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The Korean Elementary Students' Conceptions of the Simple Electric Circuit

Sangoh Seo · Jaesool Kwon
(Korea National University of Education)

ABSTRACT

The purpose of this study was to investigate students' conceptions of the simple electric circuit using a battery and a bulb. 19 fourth grade students from a rural elementary school in Korea participated in this study. Data on the children's understandings of electric circuit were collected through three sources; prediction tests, drawing tests and individual interviews. The prediction tests were paper and pencil tests composed of 10 problems, predicting whether bulbs in 10 simple circuit diagrams would light. For each prediction, the children were asked to provide a written explanation of their thinking. The drawing tests consisted of 6 problems. One was to draw the inside of the bulb base, and the others were to make the wire connections between a battery and a bulb in the diagrams, to light the bulb. The interviews were conducted with seven children who showed differing degrees of understanding. No student was aware of the wire connections inside the bulb base. Many students stated whether the bulb would light or not, according to the tip of the bulb contacting the positive battery terminal and an end of wire contacting the negative battery terminal. Most of them thought that the tip of the bulb should contact the positive battery terminal, so that the bulb would light. In short, students did not use a scientific conception of electric current to predict and explain the electric circuit.

Key words: conception of simple electric circuit, drawing test, circuit diagram

Ⅰ. Introduction

In the constructivists' view, learning is an active, continuous process whereby the learner takes information from the environment and constructs personal interpretations and meanings based on prior knowledge and experience (Driver & Bell, 1986). Science educators recognize that students have their own ideas about some of the phenomena of interest in science, and that those ideas usually differ from scientists' current views (Cosgrove, 1995).

During the past 20 years, the role of prior alternative conceptions or misconceptions in learning natural science has been explored extensively. Students use preexisting conceptions, constructed from reflection on previous experiences, to reason about newly presented science

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concepts, and to make sense of their instructional science experiences (Zietsman & Hewson, 1986). Such preconceptions are often incorrect from a scientific viewpoint, and can interfere with students' learning of science (Driver & Easley, 1978; Fredette & Clement, 1981). Some misconceptions are very resistant to instructional change, and some students persist in giving answers consistent with their misconceptions, even after large amounts of instruction (Anderson & Smith, 1987; Champagne *et al.*, 1985; Driver & Easley, 1978; Fredette & Lockhead, 1980; Osborne, 1983; Wandersee *et al.*, 1994).

One active area of research on physics preconceptions is the topic of the simple electric circuit (Chambers & Andre, 1997). Osborne (1983) identified four prevalent models of electric current constructed by children: (a) a unipolar model, in which electricity is considered to travel by a single wire to a light and none returns, (b) a clashing-currents model, in which different electricities pass from the terminals of a battery, come together violently, and are consumed in the appliance, (c) a circulating but not conserved model, (d) a circulating and conserved model. According to Osborne (1985) and Cosgrove (1989), elementary children predominantly hold either a clashing currents or a circulating and conserved model. Shepardson and Moje (1994) suggested that the nature of children's understandings of electric circuits is dependent upon the interplay between their understandings of circuit connections and understandings of electric current, and that prior to instruction, children's understandings of electric circuits were scientifically inaccurate, and tended to emphasize understandings of circuit connections.

Shipstone (1988) argued that an important source of difficulty in simple electric circuits is the construction of the bulb, which was not designed for teaching children about electricity, though widely adopted for that purpose. Typically, many children treated the bulb as a one terminal device with current flowing to it, rather than through it, and consider the threaded part of the bulb base as a device to secure the lamp in a holder (Shipstone, 1984; Shipstone, 1988; Kim *et al.*, 1999).

