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WHAT ARE STUDENTS' IDEAS ABOUT THE CONCEPT OF AN ELECTRIC CURRENT? A Primary School Perspective

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Despite the body of research in science education on the concept of electricity in areas such as electricity consumption, electricity conservation, and the benefits and dangers of electricity, very little is known about young students' ideas about the phenomenon called electricity, and specifically the concept of an electric current. In this work, 15 students in Standard 5 (ages 9–11) of a primary school in south Trinidad were surveyed and interviewed in order to obtain qualitative measures of their understanding of what an electric current is. The findings indicate that students' initial ideas were either vague or different from textbook concepts, but that after being exposed to the teaching of a unit on electricity, most students held the scientifically accepted understandings of the concept of an electric current. Furthermore, it was revealed that there was an almost exact match between students' word understandings and their picture understandings of an electric current in both instances—before and after being exposed to a taught unit on electricity.

Introduction

This small-scale research project investigated the ideas that 9- to 11-year-old students have about the concept of an electric current. It is first-hand, classroom-based research that seeks to shed some light on students' understandings, in an attempt to bridge the gap between what is taught in the classroom and what understandings students develop as a result of what was taught. Even though there is little research into students' specific ideas about electric current, there are a number of studies of students' views on the uses of electrical energy (Borges & Gilbert, 1999; Boyes & Stanisstreet, 1990; Newton & Newton, 1996; Parker & Heywood, 1996). Other studies of students' views on electricity consumption and conservation (e.g., Sunal & Sunal, 2003), as well as their ideas on the generation of electricity (e.g., Malandrakis, 2007) also exist, but very little is known about the ideas that come to students' minds when they hear the term *electric current*.

Anecdotal evidence suggests that many practising primary school teachers in Trinidad and Tobago consider electricity to be one of the most difficult topics for students to grasp when delivering the primary science syllabus. Such anecdotal evidence further reveals that many primary school science teachers deliver science instruction mainly through rote methods, with hands-on, interactive science learning being an "occasional occurrence." Thus far, there has been no explorative survey done to reveal what conceptions students hold with respect to the concept of an electric current, either before being exposed to the topic in a formal classroom setting or after the topic has been formally taught to them in the classroom. This is the primary rationale for this work.

The overarching goal of this work is to identify students' (in the 9–11 year age group) ideas about what an electric current is. Three research questions guided the approach adopted in this work:

1. *What are students'* word *understandings of the term electric current before and after a unit on electricity?*
2. *What are students'* picture *understandings of the term electric current before and after a unit on electricity?*
3. *What relationship/s exists/exist between students'* word *understandings and their picture understandings of the term electric current before and after a unit on electricity?*

This work has been conceptualized in the local context as a small step aimed at revealing what kinds of conceptions a class of Standard 5 Trinidadian students have concerning the concept of electric current before and after instruction. As outlined in the primary school science syllabus document, students at the Standard 5 level are expected to be exposed to the following concepts: current flow under various conditions, electrical conductors and insulators, circuit components, simple series and parallel circuits, and simple applications of electrical circuits in the home. This content builds on students' knowledge of energy, and specifically electrical energy, which they would have been exposed to at the earlier levels in primary school, namely, Standards 1 and 3.

This work is significant in that the findings will add to the existing body of literature, in the local context, on students' ideas and understandings of scientific terms; but, more specifically, it aims to show how it is possible to achieve conceptual change among students when they are taught complex science topics about which they may already have some informal ideas. Furthermore, this work may serve to encourage primary school teachers involved in science teaching to explore, in creative ways, the perceptions of their own students, not only about electricity and electric current, but also about other science terms and concepts as well.

Literature Survey

Conceptual change is an idea that has been widely discussed in many published works and, in general, the literature speaks to four views of conceptual change:

1. The view of conceptual change as a process that enables students to synthesize models in their minds, beginning with their existing explanatory frameworks (Vosniadou, 2002).
2. Chi and Roscoe (2002) describe conceptual change as repair of misconceptions.
3. diSessa (2002) suggests that it is the reorganization of diverse kinds of knowledge into complex systems in students' minds.
4. Ivarsson, Schoultz, and Saljo (2002) argue that conceptual change is the appropriation of intellectual tools.

In the current work, students would have been exposed to some ideas and understandings about electric current, and though these may have come from informal settings in most instances, in some cases, their existing ideas may have been formulated from classroom experiences at the lower levels of their primary schooling. In this context, therefore, any conceptual change arising from this work, incidental or otherwise, would resonate with the view expressed by Vosniadou (2002).

In respect of the topic of electricity, and specifically electric current, Etheredge and Rudnitsky (2003) suggest that electric current can be a difficult concept to teach at the primary level, and that while most students have heard the term before, they really know very little about the concept itself. Newton and Newton (1996) and Malandrakis (2007) suggest that many students think of electric current flow in five distinct ways or models, and that the "single wire" model is the model most easily retained by young students after the teaching/learning instruction. Kibble (1999), in an activity involving young children aged 7-11, found that children in this age group had a wide variety of picture understandings of the terms electricity and electric current, and that when exposed to practical, hands-on classroom activities many students exited the learning experience with the scientifically acceptable understandings. He reported further, that for students who were exposed to the same content of learning but whose learning occurred in the traditional paradigm—through rote methods such as teacher telling and note-taking—only few exited the learning experience with the scientifically acceptable understandings. In agreement with this finding, Dunbar (2000) suggests that when students are provided with learning opportunities that allow them to act like real scientists, and when they are encouraged by teachers to think like scientists, they become more immersed in the classroom learning and that the likelihood of developing scientific misconceptions is greatly reduced.

All these findings seem to suggest that students' prior knowledge/ideas/concepts must be invoked in new classroom experiences; experiences that involve the use of dynamic and evolving contemporary teaching/learning strategies to enable students to make conceptual changes and/or to develop new ideas about a topic. In the current work, the class teacher made conscious efforts to enact classroom instruction as prescribed by Dunbar (2000), and developed classroom activities that facilitated the view of conceptual change articulated by Vosniadou (2002) to ensure that science learning in this exercise occurred through meaningful engagement of the learner in relevant well-structured, hands-on activities and group collaboration.

Methodology

In Trinidad and Tobago, all primary schools follow the same science syllabus, and there are recommended textbooks, with accompanying workbooks, which the Ministry of Education suggests that teachers use in the delivery of science instruction. Science is a formal subject at all levels of the primary curriculum. While the dominant method of teaching advocated for primary science is the activity-centred approach, many teachers do not readily adopt this approach in their classroom (Maharaj-Sharma, 2008). In the specific case of this study, the class teacher was familiar with Dunbar's (2000) approach, and indicated that during the previous two years she had made deliberate efforts to adopt this prescribed method of instruction in her teaching. No specific random or purposive selection was employed to select the teacher to participate in this study; it was a case of the class teacher volunteering to engage in the study because of an interest she shared with the researcher about wanting to find out more about students' ideas about the concept of electric current.

A Standard 5 class (ages 9–11) with 15 students of mixed socio-economic backgrounds and mixed academic abilities (9 girls and 6 boys) in an ordinary primary school in southern Trinidad was studied. The aim was to obtain qualitative data on students' ideas. The researcher accepts that the sample used to derive the information was small but, as far as the researcher knows, little research is available on this specific topic.

One week before the class was taught the unit on electricity, the researcher spent five minutes with each student asking them to say/explain what words or ideas came to their mind when they heard the term electric current. Additionally, in this first intervention phase, the students were asked to sketch a picture to reflect the idea/s that came to their minds when they thought about what an electric current might be.

Following this first intervention phase, students were engaged for a period of six weeks, during which time the unit on electricity (as outlined on the syllabus document for their level) was taught to them by their class teacher. The general objectives of the unit were that at the end of the unit, students should be able to:

1. appreciate the role of electric currents in their daily lives;
2. distinguish between electrical conductors and electrical insulators;
3. appreciate the concept of mobile charges;
4. identify various electrical components;
5. use electrical components to assemble simple circuits;
6. understand the difference between series and parallel circuits; and
7. make decisions on the type of circuits to be used in simple applications.

The unit consisted of 12 lessons, each focusing on an aspect of electricity and delivered in sequence, as indicated below:

- **Lesson 1 – Introduction to electricity.** This lesson proceeded by way of a whole-group discussion in which a number of teacher-selected pictures and models were used.
- **Lesson 2 – Electrical conductors and electrical insulators**. Students interacted with text stimulus in conjunction with common everyday objects to classify a range of objects into electrical conductors and electrical insulators.
- **Lesson 3 – Structure of electrical conductors**. Students were exposed to a video which showed in simple form the metallic bonding (free electrons) characteristic of electric conductors. A follow-up activity provided students with the opportunity to demonstrate understandings gleaned from the video through word explanations and drawings.

- **Lesson 4 – Mobile charges**. Selected age-appropriate, computer-simulated video clips were used to explain this concept. These were complemented by related hands-on activities, which involved putting together models (by following instructional steps) to represent the movement/drifting of charges. Students subsequently interacted directly with the models in activities that allowed them to handle and manipulate a number of different configurations to aid in the development of their understanding of the nature and behaviour of mobile charges.
- **Lesson 5 – Circuit components**. In this lesson, students were exposed to a range of simple circuit components through hands-on interaction with the components. In jigsaw group activity they explored the functions of the components. Each group was given a different set of components and short descriptions of each component, and was asked to read the descriptions (which included the component name and its function) and to match the components to their respective descriptions. The groups then came together and each group taught the other groups about the components they learnt about using the actual examples and the descriptions.
- **Lesson 6 – More circuit components**. This lesson proceeded in a manner similar to Lesson 5.
- **Lesson 7 – Introduction to circuits**. The closed-loop idea of a circuit and the complete flow of charges were explored in this lesson through a number of student-aided demonstrations.
- **Lesson 8 – Building circuits**. This lesson built on Lesson 7, but here students worked in small groups to build their own circuits and to explain how they worked.
- **Lesson 9 – Series Circuits**. The particular arrangement of components in a series circuit was explored in this lesson, and students worked with the various components to explore the advantages and disadvantages of series circuits.
- **Lesson 10 – Parallel circuits**. This lesson followed the same format as Lesson 9, but with the focus on parallel circuits.
- **Lesson 11 – The switch**. In this lesson, students were exposed to the specific function of the switch in electrical circuits. They explored these functions by engaging in problem detection and corrective suggestions for a number of prewired circuits.
- **Lesson 12 – How my circuit works**. In this lesson, each student built his/her own circuit using components provided and explained how the circuit worked.

In all instances where classroom discussion occurred, the teacher used students' prior knowledge and understandings either to initiate the discussions or to clarify stated misconceptions; this approach that Vosniadou (2002) advocates can facilitate conceptual change in students' minds. Throughout the unit the teacher used structured group work, which involved activities that included pictures, diagrams, and models. The activities encouraged students to do drawings of various concepts covered in the unit of work. An example of one such activity is shown in Appendix A.

Personal interviews, each one lasting about 10 minutes, were conducted with all the students two weeks after the unit on electricity was taught to them. The Interview-About-Instance (IAI) protocol was adopted and suitably adapted, in terms of length and focus (Gilbert, Watts, & Osborne, 1985) for this work.

Data Collection

Phase I – Word and picture understandings before a unit on electricity

In this phase, the researcher conducted short interviews, lasting no more than 5 minutes, with each student, to identify their ideas about the concept of an electric current. Most of the students had a fair command of the English language and were able to write words or phrases to reflect their ideas. In the two cases where spelling was a challenge for the students, they were able to explain verbally their understandings of an electric current. To maintain the authenticity of the process, the sessions were audiotaped. In all instances, students were asked to represent their picture understandings of an electric current by drawing (on paper). Students completed the drawing exercise with great ease and comfort, even those students who had difficulty with spelling. For the researcher, this activity revealed that their spatial intelligence (Gardner, 2006) was acutely developed. The class teacher subsequently verified that the students participated in many drawing activities in everyday classroom activities and that they were familiar with the skill. These drawings were done on standard letter size sheets of paper.

Phase II – Teaching the unit on electricity

The researcher was invited to sit as an observer in the classroom during the teaching of the unit on electricity. There was good collaboration between the researcher and the classroom teacher to facilitate the process, but no collaboration occurred on the content delivered in the unit or the pedagogical tools used in the delivery.[2] The lessons included the use of many colourful pictures and many group and hands-on activities, which provided students with the opportunity to speak about what they were learning and to explain what understandings they were developing as the lessons progressed. To a large extent, opportunity was provided for all students to draw pictures and sketches of several ideas in the unit. In both instances—word understandings and picture understandings—any misconceptions observed/detected in the students' work were clarified by the class teacher through the use of further explanations, additional pictures, and/or practical demonstrations.

Phase III – Word and picture understandings after a unit on electricity

Two weeks after being exposed to the unit on electricity, the students were interviewed by the researcher. To reveal their word understandings, they were asked the same sequence of questions as in Phase I. Again, the interviews were audiotaped. Picture understandings, too, were captured in a similar manner as described in Phase I.

Data Analysis

Data from the interviews before and after exposure to the unit on electricity were transcribed, reviewed, coded, and labelled to reveal the main ideas students attempted to communicate. Students' transcriptions and their accompanying drawings were individually reviewed, repeatedly, to determine, in the first instance, the degree of congruence between their word explanations and their drawings; and, secondly, to attach appropriate labels reflective of the ideas expressed by the students. Some labels emerged naturally from the students' responses while others had to be inferred from the data. The class teacher, who had critical tacit knowledge of her students, was invited to be part of the analytical process to ensure that students' words, phrases, and statements, as well as their drawings/sketches, were accurately captured. The initial labels were reviewed and similar/related ones were collapsed and replaced by broader labels to facilitate the extraction of meaning and messaging from the data. Extreme care, through detailed collaboration with the class teacher, was taken to guard against researcher subjectivity and to maximize objectivity in the data analysis procedure.

Results and Findings

The variety of responses given by the students **before** being exposed to the unit on electricity included ideas of an electric current being a light bulb, an electrical spark, and being related to a plug in the wall and to electrical transmission lines. Some students appeared to have linked the term electric current to its homophone "currant" to mean the fruit – black currants. This was revealed from their picture representations.

After exposure to the unit on electricity, when asked to draw what came to mind when they heard the term electric current (Phase III of the study), all but two of the students drew representations similar to those they had met during the unit. In each case, the teacher insisted that students articulate their word understandings of an electric current, each using their respective diagrams, in an attempt to gauge the extent to which their word explanations, and hence their conceptual understandings, were congruent with the drawings they presented. Even if there were cases of students simply reproducing the drawings provided by the teacher, the degree of conceptual understanding they had developed from the unit could be gleaned from their word explanations. In fact, students' responses, both word explanations and drawings, were sufficiently consistent to infer that most students exited this learning with explanations of their idea of an electric current consistent with the "single wire" model.

The word and picture understandings obtained from students **before** and **after** exposure to the unit on electricity were scanned, resized, and tabulated, and are presented in Appendix B. Some examples of their actual sketches are presented in Appendix C.

At the Standard 5 level, the science syllabus document identifies, among other concepts, an electric current—a flow of charges in a complete loop—as the content knowledge students should have at the end of the unit on electricity. The suggested teaching strategy includes a teacher demonstration of a simple circuit consisting of a battery, pieces of wire, and a bulb to emphasize the idea of a complete loop. The syllabus document suggests further that this demonstration should be complemented with teacher explanations and the use of suitable pictures that teachers ought to source to show the "movement of charges."

As can be seen from the illustrations in Appendix B, **before** exposure to the unit on electricity, there was congruence between students' word understandings and their picture understandings, that is, whatever ideas they had about an electric current (even if these were scientifically unsound) **before** the classroom learning were consistent in terms of their word and picture understandings.

Researcher observations revealed that the teacher proceeded to deliver the content of the unit as suggested by the syllabus document and, adopting Dunbar's (2000) approach, employed a number of demonstrations, hands-on activities, video clips, and a wide range of relevant stimulus material inclusive of charts, textbooks, diagrams, and models to stimulate classroom learning.

It was clear from students' responses after the unit (in Phase III of the project; 2 weeks after the unit was taught to them) that all, except two students, understood an electric current to be a flow of "moving charges" (see columns 4 and 5 of Appendix B). Furthermore, their diagrammatic/picture understandings in all cases were in congruence with their *new* word understandings.

When probed further by the researcher as to what they understood by "moving charges," their responses were somewhat varied. The following were responses obtained from each of the 15 students:

Student 1: "... like little marbles moving in the wire…"

Student 2: "things floating around in the bulb to make it light…"

Student 3: "the little things that move…and make the bulb light…"

Student 4: "…moving things…like very tiny balls…that move…"

Student 5: "hard things that move…but they are very small"

Student 6: "…they float through the wire"

Student 7: "like moving little marbles…"

Student 8: "…the little things that floats [sic] *along the wire…"*

Student 9: "…fast moving little things"

Student 10: "small hard balls that fly from one wire to another wire…"

Student 11: "things that move fast and make the bulb light"

Student 12: "…like marbles…but no [sic] *so big…moving fast…"*

Student 13: "little charges that go through the wire…"

Student 14: "things moving very fast in the wire…"

Student 15: "the things that are moving fast in it [wire]…"

It was clear that after the unit on electricity the students understood moving charges to be "little" and "fast-moving." Physicists will argue that both terms are relative and that in a very general sense such a description of an electric current is not entirely scientifically accurate (Cutnell & Johnson, 2001).[3] Educators will suggest that the fact that students emerged from the learning experience with such ideas is significant in terms of the mental understandings of what constitutes an electric current (Summers, Kruger, & Mant, 1997).

This researcher agrees with both the physicist's perspective and the educator's point of view, and suggests that there is need to review either 1**)** the resource materials used by the teacher in the delivery of the lessons, including the textbooks; 2) the teacher's own understanding (a consequence of her own learning experience on the topic); or 3**)** both, to determine the influence of these on the content and the context of the science instruction presented to the students. This concern warrants further investigation and perhaps ought to be explored in another research project.

Interaction and discussion with Student 2, whose idea did not change after the unit on electricity, revealed that his exposure to the concept of electricity was limited to lighting. This student came from a home in which there were no televisions, radios, or other electrical appliances; in fact, the family had only recently obtained an electrical connection to provide lighting for the home. This student therefore may have been somewhat overwhelmed with the new experience of getting light from a bulb, and perhaps this might explain why his responses focused on the bulb. This state of being overwhelmed when exposed to an unfamiliar concept, idea, or feeling has been described by Hartman (2001) as an intricate interplay of metacognition, which arises when students attempt to negotiate existing understandings with new knowledge and insight.

Student 10, however, had greater exposure to electrical appliances and spoke about plugs and wires quite freely, yet seemed to have not appreciated the "flow of charges" or the "moving charges" concept the teacher explained in the classroom. Inghilleri (2002) suggests that the idea expressed by Student 10 is not necessarily a reflection of an understanding that is scientifically unsound but, rather, of a more "divergent view" of the concept, and suggests further that such divergence in the understanding of science topics/concepts warrants further investigation.

What Does This Work Show?

The procedure adopted in this work and the findings derived may appear simplistic, as no new strategy was employed and no comparisons with other classes, schools, or teachers were made. Electricity is a frequent topic in all the primary and secondary school science syllabus documents in Trinidad and Tobago, and students' conceptual understandings span a range of ideas to the extent that often at the higher secondary levels, when teachers make assumptions about students' understandings—some basic—in the topic, they find out later that many students have misconceived notions about concepts they met at earlier levels in the education system. This work reveals the following:

1. Electricity is a very common term—primary school students hear it often, more often outside school that inside school.
2. The explanation of what an electric current is that students receive outside school is sometimes inadequate and often not scientifically sound.
3. Because we live in an electronic era, the bombardment of the term in a number of contexts outside the classroom leaves students with "mixed ideas."
4. "Mixed ideas" can be effectively distilled in the science classroom through the use of appropriate teaching/learning strategies in the delivery of the topic.
5. Students' prior (layman) ideas may not be scientifically sound, but these can be transformed through meaningful classroom instruction, activities, and interactions.[4]
6. Contemporary hands-on teaching/learning strategies were employed by the class teacher to facilitate conceptual change among students (Vosniadou, 2002)—an outcome that traditional methods of delivery may not necessarily have achieved (Dunbar, 2000).[5]
7. By extension of item 6, therefore, there is merit in insisting that teachers move away from the traditional methods of delivery and instead employ appropriate creative and innovative teaching/learning strategies to deliver science instruction in their classrooms. It would seem to suggest, from this work, that this approach might be ideal for facilitating conceptual change among students.

Conclusion

The above findings are instructive in several instances and suggest far-reaching implications for the teaching of electricity at the primary level. It is the hope of the researcher that teachers will realize that students pre-existing ideas have a place in the classroom, and that alternative ideas and misconceptions can be transformed; that conceptual change can occur among students through appropriately selected classroom experiences. Furthermore, classroom teaching needs to enrich and develop students in ways that will lead them to accepted scientific views, and it is the teachers' responsibility to achieve this outcome. In Trinidad and Tobago, content coverage of electricity at the various levels of the education system—from primary through secondary—spirals from the lowest level upwards. This means, therefore, that a sound understanding at one level is a necessary requirement for coping with new understandings at the next incremental level. In other words, each level prepares students for the next level, and in this regard teachers are endowed with the critical responsibility of ensuring that students have the necessary prerequisite knowledge and the congruent sound scientific understandings to facilitate further learning on the topic.

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Notes

1. In the "single wire" model, the implicit suggestion is that current leaves the battery and travels through a single wire to a bulb which serves as a kind of electricity sink.
2. The class teacher is a graduate of the Bachelor in Education Programme, and during her tenure as a student of that programme she worked closely with the researcher. She has a deep interest in students' misconceptions and willingly volunteered to be a pioneer (in the local context) in work of this nature. The researcher is grateful for her willing participation in this work.
3. The average drift speed of moving charges in a current-carrying conductor is approximately 0.00625 m/s, which from a macroscopic perspective is in fact relatively slow (Nelkon & Parker, 1994).
4. This is an important revelation of the present work. A number of hands-on and visually stimulating teaching/learning activities were used in the delivery of the unit of work—activities that primary school science teachers would not normally adopt on a regular and sustained basis in their everyday science teaching!
5. In this regard, it is important to note that most students exited the learning experience with the "single wire" model perception of what an electric current is.

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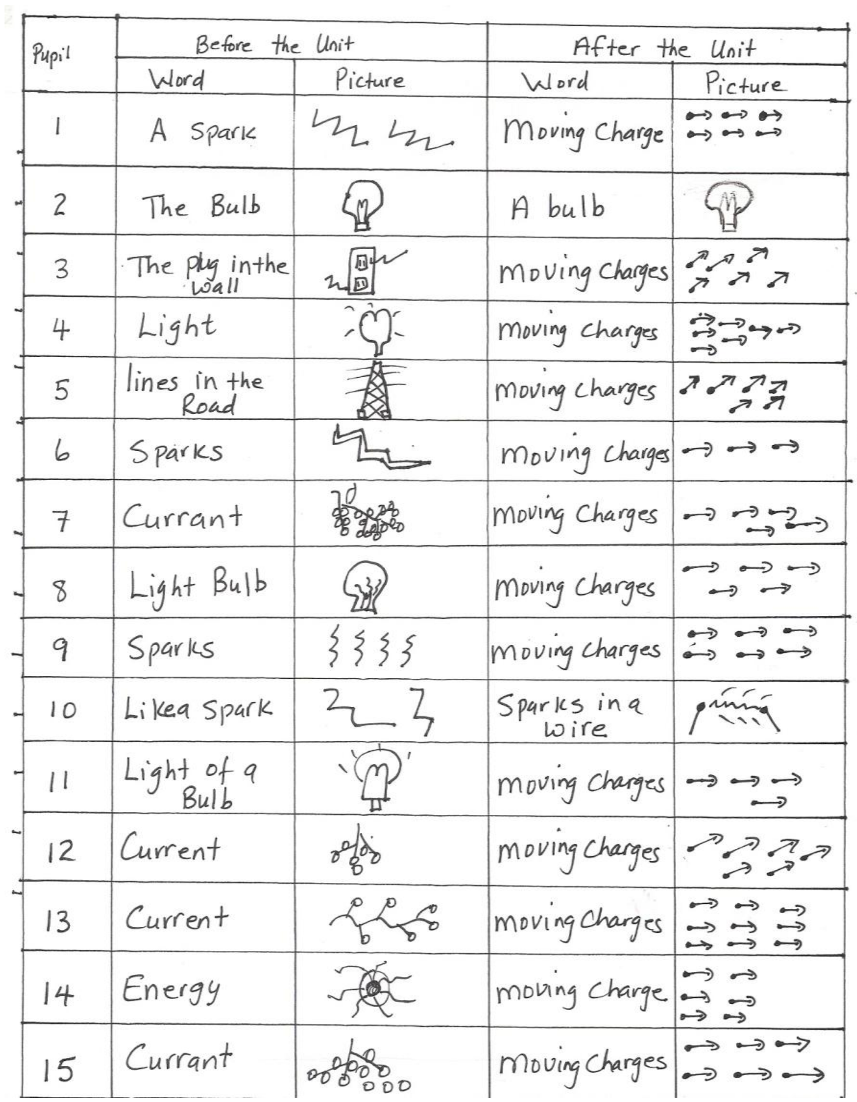
Appendix A

Drawing Activity

Please draw in the space below, a picture to show what you have learnt today about electricity.

Appendix B



Pupil	Before the Unit		After the Unit	
	Word	Picture	Word	Picture
1	A Spark		Moving Charge	
2	The Bulb		A bulb	
3	The plug in the wall		moving Charges	
4	Light		moving charges	
5	lines in the Road		moving charges	
6	Sparks		moving Charges	
7	Currant		moving Charges	
8	Light Bulb		moving Charges	
9	Sparks		moving charges	
10	Likea Spark		Sparks in a wire	
11	Light of a Bulb		moving Charges	
12	Current		moving Charges	
13	Current		moving Charges	
14	Energy		moving Charge	
15	Currant		moving Charges	

Appendix C

Some of students' actual sketches: