Primary Pupils' Conceptions About Some Aspects Of Electricity

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Introduction

In the article on action research by Cox and Craig (1997), it is pointed out that practising teachers could take advantage of their data-rich classrooms in order to provide some answers to specific questions about pupil learning. This paper reports on such an attempt by the first author in order to answer some specific questions which arise in the context of his day-to-day teaching.

Many investigations on pupils' conceptions of various aspects of electricity have been reported in the literature. The vast majority of these have been carried out based on samples of students in Europe, North America, Australia and New Zealand. While some investigations have been based on Asian students, to-date there is none conducted based on Singaporean students.

Among the overseas studies, some involve children as young as 6 and 7 years old (e.g., Newton & Newton, 1996). Others involve children aged 8 to 12 years (e.g., Osborne, 1982; Jabin & Smith, 1994; Vickery & Flitton, 1995; Parker & Heywood, 1996). There are also a number of studies which extend the research to students of age up to 18 (e.g., Osborne, 1983; Tasker & Osborne, 1985; Shipstone, 1984, 1985, 1988). These studies are generally regarded as particularly enlightening because the students studied span an age range from 9 to 18 years.

These studies suggest that students generally think of electric current flow in a circuit in five distinct ways or models. Firstly, there is the "single-wire" model which suggests that current leaves the battery and travels through one wire to a bulb which serves as a kind of electricity "sink". In the second model, the "clashing currents" model, electricity leaves the battery from both terminals and travels towards the bulb where it is "used up". In the next three models, there is one commonality in that there is unidirectional flow of electric current. However, two of these three models are in variance with the accepted science view; these are termed "unidirectional without conservation" and "unidirectional with sharing". The last model, which is the scientifically acceptable view, is termed "unidirectional with conservation". In the "unidirectional without conservation" model the current is viewed as gradually becoming weaker as it flows through the circuit as a result of encountering various components of the circuit, such as the bulb. In the "unidirectional with sharing" model, the current is distributed to and consumed equally by all components of the circuit, with all bulbs achieving the same brightness, but the current is not regarded as conserved.

The "single wire" model is reported as most common among younger children, more than 50 percent of whom set up such a circuit when asked to get the bulb to glow. The "clashing current" model appears to be favoured by about 35 to 40 percent of the children in their middle years. It is gradually replaced by "unidirectional" models - with the concept of conservation gradually becoming evident in about 10 percent of the subjects at about age 12 and rising to about 60 percent by age 18.

Rationale for Study

Anecdotal evidence suggests that many practising teachers in Singapore consider the topic of electricity as one of the most difficult in the primary four (P4) science syllabus. This is reflected in the high number of pupils who are unable to demonstrate mastery in the topic even after repeated teaching. At the same time it appears that there has yet been no study carried out to investigate what conceptions pupils hold with respect to the various concepts of electricity that are being taught to them.

Thus, this piece of action research is embarked on, as a small step towards finding out what kinds of conceptions a class of primary four Singaporean pupils might have concerning various aspects of electricity before and after formal instruction.

Method

In Singapore, all primary schools followed the same set of science syllabuses and textbooks with accompanying pupils' workbooks and teacher's guide produced by the Ministry of Education. Science is introduced as a formal subject in the curriculum only from Primary three (P3) or the equivalent of grade 3 where children are generally aged 9-10 years. The dominant method of teaching advocated for primary science is the activity-centred approach which involves pupils handling concrete materials and working in small groups of 4 to 6. At P4, pupils are placed into one of three streams according to their examination performance in three subjects, viz., English, Arithmetic and Mother Tongue Language (i.e., Chinese Language for pupils of Chinese descent; Malay Language for Malay Pupils; Tamil Language for Indian pupils, and so forth.)

The topic on electricity was only taught at the P4 level. The science syllabus for the topic broadly includes the following aspects:

- what is electricity / electric current
- simple electric circuits
- conductors and insulators

- arrangement of batteries, bulbs and switches in parallel and series arrangement

These aspects are not followed on at the P5 or P6 levels. A total of 17 periods, of 30 minutes each, is the recommended time for a teacher to teach the above aspects. The formal instruction method used is the activity-centred, guided inquiry method that involves pupils handling concrete materials and working in small groups of 4 to 6. Thus, for the topic on electricity, pupils were exposed to eight activities detailed in the pupils' science workbook.

Data Collection

The main instrument for data collection is a semi-open, paper-pencil questionnaire comprising five questions that encompass various aspects of electricity stipulated in the P4 Science syllabus.

1. The first question which comprises three parts (a) to (c) is focussed on pupils' conceptions about conductors and insulators.

   a. What do you think is an 'electrical conductor'?
   b. What do you think is an 'electrical insulator'?
   c. Do you think that water is a an electrical conductor or insulator?

      Why do you think so?

      In this instance, the expected response is that water is a conductor as it allows electric current to pass through.

2. The second question presents a drawing of an 'Eveready' battery and requires pupils to state (and support their answer with reasons) whether they think there is an electric current flowing within the brand new 'Eveready' battery.

3. The third question comprises two parts, (a) and (b). Part (a) contains four correctly drawn, identical, closed circuits. In each diagram, a possible path taken by electric current as it flows through the circuit is shown and labeled. Pupils are asked to choose from options (a) to (d), and support with their reasoning, the path that they think is correct. Option 'a' presents essentially a "clashing currents" view of current flow. Option 'b', the most appropriate answer, shows the "unidirectional model" where the path of electric current flow is through all the bits in the circuit in the direction from the positive to the negative terminal of the battery. Option 'c' shows essentially a "single-wire" view in that it depicts the current leaving the positive terminal of the battery and travelling through one wire to the bulb (which serves as a kind of electricity "sink") and at the same time there is no current flow in the other wire. Option 'd' is similar to option 'c' in that it shows a "single-wire" view but it shows the current leaving the negative terminal of the battery and travelling through one wire to the bulb, with no current flow in the other wire.

Part (b) requires pupils to suggest reason(s) why a lighted bulb in an electrical circuit dims and fades off after some time.

4. The fourth question contains a cross sectional view of a lighted torch, with three new identical batteries inserted into the battery chamber and the bulb lighted up. The batteries were labeled as Battery 1, Battery 2 and Battery 3 with Battery 3 nearest to the bulb and Battery 1 the furthest. Pupils are asked whether the magnitude of electric current flow in each of the battery is the same, or otherwise, and stating their reason(s). In this instance, the magnitude of electric current flowing within the circuit is almost constant.

Administration of the questionnaire

The questionnaire was administered to an intact class of P4 pupils (N=37) in a normal government school, prior to formal instruction on the topic. The class was generally regarded as comprising pupils of average scholastic ability and of lower socio-economic home background. The pupils were asked to express their views through written responses to the questionnaire. The same set of questionnaire was administered to the class immediately after formal instruction to study the effect of formal teaching on pupils' conceptions about the topic. Interpretation of the responses was validated through one-to-one interview sessions with a subset of the sample studied (N=14).

Findings

1. What are pupils' conceptions about conductors and insulators?

(a) What do you think is an electrical conductor?

	No. of pupils who showed some understanding	No. of pupils who did not answer or were "not sure" or had "no idea"
Pre Instruction	12	25
Post Instruction	16	21

Table 1: Number of pupils who showed some understanding of term 'electrical conductor' vis-à-vis those who showed no understanding.

Prior to instruction, twelve (32%) of the pupils demonstrated some level of understanding of the term electrical conductor. Their understanding was expressed in two main ways. Three of them stated that "it is something that electric current can flow in". Nine of them stated that

" it is a metal wire". The rest either did not answer the question or stated that they were "not sure" or had "no idea" about the term electrical conductor.