In the Korean elementary science curriculum, the simple electric circuit is presented in semester 3-2 for the first time. The unit of 'batteries and bulbs' in semester 3-2 is composed of nine activities to introduce children to concepts about electric circuits (Ministry of Education of Korea, 1996):

- Lighting up a bulb with a battery
- Finding out circuits that light up a bulb
- Observing construction of a bulb
- Two sides of a battery
- How to use bulb socket and battery holder
- Materials through which electricity can flow or not
- Lighting up a bulb with two batteries
- Comparing brightness of a bulb with two batteries, in series and in parallel
- Making a flash light

When students participate in observing the construction of a bulb, they learn the connections of the filament with the tip of the bulb and the side of the bulb in the metal base of the bulb, and discuss the pathway that the current follows from one end of a battery to the other end of it.

Although Korean elementary students learn the construction of a bulb in third grade, many children fail to understand simple electric circuits (Kim *et al.*, 1999; Kim *et al.*, 1992). Kim *et al.*(1999), who investigated Korean sixth graders' understanding of simple electric circuits, reported students' low understanding of a bulb connection and the role of the wire in a simple electric circuit.

The purpose of this study is to investigate Korean fourth graders' understanding of the construction of a bulb, and their conceptions of the simple electric circuit using a battery and a bulb. Therefore, this study provides us with a comprehensive description of children's conceptions of the simple electric circuit, implications for teaching electric circuits to elementary school students, and several suggestions for the curriculum.

Ⅱ. Method

Nineteen fourth grade students participated in this study at a rural elementary school in Korea. The participants consisted of 9 boys and 10 girls who already had learned about simple electric circuits in third grade. Pseudonyms are used throughout this study to refer to all participants.

Data on children's conceptions of electric circuit were collected through three sources; prediction tests, drawing tests, and individual interviews. The prediction tests consisted of 10 problems predicting on paper whether a bulb would light. Each problem consisted of a simple circuit diagram of a battery, a bulb, and a wire (Fig. 1). For each prediction, the children were asked to provide a written explanation of their thinking.

The drawing tests consisted of 6 problems. The first problem was to draw the connections of the filament in a bulb with the tip of the bulb and the side of the bulb in its metal base. The children were given a diagram in which the inside of the bulb was blank, and were asked to draw the inside of the bulb. The other five problems consisted of a diagram in which there were only a bulb and a battery (Fig. 2). The children were asked whether the bulb would light if there were connections between the battery and the bulb, and then asked the reason they thought so. The children who answered 'yes' to these questions were asked to draw wire(s) in the diagram so as to light the bulb, and to explain their drawings.

The interviews were conducted with seven children who exhibited differing degrees of understanding in the prediction tests and the drawing tests. Questions based upon the children's responses in the prediction and the drawing tests were asked. The interviews were audiotaped and transcribed, verbatim.

