Secondary School Students' Misconceptions about Simple Electric Circuits

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ABSTRACT

The aim of this study is to reveal secondary school students' misconceptions about simple electric circuits and to define whether specific misconceptions peculiar to Turkish students exist within those identified. Data were obtained with a conceptual understanding test for simple electric circuits and semi-structured interviews. Conceptual understanding test consists of eight open-ended questions that were designed by reviewing the related studies in the literature. The most important findings appeared in the study were the misconceptions, which emphasized the idea of "no bulb lights on if the switch is off" due to everyday language and the idea of "bulbs connected in parallel give better light than those connected in series" due to prior teachings. In addition, misconceptions, those frequently reported in the literature such as "the consumption of current", "batteries are constant current sources", etc. were also suggested in this study.

Keywords: *Physics Education, Simple Electric Circuits, Misconceptions*

INTRODUCTION

Student's preconceptions in science have aroused science educators' interest for 30 years because of the principle idea of constructivist learning theory, which was stated as "students come to the learning environment with the preconceptions, which were formed during their interactions within physical and social environment and those preconceptions affect learning" (Pfundt and Duit, 2006). The main interest of studies focus on those preconceptions of which especially contradict with scientific knowledge and create problems in learning. In this study, the notion of misconception was used for such preconceptions. Research carried out resulted with some findings about the main features of misconceptions. These findings are listed below (Driver and Bell, 1986; Driver, 1989; Mutimucuio, 1998; Widodo et al., 2002; Tytler, 2002).

- Misconceptions of students who have different culture, religion and language are frequently similar to each other.
- Misconceptions may deeply penetrate into students' minds and resist to change.

- Everyday language, culture and religion can cause the formation of misconceptions.
- Misconceptions can be parallel to the explanations made by earlier scientists in interpreting scientific phenomena.
- Misconceptions may develop after a formal teaching.

Many researchers came up with the same findings during the investigation of students' misconceptions about simple electric circuits (Osborne, 1983; Cohen at al., 1982; Tiberghien, 1983; Shipstone, 1984; Kärrqvist, 1985; Shipstone et al., 1988; Mc Dermott and Shafer, 1992; Barges et al., 1999; Lee and Law, 2001; Küçüközer, 2003). The most frequently encountered findings are given below:

- The concepts of current, energy and potential difference are not respected as different concepts and used interchangeably with each other.
- Current is consumed by circuit components.
- Current comes out from the (+) pole of the battery and enters to the bulb where it is consumed to light the bulb which is not affected by the second wire connected between the (-) pole and itself.
- Current comes out from the both poles of the battery and clashes in the bulb to light it.
- Current is divided equally in each line of the parallel circuits.
- A change before the bulb affects the brightness of the bulb in circuit connected in series but the same bulb is not affect by change in anywhere of the circuit after the bulb.
- Batteries are constant current sources.

Misconceptions outlined above were reported in studies conducted with students in different countries and with different age groups. Shipstone et al.'s (1988) study is an important research, which summarizes that students in five European countries also have similar misconceptions about simple electric circuits.

The misconception of "current is consumed by circuit components" which is listed above is almost reported in all studies about electric circuits. This is such an idea that takes place in the novel "Snow" by Orhan Pamuk. In one episode of the novel (p. 107), speech made by two friends who fell in love with the same girl about committing suicide at the same time was given below:

> They could not decide how who is going to die. Since both knew that the real happiness was to sacrifice oneself for the happiness of the other. If one of them, Fazıl for instance, suggested clasping electric current with a naked hand at the same time, Necip on the other hand was inferring that it was a sly trick found to sacrifice himself to die because of the less electric current drawn by the plug on his side...

Students sometimes may have misconceptions stemming from the use of everyday language (Gilbert et al., 1982; Leach and Scott, 2003). Gilbert et al. (1982) summarize strikingly this situation bellows.

> Many words in science are used in an alternative way in everyday language. Often a student can listen to, or read a statement in science and *make sense* of it by using the everyday interpretation of the word. The interpretation is not the one intended by the teacher or textbook writer. For example: The air is made up of small particles (is anything else made up of small particles?) glass. They are made out of small particles of sand which have been turned hot. ... turned clear and then sort of take them out. ... And put them between two pieces of metal when they have been hardened and when they take it off they find that they have a clear surface called glass. (Step 7; age 11) The word 'particle' is commonly used in science classes to mean atom, molecule or ion. In everyday use it

refers to a small, but visible, piece of solid substance. The everyday [p626 starts] meaning has been applied to air. The interviewee has apparently presumed that the 'particle' size in sand is retained in glass. A parallel has been drawn between glass and air based on appearance.

