is the valued form of the supply emf.

v.   Since the symbols for potential difference and supply emf are different (V and ε, respectively), they are different concepts.

vi.   Supply emf not only produces electrical energy, but also heat and light energy.

vii.   The three concepts are the same thing and they supply power to the circuit.

Teacher candidates also do not correctly understand the relation between these three concepts. Two statements from the interviews illustrating their misunderstandings are given below:

I: What is a generator? S1: It supplies potential energy to the circuit by passing a live current. I: What is supply emf? S1: It is related to electrons and it has electrons. Because of it, it has a life current. I: Are emf and generators the same concept? S1: They are different. A generator passes current, and there is only one generator in a circuit. Emf is a component in the circuit.

I: What is a generator? S2: It is the component that supplies power and energy to the circuit. I: What is supply emf? S2: Another name for the generator is emf. I: What kind of a relation is there between these three components? S2: The generator is the common name. Emf comes into being as a result of the difference between the poles of the generator. Potential difference is the valued form of emf. I: There are both the energy that charges spend and the energy that charges gain. I: Which concepts do match to these descriptions? S2: The circuit gains as much emf as the energy we give it. We get as much power as the energy that the voltage spends...

Findings and Comments about DC Energy Conversions

The fifth question solicited teacher candidates' knowledge about DC energy conversions. Teacher candidates gave similar wrong answers to the fifth question and lacked knowledge about how energy conversion occurred in a direct current generator. The following is a statement from the interviews:

I: What is the simplest current generator? S4: A battery. I: How is energy transformed a battery? S4: Since the electrons in the battery move at a certain speed, it has kinetic energy. This kinetic energy is transformed into potential energy later. I: How is the energy transformed in an accumulator and dynamo? S4: In a dynamo, the chemical energy is transformed into electrical energy whereas in an accumulator, chemical energy is first transformed into electrical energy and then into kinetic energy.

Findings and Comments about Ammeters

The sixth question solicited teacher candidates' knowledge about ammeters, and teacher candidates had no misconceptions about them. Although teacher candidates had satisfactory information about how the ammeter was connected in the circuit, they were ill-informed about the role of resistance. The teacher candidates were found to correctly believe that in order to calculate current accurately, internal resistance should be small.

Findings and Comments about Voltmeters

The seventh question solicited teacher candidates' knowledge about voltmeters and resistance. While they knowledge concerning how the voltmeter was connected in the circuit, teacher candidates were ill-informed about the role of resistance. Teacher candidates were found to hold the opinion that "*There should be no current in the voltmeter because it calculates voltage. For this reason the current should be high.*" They were also found to have the misconception that "*the internal resistance of the voltmeter should be small because resistance and voltage are inversely proportional to each other.*"

One study on the components used to measure electric current found that many high school students understand neither how an ammeter or voltmeter works nor that there should be low resistance in the ammeter and high resistance in the voltmeter in the way of connection of the resistance. It is stated that these mistaken beliefs result from the use of incorrect expressions in their classes and that students do not sufficiently internalize what they learn in class (Wainwright, 2007).

Findings and Comments about AC

The eighth question solicits teacher candidates' knowledge about AC circuits. All of the candidates were found to have misconceptions on how current occurs in AC circuits. Teacher candidates answered this question by looking at R-L-C circuits and drawings in their textbooks. In other words, it can be concluded that teacher candidates do not fully grasp the concepts of resistance or resonance.

> S2: It occurs as the current passes from the positive end of a pole to the other pole in the magnet, and this event occurs in a second. I: What do we bring the magnet closer to? S2: To the coil. I: Do we use the generator while doing this? S2: We produce the magnetic field with the gravity force of the magnet itself.

There is not any misconception about the ninth question which is related to this sub-concept and it is shown that teacher candidates have satisfactory information about the components of the circuit. However, when they were asked about the qualities of an alternative current generator, some teacher candidates talked about the poles and while others argued that since there is a permanent flow of current in the circuit, there no poles.

Findings and Comments about Alternating Voltage

The tenth question solicited teacher candidates' knowledge about alternating voltage. Teacher candidates gave similar wrong answers to this question and did not have satisfactory knowledge on this subject. A statement from the interviews follows:

> S5: The voltage which occurs as a result of alternative current is a result of the current. I: What is its function? S5: As we move the magnet closer and farther away, we continuously change the direction and as a result of doing this, we produce a current. The voltage of this current is alternative voltage and it supplies energy to the circuit.

Findings and Comments about Transformers

The eleventh question solicited teacher candidates' knowledge about transformers. Teacher candidates tried to answer this question by looking at drawings in their textbooks and used many false expressions while discussing the relationships between concepts. Moreover, questions about how electrical energy is transferred in daily life were asked in order to reveal teacher candidates' knowledge, who were found not to have satisfactory information about transformers. A sample interview made with the candidates is presented below:

> S1, S3: It is used in energy conversion. For instance, the kinetic energy that is produced by the current in the circuit is transformed into electrical energy.

> S6, S7, S8: It comes into being as a result of the inverse proportion between the number of turns and voltage. Current and voltage are directly proportional to each other.

Findings and Comments about Generators

The twelfth question solicited teacher candidates' knowledge about generators. Teacher candidates were unable to answer this question correctly and were found to associate generators with the idea that they are activated when the electricity is cut off in schools, libraries, and work places. Moreover, teacher candidates confused generators with transformers, stating that they worked according to the same principles. However, this subject is discussed in their textbooks during every year of their university education and are used not only in the physical sciences, but also regularly in daily life. Despite these facts, teacher candidates were found to have a number of misconceptions about them.

> S5: They [generators] are used to provide electricity when the electricity is cut off. They store electric current. We cannot apply direct voltage to produce the current. For this reason, we should produce electricity using something else. I: What is this something else? S5: It's the result of an electric field.

Findings and Comments about AC Energy Conversions

It is seen that many teacher candidates have problems about the ordering of the different kinds of energy and that they arrange the different kinds of energy as follows:

S1, S4, S8: [1] Thermal power plants: Mechanical-electric, [2] Hydroelectric power plants: Kinetic-potential electric, and [3] Nuclear power plants: Electron's mechanical energy is transformed into electrical energy.

S3, S6: [1] Thermal power plants: Kinetic-potential-mechanical-electric. I: What is used as the raw material? S3, S6: Water is used. [2] Hydroelectric power plant: Potential-kinetic-mechanical-electric, and [3] Nuclear power plant: transformation of the chemicals into electricity.

Discussion and Suggestions

In this study, the correct knowledge (academic success) and misconceptions of 2nd, 3rd, and 4th year teacher candidates studying in a Department of Science Education in Turkey were determined and how the results differed according to one's year of study and gender examined. To date, studies have used a variety of strategies and techniques to reveal students' misconceptions regarding electric current, including concept maps, interviews, observations, analogies, and discussions. As for this study, semi-structured interviews were used. This technique is often used so that participants may express themselves in a more relaxed way thereby enabling the researcher to gain a better understanding of participants' opinions on the subject in question.

In the following section, the significance of this study's results are discussed in a wider framework and further implications for teaching the 9 sub-concepts are interpreted (DC, potential difference, generator/supply emf, DC energy conversions, AC, alternating voltage, transformers, generators, and AC energy conversions). However, since the participants of this study had no serious misconceptions about ammeters or voltmeters, they will not be discussed.

Undoubtedly, student's correct understanding of content (academic success) is of high significance if the aim of teaching is to be realized. Another result of the study is that there is no meaningful difference on the teacher candidates' ECCT scores based on their year of study. Science subjects begin to become more abstract and their content more difficult in middle school, causing students' academic success to be negatively affected as their grade level increases (Bursal, 2013). On the other hand, there are no studies in the literature on whether there is a difference in academic success based on one's year of studying in university. Therefore, since teachers are frequently mentioned in the literature discussing differences in academic success among university students as being one of the reasons that students have misconceptions (Pardhan & Bano, 2001; Yip, 1998), revealing what abstract steps should be taken to

remedy this situation is one of the positive results of the current study. Furthermore, the present study is thought to be significant in terms of determining which methods should be used to teach topics related to electric current beginning in 4th grade of primary school. The study is also important in that it investigates the reasons affecting academic success.

The fact that students have similar demographic qualities (e.g. similar social, cultural, and environmental backgrounds) may be included as factors affecting academic success. However, gender may constitute another factor affecting academic success (Şahin, 2007). It is seen in the studies that gender's influence on the academic success becomes more pronounced as age and grade level increases (Başer, 2006; Sencar & Eryılmaz, 2002). In this study, the academic success scores that teacher candidates obtained from the test were influenced by gender, with males obtaining higher scores $[t_{(32-100)} = .455, p < .05]$. There are a wide variety of findings in the literature describing the difference between male and female students' levels of e academic success in science courses, with most results indicating that males perform better in their science courses (Evans, Schweingruber, & Stevenson, 2002; Greenfield, 1997; Nosek et al., 2009; Spelke, 2005). The results of these studies support the finding that academic success regarding electric current varies by gender. Different reasons have been given to explain why males perform better academically than females in science related courses, with biological and sociological reasons being cited in the literature (Engelhardt & Beichner, 2004; Greenfield, 1997; Spelke, 2005). Engelhardt and Beichner (2004) found that while male students answered questions on DC circuits more easily than did female students, female students tended to misunderstand the subject. Consequently, educators should aim to improve both females and males who are less successful in science instead of attempting to make them even with each other (Bursal, 2013). In addition to this, teachers should be intimately aware of each of their students' knowledge and experience and should make concerted efforts to use those methods that allow male and female students to equally gain experience by considering the qualitative and quantitative advantage that males have due to their practical experience (Sencar & Eryılmaz, 2004).

When the current study's findings on teacher candidates' misconceptions concerning electric current are analyzed, it is seen that the root cause of their misconceptions are all different.

Upon examination of the findings, the fact that teacher candidates held the misconception that generator creates an electric current, a misconception that is also frequently seen in the literature, is of note. As the two concepts *current* and *generator* are frequently seen in the subjects, textbooks, and both printed and visual materials the students use, many students develop misconceptions about these two concepts

and generally associate them with each other. This misconception was observed in the current study to be held by candidate teachers, indicating parallelism with a many other studies on this subject (Aykutlu & Şen, 2012; Çıldır & Şen, 2006; Dupin & Johsua, 1987; Engelhardt & Beichner, 2004; Heller & Finley, 1992; Kärrqvist, 1985; Lee & Law, 2001; Örgün, 2002; Psillos et al., 1988; Wainwright, 2007). As differently from this study, the following two misconceptions were revealed: that (i) both potential and kinetic energy exist in batteries and move the electrons and that (ii) current is created as a result of that potential power affecting the electrons moving in the conducting wire. In reality, it is the electric field that creates the electric power allowing electric charges to move in the conducting wire, and current is created by charges moving in this way. During the interview, although most of the teacher candidates mentioned that electrons move in a conducting wire, they did not mention the electric power that enables the electrons to move. The number of such misconceptions is so high both in the literature and in general that students are unaware of the fact that current is produced as a result of electrical-potential difference (Wainwright, 2007). Similarly, Saarelainen, Laaksonen, and Hirvonen (2007) determined that university students have only qualitative knowledge about electrical force of attraction and repulsion.

While none of the teacher candidates correctly defined potential difference, they gave different explanations for the formula V=I.R, stating that potential difference is a kind of energy, that it is produced by the current, and that it is used to measure the current. The misconception that the current produces the potential difference is common in the literature, with several studies emphasizing that students hold incorrect opinions about the process of these two fundamental concepts (Aykutlu & Şen, 2012; Çıldır & Şen, 2006; Yeşilyurt, 2006). One of the reasons for this misconception is that students consider generators to be a stable current source instead of a source of potential difference while also not completely comprehending Ohm' law, seeing it simply as a mathematical formula (Çıldır, 2005). As a matter of fact, it is thought that such misconceptions are a result of an emphasis on teaching quantitative aspects instead of gaining real conceptual understanding. As such, students can easily misunderstand the formula V = I.R, believing it not to indicate potential difference as there is no current in a circuit with an open switch (Wainwright, 2007).

Regarding the question about function of the potential difference, teacher candidates gave different answers to it and associated this concept with resistance and electric fields. It was understood through their answers that they did not have a correct understanding of electric fields or their relationship with potential difference, trying instead to explain electric fields based on the shapes in their textbooks. Citing other reasons, Adrian and Fuller's (1997) also found in their study that students had difficulty in understanding the effects of potential difference and electric fields. They

did, however, find that the participants in their study correctly understood potential difference to be a source of electric fields regardless of whether a current existed in the circuit or not. However, the function of potential difference in a circuit is to form an electric field in the battery. Participants' answers also revealed that they had misconceptions regarding electric fields, confusing them with magnetic fields by mentioning poles. In both the studies conducted by Bagno and Eylon (1997) and by Bagno, Eylon, and Ganiel (2000), students' incorrect explanations were a result of their misconceptions concerning electric and magnetic fields. Both the findings of the current and previous studies indicate that students have difficulty understanding such concepts as electric fields, potential difference, magnetic fields, and their relations (Philippi, 2010).

Another misconception was that teacher candidates considered generators to be the circuit's energy source and necessary for the current, as seen in their answers to the first interview question. It was determined that teacher candidates gave a variety of different explanations to describe the relationship between the three concepts because they did not have a clear understanding of emf. These misconceptions are noteworthy because similar results were not seen in the literature. Galili and Lehavi (2006) determined that 44% of the sample is "the energy per charge" of emf and that 24% of the sample defined this concept as only "work." Some teacher candidates also stated that generators and electromotive force were the same concepts in the current study. The interviewer asked the teacher candidates "there are energy the charges spent and also, energy the charges obtained in a circuit. The question of which concepts suit for these definitions?" to learn how they perceived of the relation between emf and potential difference, finding that many students held similar misconceptions in regard to these two concepts namely that the energy that the charges spend in a circuit is due to emf. There is a study in the literature stating that potential difference is equal to emf (Galili & Lehavi, 2006). In addition to this, teacher candidates stated that there had many difficulties in understanding many of the aspects related to how induced emf was realized in a closed circuit. One explanation for their difficulties is that this specific concept is presented in their textbooks as an aspect of electromagnetism and is not taught in a basic, easy-to-understand manner; instead, what is taught is its relationship with other concepts using mathematical formulas (Raduta, 1998).

The simplest generator in a DC circuit is a battery. Although most of the teacher candidates correctly understood how energy transformation took place in a battery, a few thought that electric energy was stored in the battery and that this energy transformed into thermal and luminous energy. It was also determined in the current study that teacher candidates incorrectly believed that electrons had a definite speed in batteries, that they possessed kinetic energy, and that as a result of this energy transforming into potential energy, the necessary energy was provided. Moreover,

most of the teacher candidates held misconceptions regarding how energy was transformed in dynamos and accumulators. Although there are a limited number of studies on energy transformations in DC generators, it is possible to see common misconceptions that generators are the source of electric energy when discussing generators and energy (Aykutlu & Şen, 2012; Çıldır & Şen, 2006; Psillos et al., 1988; Yeşilyurt, 2006). Yürümezoğlu, Ayaz, and Çökelez (2009) distributed a questionnaire to primary school students in their second tier that was composed of open-ended questions in which one of the topics was *electric energy and transformation of this energy*. Students were shown an electric circuit composed of a battery, a lamp, and a propeller attached to an electric motor and a resistor in a cup full of water, and were then asked which energy transformations took place in the propeller and the cup. The results of the study revealed that more than half of the students either did not know or incorrectly expressed the energy transformation that took place in the battery. Consequently, it is possible to say that students have difficulty comprehending concepts related to generators and energy transformation and use similar concepts to describe them (Yürümezoğlu & Çökelez, 2010).

Another important result of the current study are teacher candidates' misconceptions regarding alternating current. Most of the teacher candidates explained that alternating current was a result of magnets without being able to explain the main factors composing the current. The fact that teacher candidates tried to explain the composition of alternating current by associating R-L-C circuits with the electric field leads the researcher to believe that their misconceptions regarding this topic are a result of what they remembered from the shapes depicted in their textbooks. In other words, depictions of this type of circuit attracted their attention while verbal and mathematical knowledge remained in the background.

This specific result indicates serious deficiencies in the textbooks used by teacher candidates and reveals that trying to explain fundamental physics subjects by oversimplifying them causes students to develop a number of misconceptions (Sefton, 2002; Wainwright, 2007). For instance, it is believed that teacher candidates' explanations for the events taking place in a simple circuit produced by connecting a generator to a lamp using a wire – an event depicted in many textbooks from primary school to university – not only create hurdles for students, but are also insufficient for high level learning. Teacher candidates explained that electrons had a role in moving the electrical energy produced by the generator and that electrons moved at very high speeds in the circuit. It was observed that teacher candidates generally associated this event with how a lamp immediately filled a room with light after pressing the power switch. However, electrons move very slowly when transporting electrical energy whereas energy transfer occurs at a very high speed (Sefton, 2002). For this reason, depicting how this event occurs through simple drawings in textbooks is not only insufficient, but also leads students to develop misconceptions.

Furthermore, when teacher candidates were asked during the interviews whether AC generators had poles, most of them mentioned that they did. At the same time, many teacher candidates stated that an electric field was present in the platform as a result of moving the coil closer to and away from the magnet. However, current is created as a result of the change of the magnetic field about any conductor causes emf (in other words, voltage). Teacher candidates confused magnetic fields with electric ones. The semantic familiarity and the similarity of the mathematical formulas between these terms not only render them more difficult to understand, but cause confusion between them. These types of problems present in students' textbooks cause similar problems in understanding other terms (Bagno & Eylon, 1997).

A number of studies in the literature reveal that students have many misconceptions about and confuse electric and magnetic fields, emphasizing that main cause of these misconceptions are textbooks (Guisasola, Zuza, & Almudi, 2013; Kesonen, Asikainen, & Hirvonen, 2011; Raduta, 1998; Saarelainen et al., 2007; Sefton, 2002). The common view of these studies is that textbooks cause similar misconceptions because the methods used to calculate electric fields, magnetic fields, electrical power, and electrical potential are similar. It is observed that not only do textbooks emphasize verbal explanations and qualitative analysis, they also make heavy use of mathematical expressions when teacher candidates have difficulty grasping the vector and scalar products in topics related to magnetism and the electricity (Kesonen et al., 2011; Raduta, 1998).

It is also observed that studies on alternating current are not only limited in number; the concept's boundaries are also quite narrow (Biswas et al., 1998; Biswas et al., 2001). Although concepts related to this subject are not included in the primary education curriculum in the Turkish Education System, they are in higher levels of secondary education, such as in 11th grade, and especially in 12th grade physics, and during one's freshman year in university. There are a few studies in the literature that deal with this subject, with most of them focusing their research on magnetism (Bagno & Eylon, 1997; Finkelstein, 2005; Galili, 1995; Maloney, 1984; Özen & Gürel, 2003; Sağlam, 2003; Sağlam & Millar, 2006). In addition to these studies, Demirci and Çirkinoğlu (2004) revealed a number of misconceptions related to electricity and magnetism held by students after collecting participants' responses to the Electrostatics and Magnetism Concept Test, finding that many students did not have sufficient knowledge about Faraday's Law, Magnetic Induction, or other subjects.

Studies in the literature also mention the difficulties that high school and 1st year university students face in these subjects; namely that many students cannot distinguish between concepts regarding these subjects on either the experimental or interpretative level (Meng Thong & Gungstone, 2008) and that many students use

Faraday's Law without knowing its physical meaning. Consequently, the first thing that needs to be done in order for students to learn such complex concepts is to construct a hypothesis that will lead to a solution to these problems, after which different resolutions and experimental methods need to be chosen so that students may begin to understand the concepts and laws in detail (Guisasola et al., 2013).

No teacher candidates answered the question dealing with alternating current correctly, and their responses revealed that they believed alternating voltage to be a result of the current. The teacher candidates' commonly held misconception that transformers enable electric voltage and current to change according to the requirement originates from their incorrect knowledge regarding the number of turns and mathematical proportion between current and voltage. Teacher candidates also incorrectly believed that generators were used to store electric current. Finally, teacher candidates not only considered the energy transformations that occur in electric power plants to be similar with other types of energy, but also misunderstood the relations existing between concepts used in this specific area. No similar studies were seen in the literature concerning misconceptions regarding energy transformations in electric power plants. Teacher candidates' interview responses were generally based on the knowledge, shapes, and graphics found in their textbooks and printed documents.

Consequently, since electric current a subject that is difficult to understand and since it requires not only sufficient knowledge and skills but also a positive attitude while learning it, it is one of the subjects in which students have the most misconceptions. Students will have misconceptions for a number of different reasons; the most important of which are because the terminology used in daily life about the electric current does not match up with its scientific equivalent, the experiences, students learn scientific concepts incorrectly due to their or their teachers' using them as they are used by laymen in contrast to how they are used in scientific fields (Chi, 1992; Wainwright, 2007). In teaching such fundamental concepts as current, potential difference, generators, and emf, the sequence used to explain them should be paid attention to in order to prevent students from developing misconceptions. In this way, students will be able to place the concepts into their cognitive structures in an appropriate manner, which will then positively influence their understanding of other concepts. For example, firstly, the concept of charge should be explained followed by mentioning the structure of conducting items when explaining how current is produced (Çıldır, 2005). Alternative teaching methods that are experimental and qualitative in nature should be chosen to those included in students' current textbooks to overcome the misconceptions (Flynn, 2011).

The following suggestions can be made to those researchers wishing conduct further research regarding this topic:

   i.   Since electric current is very frequently used in daily life, concepts, such as hydroelectricity, generators, and electric devices should be taught together with their related subjects,

   ii.   Necessary laboratories arrangements should be made so that students may conduct experiments related to electric current and the concepts used in this subject should be made more concrete,

  iii.   Students' misconceptions regarding this subject should be revealed using different evaluation techniques in all the levels before beginning to teach about electric current and activities to eliminate these misconceptions should be developed and organized according to the results of these evaluations,

  iv.   Pilot applications aiming to define and reduced the misconceptions frequently encountered in the literature should be included in the curriculum of science education programs (special teaching methods, etc) in universities, and

   v.   Teacher candidates' gender should be considered before teaching and using methods to define their prior knowledge so that this variable may play an equalizer role throughout one's entire educational career.

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