After instruction, sixteen (43%) of the pupils demonstrated some level of understanding of the term electrical conductor; among these, six stated that it "lets electric current to pass through" while ten of them stated that "it is something that is made of metal" (or something to that effect). However, the rest of the pupils either did not provide any relevant answers or stated that they were "not sure" or had "no idea".

(b) What do you think is an electrical insulator?

	No. of pupils who showed some understanding	No. of pupils who either did not answer the question or stated that they are "not sure" or have "no idea".
Pre Instruction	4	33
Post Instruction	16	21

Table 2: Number of pupils who showed some understanding of term 'electrical insulator' vis-à-vis those who showed no understanding.

Prior to instruction, only four pupils (11%) showed some level of understanding of the term electrical insulator. Among these, one stated that "it is a bad conductor of electric" while three stated that "it is rubber or plastic" The remaining thirty three (89%) either stated explicitly that they "don't know" or gave irrelevant comments (such as "it is a thing that could touch water" or "because there is no electric" or "because light could pass through it" or "the light will stop").

After instruction, 16 pupils (43%) were able to show some understanding. Among these, eight pupils stated that "it does not let electric current to pass through" while four stated that "it is plastic, rubber or glass" and yet another four pupils stated that "it is anything that is not metal". The rest did not give any relevant answers.

(c) Classify and explain whether if water is an electrical conductor or insulator

	No. of pupils who stated that water is a conductor	No. of pupils who stated that water is an insulator

Pre Instruction	25 (only 5 with acceptable reason)	12
Post Instruction	20 (12 with acceptable reason)	17

Table 3: Number of pupils who classified water as an electrical conductor vis-à-vis those who classified water as an electrical insulator.

Prior to instruction, twenty five pupils (68%) stated that water is a conductor of electricity. However, among them, only five (14%) were able to offer an acceptable reason for their answer by stating that "water lets electricity to pass through it". The rest (54%) gave unacceptable answers such as "water is a liquid", "water is a good conductor of heat", "no idea". The remaining twelve (32%) stated that water is an insulator giving reasons that "it has no electric current", "it allow electricity to pass through them" or "no idea".

After instruction, twelve pupils (32%) stated that water is an electrical conductor and were able, at the same time, to provide an acceptable reason for it being so. At the same time, there were seventeen pupils (i.e., an increase of five pupils) who stated that water is an electrical insulator.

2. Do you think an electric current exists in a battery?

	No. who stated that battery has no electric current flowing in it	No. who stated that battery has an electric current flowing in it	No. who are not sure or have no idea
Pre Instruction	10	19	8
Post Instruction	7	20	10

Table 4: Number of pupils who stated that an isolated battery has no electric current flowing in it vis-à-vis those who stated that it has an electric current flowing in it.

Prior to instruction, ten pupils (27%) stated that there is no electric current flowing in the battery. A variety of reasons were given and they included reasons such as "there is no casing and bulb", "battery don't have current", "battery is not in contact with anything" and "battery has no switch or wire". Nineteen (51%) however, stated that there is an electric current flowing in the battery. Reasons offered included, "it can give off light", "there is wire in the battery", "it is made of metal", "battery can make radio and torchlight work". The remaining eight (22%) explicitly stated that they did not have any idea.

After instruction, there were seven pupils (19%) who stated that there is no electric current flowing in the battery, which is rather unexpected since this represents a decrease of three pupils from previously. At the same time there was a small increase in the number who stated that the battery has an electric current flowing in it as well as in the number who stated they were not sure or had no idea.

3(a) Can you identify the path taken by electric current in a closed circuit?

	Option a	Option b (correct answer)	Option c	Option d	I have no idea
Pre Instruction	17	9	6	1	4
Post Instruction	8	23	3	0	3

Table 5: Number of pupils who opted for different paths of current flow

Prior to instruction, nine pupils (26%) chose option 'b' as the correct answer. However, among them, only three suggested that electricity current flows round and round. The other six did not know why. The main reason given by the pupils who chose option 'a' was " energy is passed from the battery through the two wires to the bulb". The main reason given by pupils who chose options 'c' or 'd' was that "the battery supplies current to the bulb". There were four pupils who stated that they had no idea how an electric current flows in a closed circuit.

After instruction, twenty three pupils chose option 'b' as the correct answer. While this represents an increase of fourteen pupils who chose the correct answer, twelve of these did not really offer an acceptable reason; instead, they had either not offered any reasons at all or had merely given tautological responses, such as "it is correct".

3(b) When a battery is connected to a circuit like the one you have chosen in part, why is it that after some time, the bulb will not light up any more?

	There is no more energy from battery	All electricity is used up	Battery current has weakened	Battery has gone flat	No idea or irrelevant response
Pre Instruction	0	1	15	1	20
Post Instruction	15	8	0	1	13

Table 6: Number of pupils who gave the different kinds of responses to the question why the bulb will not light up anymore after some time

Prior to instruction, nineteen pupils (51%) stated that they had no idea why the bulb dims and fades off after some time; and there was one pupil who gave a somewhat irrelevant response, viz., "No, the battery will keep going". There was one pupil who stated that "the electricity is used up" and also one pupil who stated that "the battery had gone flat". At the same time, there were fifteen pupils (40%) who gave the reason that "the battery current has weakened".

After instruction, there were fifteen pupils who gave the acceptable reason that "there is no more energy from the battery" or "the energy of the battery is used up". At the same time, there were eight pupils (22%) who gave the reason that "the electricity is used up". There was no suggestion by any pupil of the conversion of electrical energy to light and heat.

4. *Can you identify which battery has the most current flowing through it?*

	Same amount of electric current through' all 3 batteries	Battery 1 has most current flowing through	Battery 3 has most current flowing through	I have no idea
Pre Instruction	2	8	22	5

Post Instruction	6	8	14	9

Table 7: Number of pupils who indicated whether Batteries 1, 2 and 3 have same or different amount of current flowing in them

Prior to instruction, only two pupils (5%) stated that the batteries all have the same current flowing through them. Thirty pupils (81%) however, suggested that relative position of the batteries from the bulb and with each other determine the extent of electric current flowing through them. The remaining 5 pupils (14%) stated that they have no idea.

After formal instruction while there is an increase in the number of pupils who stated that the amount of current flowing through all 3 batteries is the same, these pupils remained unable to furnish a reason for their answer.

The pupil's responses to this question could be taken as an indication, albeit tentative, of the pupil's model of current flow in a closed circuit. Thus, it could be inferred (albeit tentatively) that the twenty two pupils who stated that the amount of current flow in the batteries are not the same probably did not have the accepted "unidirectional with conservation" view of the electric current. Instead these pupils appeared to subscribe to the view that electric current gets consumed as it flows in the circuit.

Discussion

The results to question 1 show that in spite of formal instruction, more than half of the P4 pupils have not grasped the concept of electrical conductors and insulators; and were at the same time unable to classify water as an electrical conductor. Some of them appeared to have confused heat conductors with electrical conductors. This is perhaps due to the fact that the topic of heat and heat conduction was taught to the class immediately before the topic on electricity.

The results to question 2 show that formal instruction did not improve pupils' conception on whether there is a current flowing in the battery; instead, the opposite outcome was observed in that there was a decrease in the number of pupils who stated correctly that there is no electric current flowing in the battery. This is a matter for concern and this question was probed in depth at the one-to-one interview with selected pupils. In the interview, pupils were presented with a battery and asked whether they thought there is a current flowing in the battery. Five of these pupils answered in the affirmative. They were then encouraged to explain their thinking. Two of them suggested that "battery contains electricity", and when probed further as why they think there is a electric current flow in the battery, they replied that "electricity is electric current, isn't it?"

Thus, it appears that pupils "who really know their stuff" such as those two interviewed are put in a somewhat confused situation. On one hand, they have acquired the intended science concepts that "battery is a store of electricity" and that "electricity is a flow of electric current"; on the other hand, they have not learned the finer distinctions between these two concepts. From their perspectives, based on these two concepts they have acquired, it would appear quite logical to infer that there must be a current flowing within the battery itself.

This suggests that perhaps the teacher should point out more specifically that the battery contains chemicals which react to produce electric current, but it does not mean it stores electricity in the sense that reservoirs store water. Perhaps the concept that "the battery is a store of electricity" should be replaced with "the battery is the source of energy in an electrical circuit" in order to minimize pupils' confusion. This in turn would suggest the topic on "electricity" should be moved from P4 to P5 or even P6 after concepts of energy and energy conversion have been covered. In other words, some re-sequencing of the current topics in the syllabuses might be appropriate if pupils' learning is to be enhanced.

The results on question 3b (on the reason why a lighted bulb dims and fades off after some time) are another reflection of the difficulties experienced by pupils which have been surfaced in question 2. These relate to the fact that the concepts of energy and energy conversion have not been taught to the pupils prior to the teaching of the various aspects on electricity. While it can be argued that the reason why a battery goes flat is not strictly in the P4 syllabus, yet it is not uncommon for pupils to raise the such a question (since it is part of everyday experience that batteries do have limited life-spans and need to be replaced after some time.)

From pupils' responses to questions 3a and 4 some inference could be made as to the kind of mental models pupils might hold with respect to current flow in a circuit. The results on question 3a (identification of path taken by the electric current) suggest that after formal instruction, about one fifth of the pupils appear to hold the "clashing current" model of electric flow while about one-tenth of the sample appear to hold the "single wire" model of current flow. While these proportions are not generaliseable to the entire cohort or population, they are not unexpected given the findings reported of overseas sample as stated in the introduction section of this paper. These figures are a reminder to classroom teachers that a variety of different conceptions persist even after teaching and that more specific conceptual change teaching strategies might be called for if these less acceptable models of current flow are to be replaced with the scientist's view.

From pupils' responses to question 4, it could be inferred (albeit tentatively) that the pupils who stated that the amount of current flow in the batteries are not the same probably did not have the accepted "unidirectional with conservation" view of the electric current. Instead these pupils appeared to subscribe to the view that electric current gets consumed as it flows in the circuit. Thus it appears that at most only 15% of the sample thought that electric current is conserved as it flows in a closed circuit. This figure is not unreasonable compared with the corresponding figures reported in overseas studies. The results suggest that conceptual change strategies might be called for, if pupils' alternative conceptions of current flow (i.e., conceptions which are contrary to the "unidirectional flow of current with conservation") are to be addressed.

Overall, the study also reveals the difficulties involved in using a semi-open questionnaire to investigate the P4 pupils' conceptions of electricity. This is because the items in the questionnaire inevitably introduce various concepts and ideas, which might or might not be pre-existing in pupils' minds. Perhaps some of the pupils' learning about electricity has come about through the senses and remain so, in the enactive mode (in Bruner's terms). This suggests that perhaps a more reliable and valid instrument for accessing pupils' conceptions might be the one-to-one clinical interview involving the use of a minimum number of technical terms; and at the same time, the optimum use of concrete materials.

Conclusion

Whilst the findings of the action research reported here should be limited to the sample of P4 pupils studied and are not generalisable to the entire P4 population, they nevertheless point to some of the specific difficulties that P4 pupils could face in the learning of certain aspects of electricity.

Further studies, involving, among other things, one-to-one interviews with a larger, random sample of pupils could provide more valid data on the specific difficulties faced by pupils in learning the various aspects of electricity included in the primary science curriculum. Such data would also be useful in the design of conceptual change strategies to address pupils' difficulties as well as helpful in syllabus or curricular revision and implementation.

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