Students' acquisition of new misconceptions during teaching is one of the possible situations (Linn, 1986; Sherry et al., 2001). The existence of misconceptions in students' minds during teaching sometimes depends on the extent to which teachers hold the same misconceptions (Pardhan and Bano, 2001; Küçüközer and Demirci, 2005).

In light of the studies and ideas outlined above, this study aims to reveal secondary school students' misconceptions about simple electric circuits. Therefore, questions to be sought for the responses are:

1. What are the misconceptions of first year secondary school (Grade 9) students about simple electric circuits?
2. Does any misconception specific to Turkish students exist?

METHODOLOGY

This research is a qualitative study in which conceptual understandings test (CAT) involving open-ended questions was used and interviews were conducted to find out students' pre-knowledge.

CAT was administered to 76 students in three Grade 9 classes in the city of Balıkesir and interviews were conducted with randomly selected 9 students who responded to **CAT**. Students were previously instructed about the topic in the 6th grade.

CAT and interviews as data collection tools and analysis of data are explained below.

A- Conceptual Understanding Test

The designed conceptual understanding test consists of 8 questions, 6 of which are selected and partially modified from the studies investigating students' ideas about simple electric circuits in the literature (Shipstone, 1985; Shipstone et al., 1988; Mc Dermott and Shaffer, 1992; Lee and Law, 2001) and 2 of them (questions 1 and 2) redevised by the researchers.

In the pilot phase of the study, CAT was administered to 108 students from three different secondary schools and interviews were conducted with randomly selected three students who responded to CAT beforehand. Thereafter, content validity of CAT was checked with the direction of views of five experts in physics education area. According to analysis results of pilot study some changes in the questions, which were difficult to respond, were made. For instance, students responded in difficulty and those who responded misunderstood the second part of question 5 (see Figure 1). Although the first solution to this problem was thought to reject the question, explanations indicating misconceptions which arise from the use of everyday language like "none of bulbs light up when the switch is closed" or "all bulbs light up when the switch is open" took the researches a decision of rephrasing the question and using the final form of it CAT. Figure 1 shows the question 5 asked in pilot and the final CAT study forms.

All the questions were in open-ended form in the pilot study. According to the analysis of the data obtained, the most frequent responses given to each of the questions were used as alternatives to multiple-choice items in CAT. Students were asked to select only one alternative for each question (except question 1) and to explain their choices to the empty lines given below to the questions. If the students found none of alternatives to be correct then they were allowed to use empty space shown as .... at the end of the given alternatives to write down the correct option of their own.
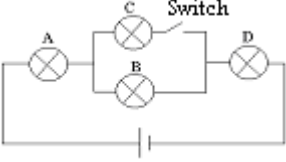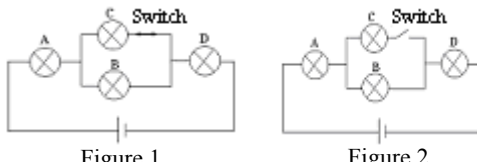
I	II
All the bulbs are identical in the circuit shown below.	All the bulbs are identical in the circuit shown below.

Figure 1. *The final forms of question 5 used in pilot (I) and CAT study (II).*

Students were informed about the aim and the content of CAT beforehand. It is emphasized that the aim of the study was not to give marks to students and therefore students were encouraged to write their ideas freely. Students were free to take their time during the administration of CAT and on average they completed answering the questions within 40 minutes.

B- Interviews

Semi-structured interview technique was used in the study. Interviews were conducted to examine deeply the ideas obtained from CAT. Firstly, the reasons beneath the explanations made to CAT and the questions from the interview schedule were asked. According to the progress made during the interviews, additional questions were also asked in some instances. Students were interviewed between 22 and 40 minutes time period. Maximum attention was paid not to lead the students but to strive to develop to interaction in a natural and comfortable atmosphere. All the interviews were recorded with the consent of students and transcribed. Some of the interview data that support the data obtained from each CAT question was presented in the findings section.