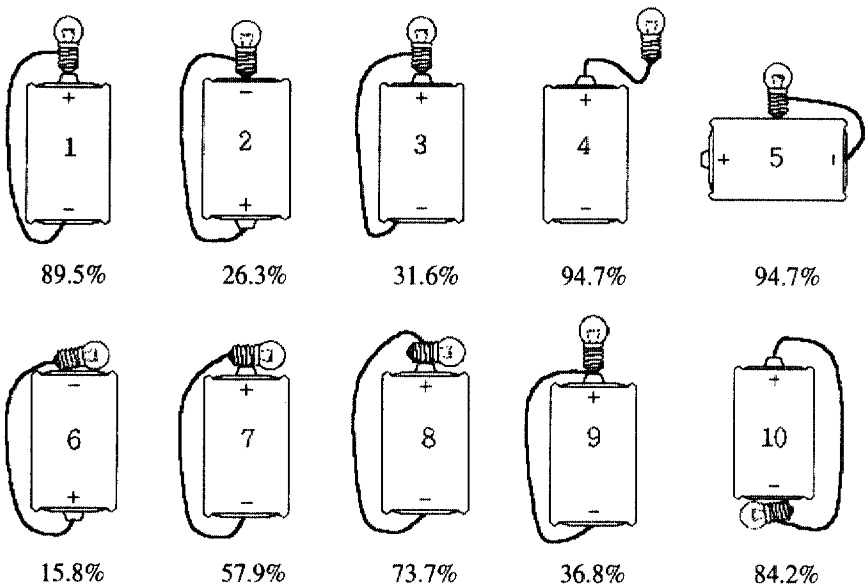

Fig. 1. The simple electric circuit diagrams, and percentage of correct answers

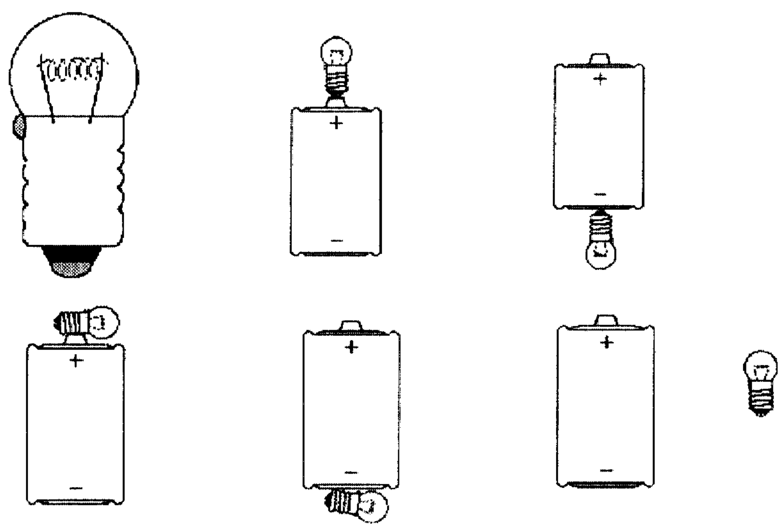

Fig. 2. The six drawing diagrams

Ⅲ. Results and discussion

We used the prediction and drawing tests to investigate children's conceptions of a simple electric circuit. An analysis of the data gained from the prediction tests, the drawing tests, and individual interviews, revealed several misconceptions that fourth graders had in the electric circuit problems. Many children emphasized the role of the tip of the bulb, and thought that the bulb must be in contact with the positive battery terminal to light the bulb in a simple electric circuit composed of battery, bulb and wire. Some children gave responses that showed a unipolar current model, in which electricity is considered to flow by a single wire to a bulb, and none returns. All children who participated in this study were unaware of the construction of a bulb. Nobody gave correct answers to all of the problems in the prediction tests and the drawing tests.

In the next section, we present children's understanding of the construction of a bulb by their drawings of the inside of the bulb base, and children's understandings of the electric circuit as inferred from the data on the circuit problems. In the following section, we provide representative samples from the case records.

1. Children's Understandings of the construction of the bulb

Fig. 3 Shows the children's drawings of the inside of the bulb. None made the scientific response of a connection of the filament with the tip of the bulb and with the side of the bulb (Fig. 3. a). Fifteen children (78.9%) drew two lines between the filament and a black insulating

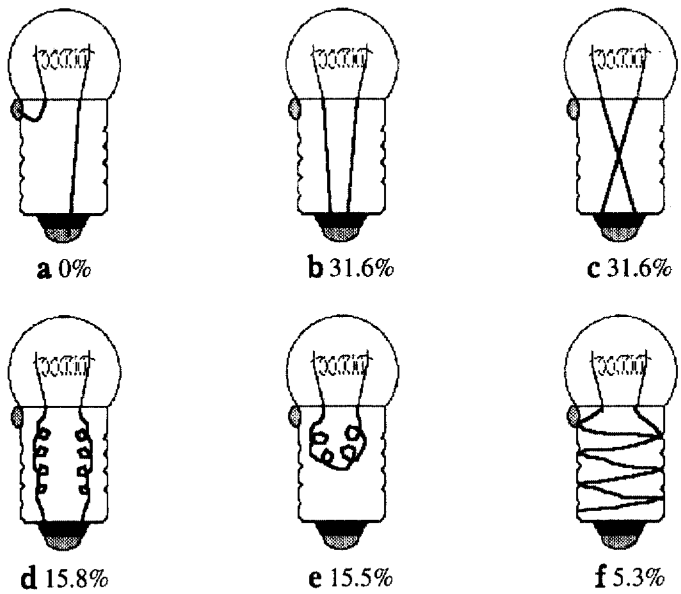

Fig. 3. The children's drawings of the inside of the bulb, and percentage of each drawing

material in the bulb base (Fig. 3. b, c, d), three children (15.8%) connected both ends of the filament (Fig. 3. e), and only one child connected the filament with the side of the bulb (Fig. 3. f). When we asked seven children if they had looked at, or learned about the inside of the bulb, they answered that they had no experience about that.

Without understanding of the construction of the bulb, it is impossible for children to understand the electric circuit, the flow of a current of electricity in a simple electric circuit using a battery, a bulb and a wire. Although the children already had learned the construction of the bulb in third grade, none were aware that the bulb has two electric terminals; the outside terminal and the center terminal of the bulb, located in the side of the bulb and the tip of the bulb.

Several explanations may be considered for why the children did not know about the inside of the bulb, although they already had learned about it. First, there might be some problems in the teaching practices about the construction of the bulb. In order to observe the inside of the bulb, students would have to break the bulb. But this hands on activity seems to be dangerous to the children. Therefore, instruction about the construction of the bulb might have been given without students' hands-on activity. Second, students had little experience dealing with the bulb without the bulb socket. According to the Korean elementary science curriculum, students receive in total 23 lessons about electric circuit. But bulbs without the socket were used in only 3 lessons, in introductory instruction about electric circuits. Third, the construction of the bulb may be difficult for third grade students. Understanding the construction of the bulb involves the concepts of electrical conductor and nonconductor.

The results of the children's drawing of the inside of the bulb indicate problems in the science curriculum or instructional practices concerned with electric circuit.

2. Children's Understandings of the Electric Circuit

The result of the children's responses and drawings to the drawing tests was presented in Fig. 4. The rate of correct answers was very low. The number of children who gave correct answers to problem 1 was 5 (26.3%), to problem 2 was 4 (21.1%), to problem 3 was 5 (26.3%), and to problem 4 was 2 (10.5%), and nobody gave the correct answer to problem 5. The rate of correct answers in the drawing test was relatively low compared with the prediction tests (Fig. 1).

Several cases showed a unipolar current model. In response to the first question 'Will this set-up light?' at each problem, all answered 'no', except two children, Hunhee and Sunjoo in problem 3. In problem 4 of the prediction tests (Fig. 1), Yunhee responded that the bulb would light. These responses by Hunhee, Sunjoo, and Yunhee represent a unipolar current model, in which electricity is considered to travel by a single wire to a light, and none returns (Osborne, 1983). However, it is difficult to say that they had a unipolar current model, because they didn't represent a unipolar current model in the other problems. Their inconsistent responses to the problems in the prediction and the drawing tests demonstrated that their conceptions about electric circuit were inconsistent in the circuit conditions.

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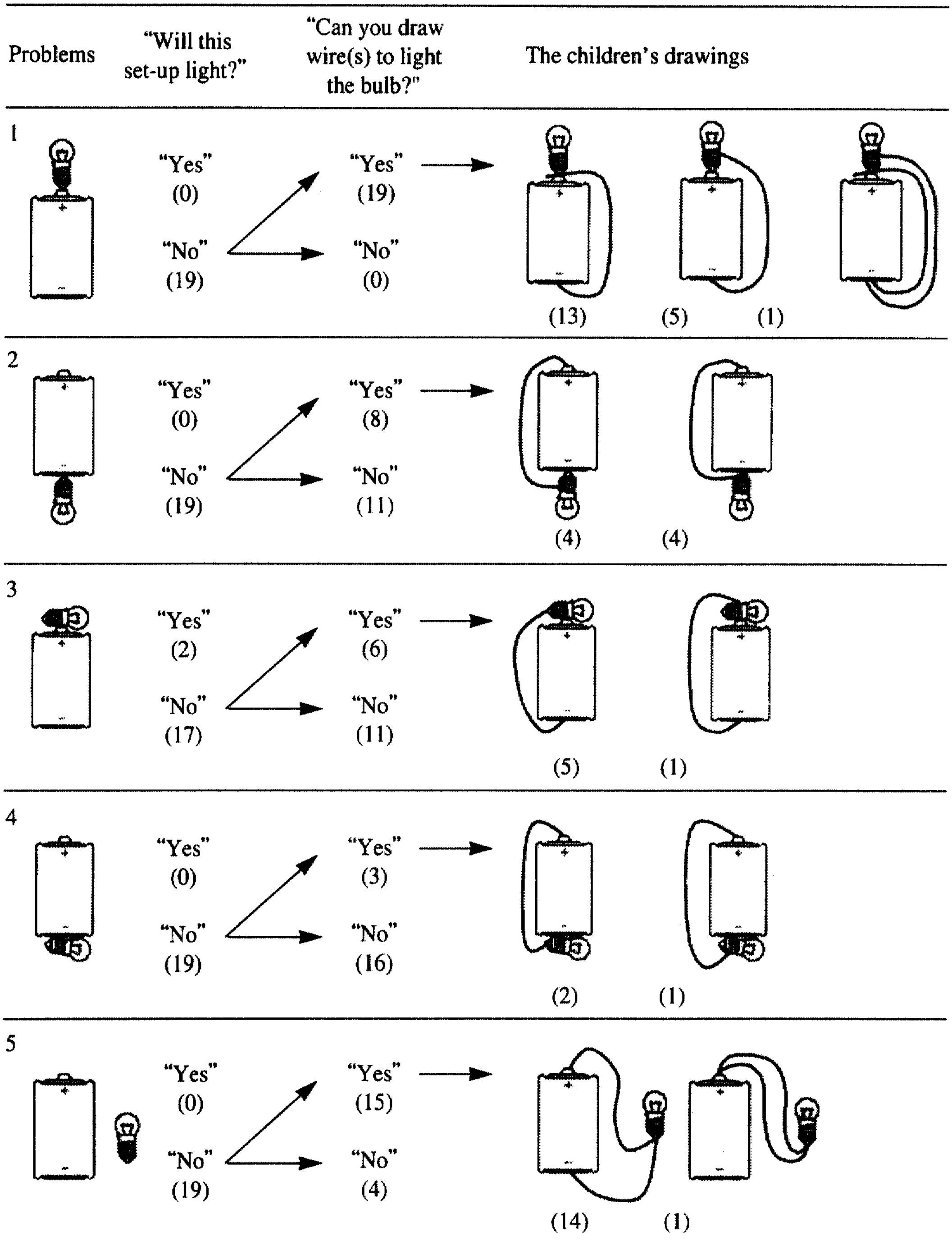

Fig. 4. The children's drawings of connections between a battery and a bulb

Many children emphasized the positive battery terminal, which the bulb would have to be connected with to light the bulb in a simple electric circuit using a battery, a bulb, and a wire. There were five problems in which the bulb was placed on the negative battery terminal; problems 2, 6 and 10 in the prediction tests (Fig. 1) and problems 2 and 4 in the drawing tests (Fig. 4). In problem 2 of the prediction tests, fourteen children (73.7%) responded that the bulb would not light. All of them made the same predictions in the problems 6 and 10 of the prediction tests. In problem 2 of the drawing tests, eleven children (57.9%) responded that the bulb would not light, even if wires were used. All of them also gave that answer to problem 4 of the drawing tests. In these problems, they gave reasons such as 'because the bulb touched the negative battery terminal', 'because the bulb was not located properly', 'because the bulb should placed on the positive battery terminal', 'because the positive battery terminal was displaced with the negative battery terminal'. Three children, Sunjoo, Injeong, and Sangwoo predicted that the bulb would not light in problem 2 of the prediction tests, but responded that the bulb could light if wires were used in problem 2 of the drawing tests. The children's responses to these problems illustrated that many children emphasized the positive battery terminal, and responded consistently, except in a few cases.

Many children thought that the tip of the bulb should contact one end of the battery terminals in the simple electric circuit using a battery, a bulb and a wire. In problem 3 of the drawing tests (Fig. 4), eleven children (57.9%) responded that the bulb could not light even if a wire connection were made. All of them also responded with the same answer to problem 4 of the drawing tests. And eight children (42.1%) predicted that the bulb would not light in problem 7 of the prediction tests (Fig. 1) for these reasons: 'because the bulb leaned', 'because the tip of the bulb had to contact the battery', 'because the side of the bulb contacted the battery'. There were four problems in which the side of the bulb contacted the battery in the prediction tests (problem 6, 7, 8, and 10). The response rate to these problems that stated that the bulb would not light was 71.1%. These results proved that many children regarded the tip of the bulb as more important than the side of the bulb.

Many children were unaware of how to make connections of the wire with the bulb to light the bulb. In problem 1 of the drawing tests, all children responded that the bulb would not light in that set-up, but they could make connections that would light the bulb. Thirteen children (68.4%) drew a line between the negative battery terminal and the tip of the bulb. And in problem 5 of the drawing tests, fourteen children (73.7%) drew two lines, from each end of the battery to the tip of the bulb. In problem 9 of the prediction tests, twelve children (63.2%) predicted that the bulb would light. They explained that 'because electricity could flow through the tip of the bulb', 'the bulb would light if the wire contacted the bulb and the battery', 'because the wire contacted both ends of the battery'. These results indicated that many children were unaware that two electrical terminals of the bulb should contact an end of the battery, and they thought that the role of the tip of the bulb was more important than the side of the bulb. This coincides with the children's drawings of the inside of the bulb in which fifteen children made connections of lines with the tip of the bulb.

Many children thought that the margin of the negative battery terminal didn't transmit electricity. Thirteen children (68.4%) predicted that the bulb would not light in problem 3 of the prediction tests (Fig. 1). Their reasons were 'because the wire was not touching properly with the negative battery terminal', 'the wire should be located in the center of the battery'. This result proved that children had little experience in handling apparatus such as a battery, wire, and bulb without socket.

Hojin's explanations

To illustrate the children's conceptions of the simple electric circuit, we present interview excerpts from the case records of Hojin. Hojin was selected because he was a typical student.

Hojin was unaware of the inner construction of the bulb. He drew two straight lines between the filament and the black insulating material in the bulb base (see Fig. 3.b). His answers to questions about the construction of the bulb illustrated that he was not confident of his answers.

I: Do you think electricity can flow through this part [side of the bulb]?
H: Maybe.... will flow because of iron.
I: How about this part [tip of the bulb]?
H: Um..... will flow.
I: How about this part [black insulating material]?
H: ....will not......
I: Have you ever learned about the inside of a bulb?
H: No.
I: Have you ever looked at the inside of a bulb?
H: No.

Hojin did not know the structure of the inside of a bulb, and did not even remember receiving lessons about the inside of the bulb in third grade.

Hojin thought that the tip of the bulb should contact one end of the battery terminals in a simple electric circuit that consisted of a battery, a bulb and a wire. An extract of the interview in problem 3 of the drawing tests is presented below to illustrate his understanding about the tip of the bulb.

I: Will this set-up light?
H: No.
I: If you make a wire connection, will the bulb light?
H: No.
I: Why do you think so?

H: The tip of the bulb is not touching the battery, the side of the bulb is touching the battery.

I: Let's make a connection like this (drawing a line between the tip of the bulb and the negative battery terminal). Will it light?

H: No.

I: Why do you think so?

H: The side of the bulb is touching the battery.

I: Then, let's try like this (drawing a line between the side of the bulb and the negative battery terminal). How about this?

H: It will not light.

I: Why?

H: Because the tip of the bulb is out of place.

Hojin gave the same explanation in problem 4 of the drawing tests. He responded consistently to other problems concerned with the tip of the bulb. Hojin regarded the tip of the bulb as the important part, rather than the side of the bulb. Therefore, he thought that the tip of the bulb had to be touching one of the battery terminals.

Hojin was unaware that two electrical terminals of the bulb should be connected with ends of the battery. He did not even know that the bulb has two electrical terminals. We present Hojin's responses to problem 1 of the drawing tests.

I: Look at this diagram. Will this set-up light?

H: No, it will not light.

I: If you make a wire connection, will the bulb light?

H: Yes.

I: Have a try.

H: (drawing a line between the negative battery terminal and the tip of the bulb)

I: Can you explain your drawing?

H: The tip [the tip of the bulb] is in the proper place [the positive battery terminal], and the wire is in the proper place too.

I: Let's make a connection like this (drawing a line between the side of the bulb and the negative battery terminal). Will it light?

H: Yes.

I: Why do you think so?

H: Because.... I think the tip of the bulb is connected with the side of the bulb.

Hojin explained problem 2 of the drawing tests in the same way. He thought that the tip of the bulb was connected with the side of the bulb, therefore, only if the tip of the bulb was touching one end of the battery terminal, the bulb would light, though the wire connected the other end of the battery terminal and the side of the bulb. Hojin's response illustrates that students understanding of the construction of the bulb is important to understand the electric circuit, so that has to come ahead of the understanding of the electric circuit.

Ⅳ. Conclusion and Implications

We investigated fourth grade students' conceptions of a simple electric circuit through the prediction tests, the drawing tests, and individual interviews. Most children held an understanding of electric circuits that contradicts the scientific view. Although the children already had learned in third grade about electric circuits and the structure of the bulb, the children's understanding was very low. Nobody made all correct answers to all problems of the prediction tests and drawing tests. The rate of correct answers in the drawing tests (16.8%) was relatively low, as compared with the prediction tests (60.5%).

The analysis of data gained from children's responses and explanations in the tests and interviews revealed the children's understandings of electric circuit. All of the children were unaware of the construction of the inside of the bulb. Most of them did not remember receiving lessons about the structure of the bulb in third grade. Most of the children explained their predictions and drawings with a circulating current model, but some children's responses were based on a unipolar current model. Many children emphasized the positive battery terminal, rather than the negative. They thought that the bulb had to be connected with the positive battery terminal to light the bulb. And many children regarded the tip of the bulb, rather than the side of the bulb, as the important part. They thought that the tip of the bulb had to contact one end of the battery terminals. Many children were unaware that the bulb has two electrical terminals that should be connected with both ends of the battery to light the bulb.

The children's responses prove that it is impossible to understand the concept of electric circuit without first understanding the construction of the bulb in elementary school. In conditions where children have no understanding of the construction of the bulb, to teach the children the concept of electric circuit by a simple electric circuit that includes a bulb may cause misconceptions.

These conclusions carry implications for instructional practices and the science curriculum in elementary school. First, the result of this study showed that there were some problems in the elementary science curriculum or in instruction concerned with the electric circuit. Shipstone (1988) claimed that understanding of electric circuits was difficult for children because the construction of the bulb was not designed for teaching children about electricity. Although the construction of the bulb was included in the elementary science curriculum in Korea, none of the children were aware of the construction of the bulb. These results should be considered in a reconstruction of the curriculum.

Secondly, children's hands-on activity dealing with a battery and bulb without socket should be reinforced. The result of this study proved that children were unaware of the construction of the bulb and battery, though they had been taught about electric circuits.

Thirdly, we agree with White and Gunstone (1992) that the assessment of children's understandings of electric circuits should involve multiple, diverse assessment tasks. Teacher assessment has been conducted mainly through the use of paper and pencil instruments. But the result of this study revealed that it is difficult to understand children's conceptions of electric circuit only by prediction tests. We propose the use of drawing tests to probe children's conceptions of electric circuit.

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