Factors Mediating the Effect of Gender on Ninth-Grade Turkish Students’ Misconceptions Concerning Electric Circuits

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Abstract: This study was designed to identify and analyze possible factors that mediate the effect of gender on ninth-grade Turkish students’ misconceptions concerning electric circuits. A Simple Electric Circuit Concept Test (SECCT), including items with both practical and theoretical contexts, and an Interest-Experience Questionnaire about Electricity (IEQ) were administered to 1,678 ninth-grade students (764 male, 914 female) after the completion of a unit on electricity to assess students’ misconceptions and interests-experiences about electricity. Results of the concept test indicated that general performances of the students were relatively low and that many students had misconceptions in interpreting electric circuits. When the data were analyzed using MANOVA and follow-up ANOVAs, a gender difference for males was observed on the dependent variable of total scores on the 10 practical items; however, there was no significant gender difference on the dependent variable of total scores on the six theoretical items. Moreover, when the same data were analyzed using MANCOVA and follow-up ANCOVAs, controlling students’ age and interest-experience related to electricity, the observed gender difference was mediated on the total scores on the practical items. © 2004 Wiley Periodicals, Inc. J Res Sci Teach 41: 603–616, 2004

There is a consensus in the literature noting that differences between sexes initiate at birth and proceed through childhood (Bem, 1981; Eccles, Adler, & Meece, 1984; Linn & Hyde, 1989). Historically, two explanations have been suggested to account for the girls’ lower performance in achievement: the biological explanation and the sociological explanation. First, gender imbalance was thought to be the result of different brain structures; however, explanations based on gender-specific socialization had displaced the brain difference model. While much of the earlier debate in the 1970s focused on the roles played by biological and sociological factors (Maccoby & Jacklin, 1973; Sherman, 1978), most of the recent research has been directed towards identifying sociocultural factors that contribute to the observed gender differences. Bem (1981), Eccles et al. (1984), and Linn and Hyde (1989) all proposed that early differences between boys and girls in science become magnified by cultural influences from society and school. Related literature has shown that males outperform females (Erickson & Erickson, 1984; Greenfield, 1997; Johnson,
Hence, the focus has been on girls’ underachievement in science, and many hypotheses have been suggested to explain this phenomenon. Researchers have identified a number of probable causes for the gender difference in science achievement. Some were differences in cognitive abilities (Griffiths & Bette, 1985), personality characteristics (Meece & Holt, 1993), age (Shepardson & Pizzini, 1994), mathematics skills (Linn & Hyde, 1989), attitudes toward science (Jones, Howe, & Rua, 2000), and in- and out-of-school experiences (Johnson, 1987). Moreover, numerous studies have demonstrated that the domain of electricity was one of the fields in which a gender difference was observed frequently (Chambers & Andre, 1997; Shepardson & Moje, 1994; Shipstone, Jung, & Dupin 1988).

Age is one factor studied in the literature that contributes to the observed gender difference on students’ science achievement. National Assessment of Educational Progress (NAEP) results indicated that the gender gap in science achievement begins to appear at age 13 years and narrows at age 17 (National Assessment of Educational Progress, 1979, as cited in Erickson & Erickson, 1984). The results of Shepardson and Pizzini (1994) also were consistent with the NAEP findings, which suggested almost no difference between male and female students’ achievement at middle school. The most extensive data related to age have come from a cross-cultural survey of mathematic and science achievement by the Third International Mathematics and Science Study (TIMSS) (Beaton et al., 1996). The results obtained from TIMSS 1995 indicated that fourth-grade males had significantly higher science achievement than females in about half of the 42 TIMSS countries. At the eighth-grade level, males had significantly higher average science achievement than females in more than half of the countries, and at the final year of secondary school, results showed that males had significantly higher science achievement than females in all countries. Similarly, Kahle and Lakes (1983) indicated that both boys and girls express desires to participate in science-related activities at age 9; however, by 13 years of age, girls’ interest in science-related activities have lessened and the gap between male and female students’ experiences has broadened. By age 17, differences in the quality and quantity of scientific backgrounds of male and female students were even larger, indicating serious deficiencies in females’ science achievement.

A number of studies in the literature have cited the role of students’ experiences as a possible factor in accounting for the observed gender difference (Erickson & Erickson, 1984; Farenga & Joyce, 1997; Greenfield, 1997; Jones & Wheatley, 1990; Joyce & Farenga, 1999; Kahle & Lakes, 1983; Kelly & Kelly, 1978; Mason & Kahle, 1988; Resnick, 1983; Tobin & Garnett, 1987; Whyte, 1984). Kelly and Kelly (1978) were among the first who reported that boys’ greater achievement in physics might be a function of their learning throughout their experiences. Moreover, Kahle and Lakes (1983) showed that boys have different out-of-school experiences in science than their girl peers. Mason and Kahle (1988) also noted that males report significantly greater participation in extracurricular science activities. Similarly, in a study by Farenga and Joyce (1997), students completed the Science Experiences Survey to identify the number of scientific materials and activities they experienced outside of the classroom. Results of the study identified differences in experiences with respect to gender. A central and consistent finding of the aforementioned studies was that male and female students come to school with great variability in their quantity and quality of experiences (Greenfield, 1997; Jones & Wheatley, 1990; Joyce & Farenga, 1999; Resnick, 1983; Tobin & Garnett, 1987; Whyte, 1984).

Different experiences in science also have an effect on students’ achievements that extends through college into the professional years (Greenfield, 1997; Tobin & Garnett, 1987; Whyte, 1984). Girls’ fewer and different kinds of experiences cause lower achievement scores in science (Kahle & Lakes, 1983). Erickson and Erickson (1984) studied the impact of prior experiences on students’ science achievement. They examined a number of items that were embedded in a context that was much more familiar to males because of their experiences. At the end of the study, items
that included balls, electrical circuits, compasses, and other materials or situations that are more likely to be a part of boys’ everyday experiences seemed to create large differences in achievement scores between girls and boys. Responses to NAEP items also supported the findings that scientific activities and skills are not being experienced equally by males and females, which leads to lack of understanding by females. Considering all the studies, it is possible to conclude that deficiencies in experiences may be one reason for lower achievement by females.

Students’ attitudes toward science also may be the result of their experiences and activities as well as other social and cultural factors. In a study by Kahle and Lakes (1983), boys were more interested in the physical and technological aspects of the world whereas girls appeared to be more interested in human and natural aspects. Jones et al. (2000) found that there was a significant gender difference in students’ attitudes toward science. One related finding of the study was that female students had approached some concepts tentatively or with disinterest because they had frightening experiences (e.g., electric shock) where they lacked confidence. Chambers and Andre (1997) also investigated the relationship among gender, interest, and experience on learning fundamental electric-circuit concepts by conceptual change text manipulations. The major purpose of their study was to determine if gender differences in performance could be attributed to preexisting differences in experiences and interests. A multiple-choice test with 30 items was used to assess students’ qualitative understanding of electric circuits. Each item consisted of pictures including bulbs and a battery, and the students were asked if the circuit could work. Male and female students who had a higher or lower interest in electricity and greater or lesser experience with electricity studied two types of texts: a conceptual change text or a traditional text. When interest, experience, and prior knowledge were not included in the analysis, gender produced a significant main effect; however, when these three were included, the effect of gender was eliminated. In other words, their findings supported the hypothesis that prior interest level, experience, and prior knowledge mediate apparent gender differences in learning about electricity. As shown by these studies, students’ misconceptions concerning electric circuits can be influenced, at least in part, by students’ gender, age, attitude toward the topic, and prior experiences related to the topic.

In related literature, items that were embedded in a practical context which included bulbs and a battery were used to assess students’ misconceptions. Items embedded in a theoretical context which included resistances and a power supply also were used in this study to test the dependency of gender difference on the context of an item. Moreover, we hypothesize that gender difference will be mediated when the context of the questions changes from practical to theoretical. Thus, the purpose of the study is to determine if age, prior interest-experience, and context of the items moderate gender difference. There are two null hypotheses for the present study: (a) There is no significant main effect of gender on the population means of the two collective dependent variables of total scores on the 10 practical items and total scores on the six theoretical items, and (b) there is no significant main effect of gender on the population means of the two collective dependent variables of total scores on the 10 practical items and total scores on the six theoretical items when the effects of age and interest/experience related to electricity topic are controlled.

Population and Sample

All ninth-grade students in Turkey were identified as the target population of the study; however, since it is not easy to come into contact with this target population, the accessible population was determined as all ninth-grade students in Ankara, the capital city of the Turkey. Approximately 26,000 ninth-grade students live in Ankara. Of these students, 1,678 participated in the study, which is approximately 7% of whole population. Since it was not possible to select
students individually from the population, stratified cluster random sampling integrated with convenience sampling was used to obtain a representative sample. Strata are subgroups of a population, and a cluster is a sampling unit around which the sampling procedure is planned. For the present study, districts in Ankara were determined as strata, and schools were used as logical clusters. First, districts were identified, and the name of the schools in these districts were obtained. Schools were then randomly selected from each of these districts in similar proportions to the population. An average of 130 to 140 students per school corresponding to three or four classes participated in the study. Participating classes were selected by taking willingness of physics teachers into consideration. Some characteristics of the sample are given in both Figures 1 and 2 for comparing groups used in different studies. The distribution of students’ favorite lessons is given in Figure 1 and the distribution of mothers’ and fathers’ occupations is given in Figure 2.

The physics course taught in the ninth grade is a required course in Turkey. Therefore, its content is the same for all schools due to the regulations of the Turkish Ministry of Education. The content of the ninth-grade physics course includes matter, volume, mass and weight, density, elasticity of matter, matter and heat, electrification and electric charge, electrostatic forces between charged particles, electric current, conductivity and electric circuits, and simple electricity. Moreover, students at this age are already familiar with the concept of electricity from their elementary-level science classes. But, elementary-level classes include only an overview of the topics without details. Students learn by means of the knowledge transfer model rather than by hands-on activities or laboratory studies.

Instruments

Two measuring tools were used in this study: the SECCT and the IEQ. In the literature, several studies have described students’ misconceptions about simple electricity, and many diagnostic items have been developed and validated (Chambers & Andre, 1997; Cohen, Eylon, & Ganiel, 1983; Dupin & Johsua, 1987; Fredette & Lochhead, 1980; Heller & Finley, 1992; McDermott & Shaffer, 1992; Psillos & Koumaras, 1988; Shepardson & Moje, 1994; Shipstone et al., 1988). The SECCT was prepared using this wide range of sources. First, related literature was examined intensely for instruments developed by other researchers. More than 150 questions found in the literature were examined and categorized according to nine misconception models:

1. Sink Model: Students think that single wire connection allows electricity to sink from the power supply to the electrical device, thereby powering the device (Chambers & Andre, 1997).
2. Clashing Current Model: Students think that positive electricity moves from the positive terminal and that negative electricity moves from the negative terminal of a power supply; the positive and negative electricities meet at a device and clash, thereby powering the device (Heller & Finley, 1992).

3. Weakening Current Model: Students think that current flows in one direction around a circuit, but that the current gradually weakens because each device in the circuit uses up some of the current (Chambers & Andre, 1997; Heller & Finley, 1992).

4. Shared Current Model: Students think that current is the same at all points in a circuit regardless of connection types and that all devices in the circuit have the same amount of current; however, less current returns to the power supply than originally leaves (Chambers & Andre, 1997; Heller & Finley, 1992).

5. Empirical Rule Model: Students think that the further away the bulb is from the battery, the dimmer the bulb (Heller & Finley, 1992).

6. Local and Sequential Reasoning Model: Students think that changes in circuits have only local effect rather than effects on the whole circuit (Cohen et al., 1983).

7. Short Circuit Preconception Model: Students think that wire connections without devices attached to the circuit are irrelevant and can be ignored (Shipstone et al., 1988).

8. Power Supply as a Constant Current Source Model: Students think that power supply releases the same fixed amount of current to every circuit (Cohen et al., 1983; Dupin & Johsua, 1987).


Figure 2. Distribution of students’ mothers’ and fathers’ occupations.
For each of these misconception models, only one or two questions were selected from the literature in coordination with a specialist in physics education. The rest were discarded so as not to bore students with too many wordy questions. Moreover, we wanted students to complete both the concept test and the questionnaire in 40 min, which is 1 class hour in our country.

The test consisted of 16 multiple-choice items. Ten questions assessed the students’ misconceptions about the practical use of electric circuits and interpretations of these components, and the remaining six questions assessed misconceptions about the theoretical use of electric circuits. All practical items in the study were either directly taken or adapted from previous studies. For instance, five questions were directly translated into Turkish from the study of Chambers and Andre (1997) with the help of two research assistants from the Department of Secondary Science and Mathematics Education. Moreover, five questions were developed by the researchers using ideas from the studies of Shipstone et al. (1988) and Dupin and Johsua (1987). On the other hand, all theoretical items were developed by the researchers by making minor word and graphical changes on the practical items. During the adaptation of practical items to the theoretical items, figures were first adapted. Bulbs and batteries were removed from the figures and replaced by resistors and power supplies. Similarly, to obtain the parallel form of the questions with the figures, words such as “bulb” and “battery” were changed to “resistor” and “power supply,” respectively.

Multiple-choice items were preferred for the concept test because of easy and quick administration and objectivity during scoring. However, since multiple-choice items do not provide insight into students’ ideas and can be used only to evaluate students’ content knowledge, two-tier diagnostic items were used to assess students’ content knowledge together with the reasoning for their answers.

The first tier usually has two or three alternative answers whereas the second tier of each item contains the set of possible reasons for the answer given in the first tier. The reasons can be any identified misconceptions or a scientifically correct answer. In our study, however, distracters were designed in a way that each had one possible answer and reason for it as seen in the format used by Chambers and Andre (1997). In both practical and theoretical items, the students were asked if the circuit would work. Examples of items with practical context and the corresponding items with a theoretical context are given in Figure 3.

The second measuring tool, IEQ, also was developed by making use of the Chambers and Andre (1997) inventory. There were 17 items in this questionnaire, two of which requested information about the students’ gender and age. Five items addressing students’ interest in electricity were designed to be rated on a 4-point Likert scale (very interested, interested, uninterested, very uninterested), and the remaining 10 items addressing students’ experiences were rated on a 3-point Likert scale (never, sometimes, frequently). Seven items in IEQ were adapted from the inventory used by Chambers and Andre (1997). The researchers developed the remaining items. Examples of the researcher-developed items are given in Figure 4.

Most of the questions in the concept test and items in the questionnaire were selected from the published instruments of the previous researchers (Chambers & Andre, 1997; Dupin & Johsua, 1987; Shipstone et al., 1988), which might be used as evidence for test validity. Moreover, to establish face and content validity, both the test and the questionnaire were checked by two physics professors, one specialist in physics education, and two high school physics teachers from different schools. They evaluated the measuring tools according to given criteria such as the appropriateness of items for the grade level (easiness or difficulty), comprehensiveness of items, representativeness of content by the selected items, appropriateness of the format (quality of printing, size of type, appropriateness of language, and clarity of directions, etc.). Misconceptions and subsequent related questions also were supplied to the reviewers, who were then asked to
**Practical item 1**

Will the bulb light in the diagram below?

![Diagram of a bulb and a battery]

- a) Yes, because electricity can flow from the bump on the top of the battery to the bulb directly.
- b) Yes, because any connection between the battery and the bulb will cause the bulb to light.
- c) No, because electricity cannot flow in the circuit.
- d) No, because electricity can only flow from the other side of the battery.
- e) 

**Corresponding theoretical item 1**

Will the current pass through the resistor in the diagram below?

![Diagram of a battery, resistor, and current symbol]

- a) Yes, because current can flow from the power supply to the resistor directly.
- b) Yes, because any connection between the power supply and the resistor will cause the current to flow.
- c) No, because current cannot flow in the circuit.
- d) No, because current can only flow from the other side of the power supply.
- e) 

**Practical item 2**

Will there be any change in the brightness of bulb A when the bulb B, which is equivalent to bulb A, is connected to the bulb A as shown in the figure below?

![Diagram of two bulbs A and B]

- a) Yes, brightness of bulb A decreases because bulb B connected to the circuit in parallel increases the resistance of the circuit and therefore decreases the current passing through the circuit.
- b) Yes, brightness of bulb A decreases because while all the current passes through bulb A in the first circuit, the same current is shared among bulb A and bulb B in the second circuit.
- c) No, brightness of bulb A does not change because although the bulb B decreases the total resistance and increases the total current in the circuit, current that pass through the bulbs will be same since the current is divided into two branches.
- d) No, brightness of bulb A does not change because battery is a constant current source and it will continue to provide the same current to the circuit.
- e) 

*Figure 3. Examples of items with practical context and corresponding items with theoretical context.*
decide whether the items indeed contained misconceptions. Revision of the instruments was made based on their suggestions. During the pilot study, the test and the questionnaire were administered to 166 ninth-grade students from three different high schools. Internal reliability coefficients of the test and the questionnaire were .74 and .86, respectively, for the pilot study and .61 and .89, respectively, for the main study using the Cronbach alpha coefficient. Based on feedback from the pilot study, no changes were made other than spelling corrections.

**Figure 3.** (Continued)

[Diagram showing a circuit with a power source and resistors A and B, and another circuit with a single resistor A connected in parallel with a power source]

**Figure 4.** Sample items from the IEQ.

Have you ever made an experiment about electricity?

Have you ever tried to light a bulb by using battery and wires?

Have you ever had a chance of producing something by using electrical construction sets?

How interested are you in taking a physics course?

How interested are you in building electronic or electrical toys?
Procedure

Since the effect of gender on students’ misconceptions concerning electric circuits was investigated, the design of the study was causal comparative. After instruction, the researchers administered the instruments to the majority of the participants. The students’ physics teachers administered instruments to the remaining participants. Teachers were given both written material about the administration of the instruments and a verbal explanation about standardizing test administration. One class hour (40 min) was allowed to complete the SECCT and the IEQ. Directions were read and necessary explanations were made by the researchers or the teachers. Moreover, students were told that the grades of this test would not affect their physics course grades. No problems were encountered during the administration.

A correct response on each practical item was given 1 point; all points were added to obtain the total score on the practical items. A correct response on each theoretical item also was given 1 point, and all points were added to obtain the total score on the theoretical items. Total scores obtained from the practical items ranged from 0 to 10, and total scores obtained from the theoretical items ranged from 0 to 6; higher scores indicate greater achievement and hence fewer misconceptions.

Data Analysis

The significance level was set to .05 since it is the most used value in educational studies. In other words, the probability of rejecting the true null hypothesis (probability of making Type I error) was set to .05 a priori to hypothesis testing. Moreover, the power of this study was set to .99. Therefore, the probability of failing to reject the false null hypothesis (probability of making Type II error) was .01 (i.e., 1 – .99). On the other hand, effect size was considered to be medium by looking at the results obtained from previous related studies. Sample size was calculated as 151 for a medium effect size by taking the number of variables used in the study into consideration. The statistical power of the study became larger than .99 when the sample size of the study was taken into consideration.

Descriptive statistics related to total scores on practical and theoretical items, scores on the interest-experience questionnaire, and students’ ages were categorized according to gender and are presented in Table 1.

Means are relatively low compared to the maximum possible total scores for both the practical and the theoretical total scores: 10 and 6, respectively. Male students had a mean total score of 5.0 on the practical items while female students had a mean total score of 4.6, indicating that female students had more misconceptions than male students. Moreover, male students had a mean total score of 2.7 on the theoretical items while female students had a mean total score of 2.6, indicating no difference between sexes. While a difference is easily recognized on total scores on the practical items, there was no difference on total scores on the theoretical items. Moreover, students’ interest-experience scores ranged from 0 to 50, where higher scores indicate greater interest in and experience with electricity. The male students’ mean was higher than the female students’ mean (Table 1), which indicates that male students had much more interest in and experience with electricity than female students. Variability in the scores as measured by SDs was relatively stable for both sexes. Furthermore, skewness and kurtosis values given in Table 1 were used to check the assumption of normality. The skewness and kurtosis of the total scores on both the practical items and the theoretical items were in the acceptable range for a normal distribution.

Missing data analysis was done before the inferential statistics. Of the 1,680 high school students who were given the SECCT and the IEQ, 2 did not write their gender on the paper. These 2 students were excluded from the statistical analysis. On the other hand, 115 (6.9%) students did
not complete the section related to their age. Hence, this variable was tested for significance before replacing with the mean. From the $p$ values obtained, the distribution of the missing data was found to be random. Consequently, missing values were replaced with the mean of the entire sample.

Three independent variables (age, interest in electricity, and experience with electricity) were predetermined as potential confounding factors of the study. All predetermined independent variables were correlated with the two dependent variables: total scores on the practical items and total scores on the theoretical items. All independent variables were significantly correlated with the dependent variables as shown in Table 2.

Moreover, since there was a significant correlation between interest and experience scores, they were summed to create one single variable to avoid multicollinearity. Hence, a total of two variables (age and interest-experience scores) were included as covariates for further inferential analyses.

Multivariate analysis of variance (MANOVA) was conducted to determine the effect of gender on the two dependent variables (total scores on the practical items and total scores on the theoretical items). MANOVA uses a number of statistics (Wilks’s $\Lambda$, Pillai-Bartlett’s, Hotelling’s $\tau$, and Roy’s $\Theta$) to evaluate the hypothesis that the population means are equal. We preferred Wilks’s $\Lambda$ since it is frequently reported in the social science literature (Green, Salkind, & Akey, 2000). Significant differences were found among male and female students on the collective dependent

### Table 1
Descriptive statistics for SECCT and IEQ scores according to students’ gender

<table>
<thead>
<tr>
<th>Gender</th>
<th>$N$</th>
<th>Mean</th>
<th>SD</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Scores: Practical Items</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>764</td>
<td>5.0</td>
<td>1.7</td>
<td>0.2</td>
<td>$-0.3$</td>
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<tr>
<td>Female</td>
<td>914</td>
<td>4.6</td>
<td>1.7</td>
<td>0.1</td>
<td>$-0.2$</td>
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<tr>
<td>Total</td>
<td>1,678</td>
<td>4.8</td>
<td>1.7</td>
<td>0.2</td>
<td>$-0.2$</td>
</tr>
<tr>
<td>Total scores: Theoretical Items</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>764</td>
<td>2.7</td>
<td>1.3</td>
<td>$-0.1$</td>
<td>$-0.6$</td>
</tr>
<tr>
<td>Female</td>
<td>914</td>
<td>2.6</td>
<td>1.3</td>
<td>0.1</td>
<td>$-0.6$</td>
</tr>
<tr>
<td>Total</td>
<td>1,678</td>
<td>2.7</td>
<td>1.3</td>
<td>0.1</td>
<td>$-0.6$</td>
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<tr>
<td>IEQ Scores</td>
<td></td>
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<tr>
<td>Male</td>
<td>764</td>
<td>38.5</td>
<td>6.0</td>
<td>$-0.7$</td>
<td>$-0.7$</td>
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<td>32.5</td>
<td>6.3</td>
<td>0.1</td>
<td>$-0.5$</td>
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<tr>
<td>Total</td>
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<td>35.2</td>
<td>6.8</td>
<td>$-0.2$</td>
<td>$-0.5$</td>
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<td>.7</td>
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<td>914</td>
<td>15.7</td>
<td>.6</td>
<td>$-0.5$</td>
<td>1.3</td>
</tr>
<tr>
<td>Total</td>
<td>1,678</td>
<td>15.7</td>
<td>.6</td>
<td>$-0.1$</td>
<td>2.1</td>
</tr>
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</table>

### Table 2
Significance test of correlation between independent and dependent variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>Total Scores: Practical Items</th>
<th>Total Scores: Theoretical Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>.183**</td>
<td>.149**</td>
</tr>
<tr>
<td>Prior experience</td>
<td>.146**</td>
<td>.107**</td>
</tr>
<tr>
<td>Interest about electricity</td>
<td>.121**</td>
<td>.131**</td>
</tr>
</tbody>
</table>

**Significant at $\alpha = .05$
measures, Wilks’s $\Lambda = .9, F(2, 1675) = 11.4, p = .000$. Hence, analysis of variance (ANOVA) on each dependent variable was conducted as post hoc tests of the MANOVA. The ANOVA on total scores of the practical items was significant, $F(1, 1676) = 62.6, p = .000$, while the ANOVA on total scores of the theoretical items was not significant, $F(1, 1676) = 5.5, p = .067$. In other words, male students produced significantly superior performance on the practical items, but there was not a significant difference between male and female students on the theoretical items.

MANCOVA was conducted to determine the effect of gender on the two dependent variables of total scores on the practical items and total scores on the theoretical items when age and interest-experience scores were controlled. Significant differences were found between male and female students on the collective dependent measures, Wilks’s $\Lambda = .9, F(2, 1673) = 3.3, p = .038$. Hence, analysis of covariance (ANCOVA) on each dependent variable was conducted as post hoc tests of the MANCOVA. The ANCOVAs on the two dependent variables were nonsignificant, $F(1, 1674) = 3.4, p = .065$, and $F(1, 1674) = 1.1, p = .314$, respectively; therefore, there was no need to deal with the estimated adjusted means for these dependent variables. Although significant differences were found between male and female students on the collective dependent measures, significant differences were not found for the ANCOVA, possibly because of the high correlation among the dependent variables.

In summary, significant gender difference on the collective dependent variables of total scores for the practical items and total scores for the theoretical items was observed when age and interest-experience scores were not controlled. Post hoc results indicated that males performed better on the practical items than females and that there was no significant difference on the theoretical items. On the other hand, when students’ age and interest-experience related to electricity were controlled, observed gender differences were mediated on the practical items.

Conclusions and Discussion

Although most of the previous studies found that male students had fewer misconceptions than female students, the results of this study indicate that results depend on the context of the question. In previous literature, only the practical type of questions were used. Consequently, a gender difference on scores was frequently observed. In this study, additional theoretical items were used, and no significant difference between male and female students were found for these items. This research supports most findings of previous work (Chambers & Andre, 1997; Erickson & Erickson, 1984; Greenfield, 1997; Kahle & Lakes, 1983; Kelly & Kelly, 1978). For instance, like most previous studies, this study supports a gender difference when the questions asked were in a practical context, and this difference disappeared when students’ age and interest-experience related to electricity were controlled (Chambers & Andre, 1997; Erickson & Erickson, 1984). In other words, this study suggests that the context of the questions is responsible for a gender difference on students’ scores related to electricity.

The major threat to the internal validity of a causal comparative study is a subject characteristics threat. In this study, groups, not individuals, were randomly selected. Therefore, many subject characteristics (previous knowledge, age, attitude, gender, SES) might affect the results of the study. To control this threat, students’ ages, interests, and experiences were considered as possible subject characteristics and assessed with the questionnaire. The aforementioned variables were highly correlated with the dependent variables, so they were included in the covariates.

Location and instrumentation were not threats to the study since the tests were administered to all groups in similar conditions; however, mortality could have been a threat to internal validity. Consequently, missing data analysis was undertaken. Confidentiality was not a problem in this study since students’ names were not used. In addition, since the accessible population was large,
randomized, and stratified, there is no limitation about the generalizability of this study to the accessible population. Therefore, the conclusions can easily be applied to the defined accessible population.

Implications

Based on the findings of this and previous studies, we offer the following suggestions. Every physics teacher should be aware of their students’ interest in and experience with electricity before starting instruction. We found that the mean of the students’ interest-experience scores was 35.2 of 50, even after formal instruction on electricity. Therefore, we recommend that teachers use appropriate methods to improve all students’ experiences with electricity by using experiments and hands-on activities as well as by linking learned concepts to everyday, real-life experiences. In addition, we recommend that course content be reorganized so that teachers spend equal time on the application of theories to real-life situations and the theoretical background because the results of our study revealed a significant correlation between students’ interest in electricity and students’ achievement in electricity. Authors of physics textbooks also should give equal importance to the practical context and the theoretical context by giving real-life examples and including drawings and photos of resistors, power supplies, and electrical switches.

This study found that female students’ interest-experience scores were 1 SD less than male students’ scores. This implies that society as well as parents should not treat males and females differently, but provide similar experiences for both.

Finally, until equality of experiences can be achieved, measuring tools should be prepared that take into consideration the context of the questions. In other words, items with theoretical contexts instead of practical contexts should be used in the measuring tools. This helps to obtain a more valid measure of students’ achievement and misconceptions independent of gender or their interest in and experiences with electricity. The aforementioned suggestions also may be helpful for other topics in physics and in other branches of science.

References