C- Data Analysis

Data obtained from CAT were analyzed using the approaches which require the definition of scientifically complete response (nomothetic) and the classification of explanations in certain categories (ideographic) (Driver and Erickson, 1983; Kabapınar, 1998; Küçüközer, 2004). The levels used to code the responses are shown in Figure 2.
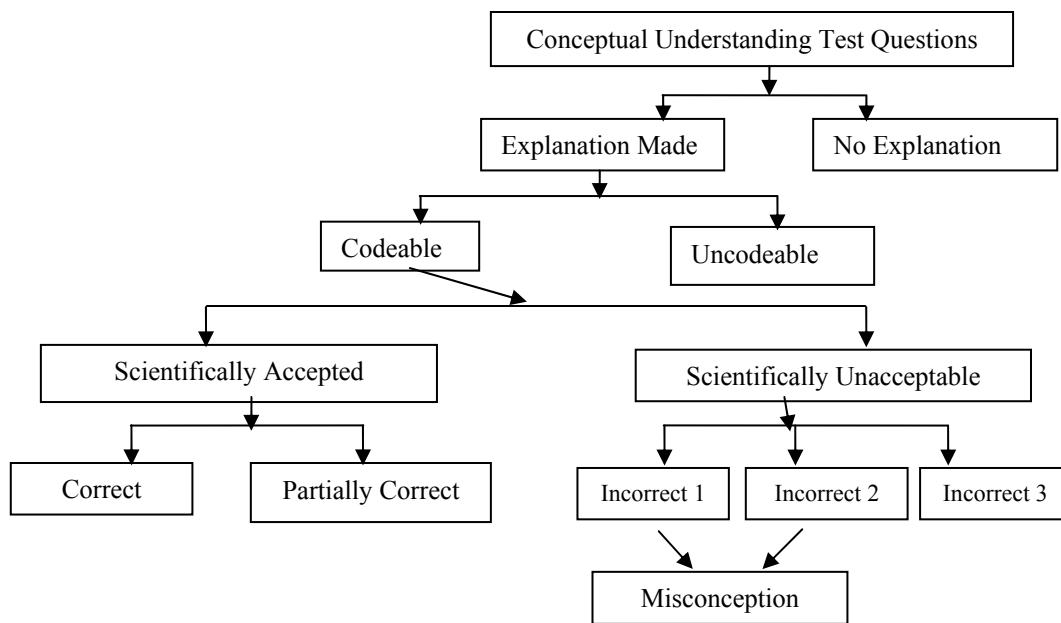
Figure 2. *Analysis of CAT Questions*

Different categories under five levels which help to classify scientifically acceptable and unacceptable explanations were determined. These categories are comprised of the classification of similar explanations that fall into the same level. Apart from these levels, uncodeable explanations and empty lines without explanations constitute the other two levels. Question 4 was given as an example to explain the levels formed. This question is mainly based on the concept of brightness of bulbs of which are used in serial and parallel circuits with the configured identical bulbs and batteries.

Scientifically Correct (A): Scientifically correct explanations take part in this level. For instance, the explanation given bellow is regarded as level A type response; "If we find the currents using Ohm's law these are I, I/2, and 2I in figures 1,2 and 3, respectively. Since the bulbs are connected in parallel, current splits between the two branches and the magnitude in one branch is I. Brightness of the bulb is proportional to the current passing through that bulb. Therefore, the correct order of the brightness is A=D=E > B=C.

Partially Correct (B): Responses involving correct but in complete explanations were considered to belong level. The next sentence exemplifies the ideas involved in this level. Brightness of the bulbs connected in parallel is the same as the single bulb and bigger than the brightness of the bulbs connected in series.

Incorrect 1 (C): Ideas including correct and incorrect explanation sentences match with this level. For instance, the following explanation corresponds with the ideas emerging in this level; "Since the batteries are identical, currents in the main circuit are the same in three circuits. Brightness of the bulbs in parallel branches is dimmer than the others due to the division of current in branches".

Incorrect 2 (D): Explanations focusing on the minority or majority of any circuit component and the way the circuit is connected coincide with this level. The next sentence can be given as an example: "Brightness of the bulbs in series is much more than the bulbs connected in parallel".

Incorrect 3 (E): Ideas involving the concepts and explanations apart from electricity correlate with this level and involve completely scientifically unacceptable arguments. The

response in the following sentence exemplifies this situation. "A is equal to D. Because both are the same. E is also the same; E is longer than B's cable. B and C are the same".

Uncodeable (F): Explanations which are difficult to understand what they imply or have no relation with the questions fall into this level. For instance the following response match with this category, "A is bigger since its resistance is powerful. B is equal to C because both have the same resistance. Since C is more resistive than D, it is bigger than D. D is equal to E since both have the same resistance".

No explanation (G): Students who did not make any explanation and write the same expression given in the alternative of multiple-choice part of the question were put in this category. The sample response to this level is as follows: "A is bigger than B which is equal to C. C is bigger than D which is equal to E".

FINDINGS AND DISCUSSION

As the analysis of data was completed in the line with research questions, the findings obtained show that misconceptions, which were reported in the literature, are specific to Turkish students

Findings obtained from question 5 reveal that the misconceptions of "none of bulbs are lit when the switch is closed" specific to Turkish language and the other never encountered in the literature that "bulbs in parallel are always brighter than those in series" are presented below. Misconceptions, which were also found in the literature and emerged in questions 4 and 7, respectively, as "batteries are constant current sources and current is consumed by circuit components", were introduced in the following paragraphs. The levels and categories of students' explanations and their percentages were shown in the tables during the presentation of findings.

The data that had the highest percentage and obtained from the rest of the questions were presented in general in the results section of this study.

A- Everyday Language Based Misconceptions

Findings obtained from the first part of question 5 concerning the correct order of the brightness of serial and parallel branch is closed were presented in Table 1.

Table 1. *The level of responses, categories and percentages constituted for the explanations made by students in the first part of question 5 (N=76)*

Level	Categories	Frequency (%)
A	As the current passes through bulb A, it divides two halves in parallel branches and joins together after flowing in bulbs B and C to flow in bulb D.	8
C	Current flows in all bulbs because the switch is closed and the brightness of all bulbs are the same	8
D	Current does not flow and none of bulbs are lit when the switch is closed.	32.9
	Current is consumed in the circuit.	13
E	Bulbs B and C are not lit when the switch is closed but bulbs A and D are lit since	2.6
	Resistance of bulbs A and D is higher than the bulbs B and C thus bulbs A and D are brighter than the other two.	2.6
	Bulbs in parallel are always brighter than those in series	2.6
	Brightness of the bulb that is far from the battery is less than those, which are close to the battery.	5.3
	Bulbs give equal brightness (Independent from the type of the connection).	2.6
	Brightness of the bulb that is close to the switch is much more than those, which are far away.	1.3
F	Uncodeable	8
G	No explanation	13

As can be seen in Table 1, few students made scientifically acceptable explanations. The category of "current does not flow and none of bulbs are lit when the switch is closed" has the highest percentage (32.9 %) in level D as involving scientifically unacceptable explanations.

In everyday language, expressions such as "close the switch" to light off a lit bulb and "open up the switch" to lit the bulb are used. Ideas of students can be seen as a specific misconception peculiar to Turkish students due to everyday language when they reason that all bulbs are dimmed when the switch is closed. For instance, student 22 gave the explanation of "*electricity does not move anywhere because of the closed switch. We use switch for example to turn off lights. None of bulbs are lit when the switch is closed*" for this question. Here, the student point out that current does not flow toward the bulbs and this cause bulbs to be dimmed when the switch is closed by giving the lights used at his/her home as an example.

Two of the students interviewed were seen to have such a misconception in their explanations given to CAT but they stressed that their ideas were wrong during the interviews. When asked why they changed their ideas, students explained as follows: "*I wrote that the bulb is not lit when the switch is off because it occurred to me that we use switches at home to turn on the lights. However I realized that my ideas was wrong when I discussed this with my friends in the class*".

B- Teaching Based Misconception

Findings obtained from the second part of question 5 concerning the correct order of the brightness of serial and parallel-connected bulbs as the switch on the parallel branch is open were shown in Table 2.

Table 2. *The level of responses, categories and percentages constituted for the explanations made by students in the second part of question 5 (N=76)*

Level	Categories	Frequency (%)
A	Bulb on the branch of opened switch is not lit and the brightness of bulbs A, B and D are the same because they are connected in series and have the same current value passing through themselves.	2.6
C	Bulb on the branch of the opened switch is not lit and current is consumed in the circuit.	8.7
	Bulb on the branch of opened switch is not lit and current flows from both terminals of the battery.	3.9
D	None of the bulbs is lit while the switch is open.	25
	Bulbs in the parallel are always brighter than those in series.	35.5
	Bulb on the branch of opened switch is not lit but current flows to the bulb C and stays there.	2.6
E	All the bulbs will have the same brightness as the switch is opened.	18.4
	Brightness of the bulb that is far from the battery is less than those, which are close to the battery.	3.9
	Bulbs give equal brightness (Independent from the state of the switch).	3.9
	Forces of A and D are bigger than forces of B and C.	2.6
F	Uncodeable	10.5
G	No explanation	2.6

Table 2 shows that students hardly responded with scientifically acceptable explanations. Two categories which emphasize in a scientifically unacceptable way that "bulbs in parallel are always brighter than those in series" and "none of bulbs is lit while

the switch is open" have the highest response percentages (35.5% and 25% respectively) in the level D.

Idea of "bulbs in parallel are always brighter than those in series" is a misconception which has never been encountered in any study in the literature so far. Two of the students interviewed who determined to have such a misconception gave the explanation as follows: "*I guess, I remember something. Our teacher in primary school drew the figures on board like this which included a bulb and a battery, two bulbs (in series) and a battery and such two bulbs (in parallel) an a battery. I do not remember quite well but he said something like; bulbs in parallel are always brighter than those in series*"; on the other hand, the other student replied: "*presumably, our teacher did something like this but I may retain this idea from the experiments done about these circuits. Aren't they correct? Why do you ask then?*"

After such explanations of the students, circuits including a battery connected to two bulbs in series and a battery connected to two bulbs in parallel were given under the topic of "resistors can be connected in series and parallel" in the grade 6 primary science textbook (Güngör et al., 2002). In general as the circuit is initially completed with a battery and a bulb during teaching of the simple electric circuits, two bulbs in series and parallel are connected to the same battery to compose different circuits. In fact, the brightness of a bulb connected to a single battery equal to the brightness of two bulbs in parallel connected to the same battery but it is less when two bulbs in series are connected to the same battery again. It can be mistakenly inferred from this situation that bulbs in parallel are always brighter than those in series. The cause of such a misconception might be thought of perceiving a generalization of this situation which can be applied to every circuit by the students.

C- General Misconceptions: Constant Current Source

Findings obtained from question 4 regarding the correct order of the brightness of bulbs in serial and parallel connected three circuits of which have identical bulbs and batteries were given in Table3.

Table 3. *The level of response, categories and percentages constituted for the explanations made by students in question 4 (N=76)*

Level	Categories	Frequency (%)
C	Batteries are constant current sources (students imply that main circuit currents in three circuits with identical batteries and the brightness of bulbs in parallel are reduced due to the division of main circuit current between the branches.	36.8
	There is a proportion of the number of bulbs to their brightness. If the bulbs are in the same number then bulbs in parallel give more light than those in series.	31.5
D	There is an inverse proportion between the number of bulbs and their brightness (Independent from the bulbs' connection type).	14.5
	There is a proportion of the number of bulbs to their brightness (Independent from the bulbs' connection type).	3.9
E	All bulbs have the same brightness because batteries and bulbs are identical.	2.6
F	Uncodeable	6.6
G	No explanation	3.9

As can be seen in Table 3, none of the students gave scientifically acceptable explanations. Two categories in level C involve scientifically unacceptable explanations which are "batteries are constant current source" and "there is a proportion of the number of bulbs to their brightness. If the bulbs are in the same number then bulbs in parallel give

more light than those in series" and have the highest response rates of 36.8% and 31.5%, respectively.

The idea of "batteries are constant current sources" is the frequently encountered misconception in the literature. During interviews, four of the nine students reasoned that *"the currents in all three circuits are equal due to the same batteries used in the circuits"*. These students see batteries as constant current sources whatever the type of the circuit's connection and think that main circuit currents are equal in all circuits in which the same battery used.

D- General Misconceptions: Consumption of Current

Findings obtained from question 7 which require the combination of currents on both sides of a bulb marked as 1 and 2 were presented in Table 4.

Table 4. *The level of response, categories and percentages constituted for the explanations made by students in question 7 (N=76)*

Level	Categories	Frequency (%)
A	Current has the same value in every point of the circuit (conserved).	10.5
D	Current decreases when it passes through the bulb.	34.2
	Current on the positive terminal side of the battery is always bigger than the current on the negative terminal side.	18.4
	Current flows to the bulb from both terminals of the battery and each have the same value.	10.5
	1>2, due to the positively charged point 1 and negatively charged point 2.	9.2
E	Point 1 transmits current to the bulb quicker than point 2 (consideration on the distance of points to the bulb).	2.6
F	Uncodeable	10.5
G	No explanation	3.9

As can be seen in Table 4, 10.5% of students made scientifically explanations. Both categories which emphasize in a scientifically unacceptable way that "current decreases when it passes through the bulb" and "current on the positive terminal side of the battery is always bigger than the current on the negative terminal side" are in level D with the highest response percentages of 34.2% and 18.4% respectively.

Almost all the students interviewed were found to have the idea of "current decreases when it passes through the bulb". When asked why the current decreases they reasoned that *"the current passes through the bulb and the bulb lights up, therefore it should decrease"*.

Misconception of "consumption of the current by circuit components" is frequently encountered in the literature such as the misconception of "batteries are constant current sources". Revealing the misconceptions outlined above also in this study is thought to be a good example of one of the general characteristic of misconceptions mentioned in the introduction part as the similarity of misconceptions of students who came from different culture, religion and language.

CONCLUSIONS

Misconceptions that are frequently encountered in the literature and discovered for the first time are brought to the light in this study.

There are two misconceptions of which are emerged in this study and not encountered in the previous studies. As explained in the findings section, one of these

misconceptions is Turkish language based and the other is teaching based. These misconceptions are outlined below.

- None of the bulbs are lit when the switch is closed (question 5).
- Bulbs in parallel give more light than bulbs in series (question 5).

In addition to the misconceptions found in the literature and reported in the findings section, a number of misconceptions which arose in the rest of the questions and encountered in which study were given below with the question numbers.

- Concept of potential difference, current and energy were used interchangeably as if they all are the same (question 1 and 6). The same finding was also reported by Kärrqvist (1985), Shipstone et al. (1988) and Borges and Gilbert (1999).
- "Bulb gives more light when the number of batteries increases (independent from the type of connection)" and "Bulb becomes brighter when batteries are connected in parallel compared to batteries connected in series" (question 2). These misconceptions were also found in the study of Lee and Law (2001).
- A configuration change in front of a bulb is regarded as having on effect upon the brightness of the bulb but that change after the bulb is thought to have no effect on the bulb' brightness in a serial circuit (sequential reasoning) (question 3). This misconception was reported in the studies by McDermott and Shaffer (1992), Shipstone et al. (1988).
- Batteries are constant current sources (question 4). This type of misconception was also documented in the studies of Cohen et al. (1983), Shipstone et al. (1988), Kärrqvist (1985), McDermott and Shaffer (1992), Lee and Law (2001).
- Current is consumed by circuit component (question 7). Such a misconception was also obtained by Osborne (1983), Cohen et al. (1983), Kärrqvist (1985), Shipstone et al. (1988), Lee and Law (2001).
- Bulbs in series always give more brightness (question 8). This misconception is also encountered in the study of McDermott and Shaffer (1992).

SUGGESTIONS

Nowadays, taking students' misconceptions into consideration during the development of curriculum and teaching materials is a situation that is pointed out and accepted by all researchers.

There were some studies related to the realisation and the development of students' conceptual understanding about simple electric circuits in the literature. There are certain views about which conceptual frame teaching should be based on these studies. These were studies that started teaching with the concepts of **potential difference** (Psillos et al., 1987; Psillos et al., 1988; Psillos, 1998; Lee and Law, 2001), **current** (Shafer and McDermott, 1992; Cosgrove, 1995) or **energy** (Shipstone and Gunstone, 1985; Licht, 1991; Berg and Grosheide, 1997) and established those on these concepts. All these studies emphasise the effectiveness of teaching applied in terms of learning of the students. In fact, which one of these three concepts chose to start teaching provides more effective learning is a matter of concern. It is also required to develop different concepts based teaching activities and materials, implement and put these which could be used by teachers into practice in our country.

In addition, how activities have to be designed for conceptual change is a point that should also be taken into consideration. It has been noticed that different models, analogies and cognitive conflict strategies are used in the studies conducted (Küçüközer, 2004). In general, models and analogies used in those studies are flowing water in pipes,

things that come out of battery while carrying energy and leave the energy behind in the bulb as joining the circuit again, pedaling system of a bicycle and central heating radiators used to heat houses.

Several teaching activities regarding the misconceptions found in this study can be suggested. Activities comprising an analogy and a cognitive conflict about one of the common misconceptions like the consumption of current by circuit components made be as follows: i) for instance, analogy given in Figure 3 (Summers et al., 1998) is a sample activity which can be used by teachers. Here; bicycle's pedals, chain's rotation, chains and rear cogwheel centre correspond to a battery, current, conductor wire and a bulb respectively.
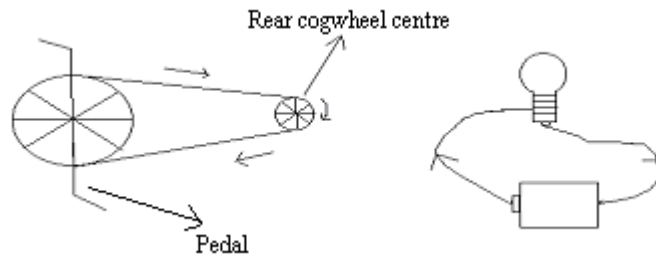
Figure 3. *An Analogy of Bicycle Pedalling System*

ii) Firstly, questioning the currents' values on both sides of a bulb and secondly showing that both ammeters measure the same values by placing an ammeter on each sides of the bulb after listening to students' explanations about a simple circuit might be an example of a cognitive conflict activity.

Misconceptions of which are emerged in ours study and not encountered in the literature show the need of investigation concerning misconceptions specifically originating from our country's culture, language and teaching strategies.

It is thought to be important that such language and teaching based misconceptions should be taken into consideration during teaching and activities aiming to overcome these misconceptions should be designed. It is necessary to warn teachers about the misconceptions caused by the use of language in the curriculum and in the teachers' handbook. Finally, it should be pointed out that students generalize the ideas fairly quickly and teaching has to be supported with different activities.

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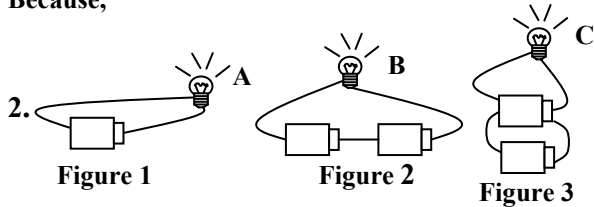
APPENDIX

CONCEPTUAL UNDERSTANDING TEST
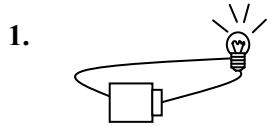
1.   A bulb is connected to a battery and gives light as shown in the figure. Explain why the bulb gives light?
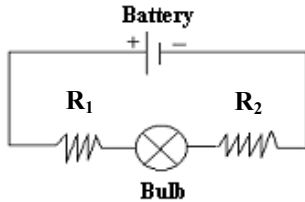
Because,

2.   Batteries and bulbs are identical in three figures. Put a X into the box next to the alternative which you think is the correct answer about the brightness of bulbs. Explain your reasoning briefly.

Figure 1   **Figure 2**   **Figure 3**

❑   A>B>C   ❑   B>A>C   ❑   B>A=C
❑   A=B=C   ❑   B=C>A   ❑   ....

Your explanation:

3.

This question involves the changes made in a sample electric circuit. Please put a X for each situation into the box next to the response you chose and explain why you choose that alternative.

a)   If R_1 decreased, brightness of bulb;

❑ INCREASES   ❑ DECREASES   ❑ STAYS THE SAME

Your explanation:

  b)   If R_2 decreased, brightness of bulb;

❑ INCREASES   ❑ DECREASES   ❑ STAYS THE SAME

Your explanation:

  c)   If R_1 increased, brightness of bulb;

❑ INCREASES   ❑ DECREASES   ❑ STAYS THE SAME

Your explanation:

  d)   If R_2 increased, brightness of bulb;

❑ INCREASES   ❑ DECREASES   ❑ STAYS THE SAME

Your explanation:

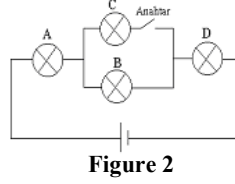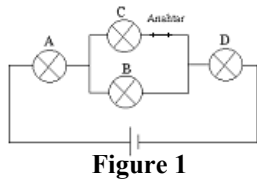4. **Bulbs and batteries are identical in the figures given below.**
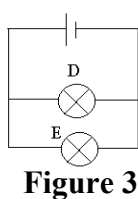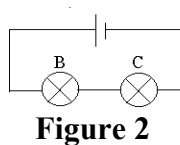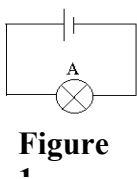
Put a X into the box next to the alternative which you think is the correct answer about the brightness of bulbs. Explain your reasoning briefly.

Figure 1   **Figure 2**   **Figure 3**

❑ A>B=C=D=E   ❑ A=B=C>D=E   ❑ A>B=C>D=E
❑ A=D=E>B=C   ❑ A=B>C>D>E   ❑ ....
Your explanation:

5. All bulbs are identical in the circuit shown in Figure 1. Use this information answers the questions below.

Figure 1   **Figure 2**

I) Switch is closed in Figure 1. Put a X into the box next to the alternative which you think is the correct answer about the brightness of bulbs. Explain your reasoning briefly.

❏ A=D>B=C   ❏ A>B=C>D   ❏ C>A=D>B   ❏ A=B=C=D
          ❏ None of bulbs are lit when the switch is closed   ❏ ....
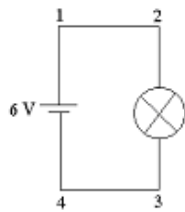
Your explanation:

II) Switch is opened in Figure 2. Put a X into the box next to the alternative which you think is the correct answer about the brightness of bulbs. Explain your reasoning briefly.

❏ A>B=C>D   ❏ A>B=D, C isn't lit   ❏ A=D>B=C   ❏ A=B= C=D   ❏
A>B>D, C isn't lit   ❏ None of bulbs are lit when the switch is opened   ❏ ....
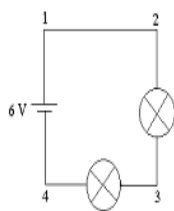
Your explanation:

6. Bulbs are identical in two circuits given below. Put a X into the box next to the alternative which you think is the correct answer about the potential difference between two specified points of each circuit.

❏ Between 1 and 2 = **6** Volt, 2 and 3 = **6** Volt, 3 and 4 = **6** Volt
❏ Between 1 and 2 = **6** Volt, 2 and 3 = **3** Volt, 3 and 4 = **3** Volt
❏ Between 1 and 2 = **0** Volt, 2 and 3 = **6** Volt, 3 and 4 = **0** Volt
❏ Between 1 and 2 = **2** Volt, 2 and 3 = **2** Volt, 3 and 4 = **2** Volt
❏ ....

Your explanation:

❏ Between 1 and 2 = **6** Volt, 2 and 3 = **6** Volt, 3 and 4 = **6** Volt
❏ Between 1 and 2 = **6** Volt, 2 and 3 = **3** Volt, 3 and 4 = **0** Volt
❏ Between 1 and 2 = **0** Volt, 2 and 3 = **3** Volt, 3 and 4 = **0** Volt
❏ Between 1 and 2 = **2** Volt, 2 and 3 = **2** Volt, 3 and 4 = **2** Volt
❏ Between 1 and 2 = **0** Volt, 2 and 3 = **3** Volt, 3 and 4 = **3** Volt
❏ ....
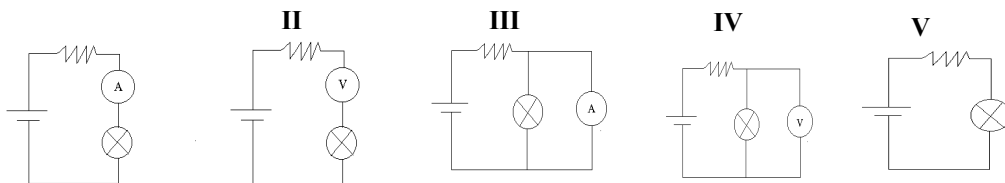
Your explanation:

7.
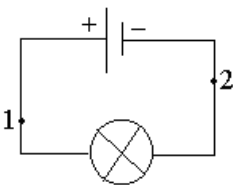
❏ 1>2
❏ 1=2
❏ 1<2

Put a X into the box next to the alternative which you think is the correct answer about the magnitude of currents in points 1 and 2 in the circuit besides. Explain your reasoning briefly.

Your explanation:

8. Resistors, bulbs and batteries are identical in all five circuits. Put a X into the box next to the alternative which you think is the correct answer about the brightness of bulbs in each circuits. Explain your reasoning briefly (A: Ammeter, V: Voltmeter).

II   **III**   **IV**   **V**

❏ I=II=V>III=IV   ❏ I=II=V>III=IV   ❏ V>I=II>III=IV
❏ I=IV=V, II and III aren't lit   ❏ I=II=III=IV=V   ❏ ....

Your explanation: