# Analysis of Case 2, Second Stage

This chapter follows chapter 11 in highlighting the analysis of the second case, by examining the data gathered after the training intervention. It takes the same structure of the previous chapter; giving an account of the overall teaching approach (12.1), disclosing the quantitative results of the 'Surface analysis' (12.2), presenting the detailed qualitative results of the 'Synoptic analysis' (12.3) and ending with discussing the pupils' conceptual understanding based on the analysis of the conducted focus groups (12.4).

## The overall teaching approach:

In chapter 7, I explained about the teaching of the subject of Electric circuit in grade 9 Omani Science curriculum. 9 lessons have been videotaped in this stage, but again, the data of the first 5 lessons are analysed only because of the previously mentioned considerations (section 7.1):

1. To match the number of the lessons videotaped and analysed for the topic of substance changes in the first stage
2. The first lessons entailed more CT than the last ones whose their time was largely spent in performing practical activities.

In the first videotaped lesson, the teacher started by exploring the pupils' thoughts regarding the difference between the concepts of static and dynamic electricity before explaining the scientific view and confirming it. Through whole CT and groups’ work, a general discussion took place regarding different issues of; where electric circuits can be found in the classroom, what the components of simple electric circuit are, how this circuit can be drawn and how it can be defined. She then moved the talk to identify the pupils' opinions of the elements necessary for any electric circuit to work. She picked up the element of wires and asked the groups to have a discussion about it. She started listening to the first group's view when the lesson ended at this point.

In the second lesson, the teacher continued in taking different opinions about the necessity of wires in the electric circuit and what can replace this component, before confirming the scientific view. One of the pupils initiated then talk about the necessity of the current and its relation to the battery. Before moving to the role of the battery, the teacher directed the discussion to defining the electric circuit and explaining the difference between insulators and conductors. She used a flash display to show the random moving of the charges before connecting the electric circuit, and the systematic moving in one direction when connected. She then asked the pupils to discuss in groups the necessity of the battery and its role in the electric circuit. She listened to the groups' opinions before summarizing them into two major ideas of the battery as a producer or as a pusher of electrons. All the groups were asked then to think of a design of a practical activity through which they can examine and decide about the two ideas. She listened to those designs before suggesting herself a design of an activity with two Galvanometers. She tried then to explain how this design can be used to prove one of the two views (If the two Galvanometers deflated at the same time, then the battery works only as a pusher of electron; it is a producer, however, if the first Galvanometer closer to the battery deflated before the other). The lesson ended while summarizing these two assumptions.

The third lesson started with an activity in which the girls of each group were trying to pass a number of pencils through each other, in the attempt to imitate the simultaneous movement of the electrons in all parts of the electric circuit when connected. The teacher tried to use this analogy to explain what she has started in the previous lesson; the idea behind the experiment with two galvanometers. One of the pupils, however, started to argue the teacher about the simultaneous movement of the charges. Another pupil was then challenging the view of the necessity of the battery in the electric circuit through a long exchange of talk. The teacher was performing then a demonstration of the experiment of simple electric circuit with two Galvanometers and asked each group to go and see the result. She opened a whole classroom discussion about what the groups have seen and how it can prove that the battery does not produce the electrons. She used a flash display to confirm this view by showing, in a microscopic level, the situation of the electrons in the electric circuit before and after it is connected. She used it to demonstrate that the battery does not produce the electrons which come basically from the wires, and that it just pushes them through the circuit.

The fourth lesson started by summarising the aforementioned information by defining the electric circuit. The teacher introduced then an activity of using a magnet to attract a number of pins and used it to open the discussion about what the battery does to move the electrons. She listened to the pupils' opinions and summarized them before presenting the scientific explanation in detail by reviewing the structure and the components of the battery. The talk then shifted to the pupils' views of the energy transform in lightening the bulb. Several opinions have been raised and although the teacher confirmed the correct scientific view, three pupils presented other opinions through which they were trying to follow the detailed energy transform throughout the circuit and not just the general one from electric energy to light. The teacher used these opinions to open the talk about the structure of the bulb and how it works to focus on the source of the energy that the bulb needs to glow. She guided the discussion to highlight the second role of the battery of providing the electrons with the energy that cause the lightness of the bulb. The lesson ended by giving the pupils some questions as homework.

At the beginning of the fifth lesson, the teacher gave the groups a drawing which shows an electric circuit with two bulbs and asks about the brightness of the two bulbs and the justification behind. Before listening to the groups' views, one pupil initiated talk about the possibility of one of the bulbs to light if the circuit is opened from the side of the other bulb. The teacher responded by exchanging a relatively long talk to reveal the pupil' thoughts and to explain the scientific view after that. She started then taking the pupils' answers of the two questions regarding the brightness of the two bulbs. She guided the discussion towards explaining about the conservation of the charges and the consumption of the energy in lightening the bulb. By the end of the lesson, the teacher started to introduce the concept of electric intensity.

In the lessons after, the talk about electric intensity and potential difference has continued, and different practical activities have been conducted starting with how to take readings from these devices and ending with taking such readings in series and parallel circuits through the application of Ohm's law. Table 12.1 offers a general description of the content of the first five lessons.

|  |  |
| --- | --- |
| Lesson | The content |
| 1- Electric circuit: kinds and components | *Review of the difference between static and dynamic electricity - Pupil's views of the electric circuits; what example can be found in the classroom, what are the components of simple electric circuit, how it can be drawn and defined – Group work and whole classroom discussion about the elements necessary for the electric circuit to work – Discussion of the importance of the wires and if they can replaced by another kind or not* |
| 2-How does the electric circuit work (1) | *Continuing the discussion of the necessity of wires – initiating the talk about the electric current, the situation of free electrons in conductors before and after the circuit is connected, and the function of the battery in generating this current- exploring the pupils' views of the role of the battery and their suggestions of an experimental design that can demonstrates if the battery is a producer or a pusher of electrons-Introducing the teacher's suggestion of such experiment and explaining the justification of how it can be used to reveal the role of the battery.* |
| 3- How does the electric circuit work (2) | *Introducing and explaining an analogy that attempts to explain the simultaneous movement of the charges throughout the whole circuit- Presenting the teacher suggested experimental design to investigate the role of the battery-responding to the pupils' argument regarding the idea behind this experiment and the necessity of the battery in the electric circuit- Conduction the experiment and discussing the pupils' observation-Explaining the scientific view of the role of the battery as a pusher.* |
| 4- How does the electric circuit work (3) | *Summarizing the previously presented information – Exploring the pupils' ideas of how the battery cause the movement of the electrons- Explaining the scientific view of how the battery performs its role through the attraction and repel forces-Listening to the pupils' views of the energy transform in the electric circuit and discussing the structure of the battery and it role in providing the energy needed for the bulb to light.* |
| 5- How does the electric circuit work (4) – Current Intensity & Potential Difference | *Responding to a pupils' view of the possibility of the lightness of the bulb for a short time in an open circuit- Listening to the pupils' views and discussing the brightness of two bulbs in one electric circuit and the justification behind-opening the talk about the conservation of the charges and the consumption of energy in lightning the bulb in the electric circuit-Introducing the concept of electric intensity.* |

*Table ‎12.1: Description of lessons in C2, S2*

## Results from the Surface Analysis

This section answers the following sub-RQ (refer to section 5.1) subsequent to the TI (b);

1.1bWhat Communicative Approach classes, does the observed CT exhibit?

This case has not witnessed a 'big' change like the one noticed in the first case, mainly because the Dialogic talk was there since the first stage. Nevertheless, there were more incidents of Interactive Dialogic talk and less of Authoritative ones. The Non-Interactive Dialogic talk that was not evident in the first stage did emerge in this stage. What is distinctive here is that all the analysed lessons witnessed all the four classes of talk as the results below illustrate. In some lessons, there was more of the Interactive Authoritative talk and in others, the Interactive Dialogic one was of the highest percentage. There was also the talk initiated by pupils which has been classified according to the CA.

Below is a review of the results from the surface analysis of the lessons at this stage, including:

1. Sum of time and ratio of each class of talk observed throughout each lesson;

2. Graphical representation (1) of the ratios of all the observed classes of talk

3. Graphical representation (2) of the ratio of the 'Authoritative/Dialogic' types

*Figure ‎12.1: Surface analysis’ results of C2, S2*

|  |  |  |
| --- | --- | --- |
| Time/Ratio of each class of talk | Graphical representation 1 | Graphical representation 2 |
| |  |  |  |  |  | | --- | --- | --- | --- | --- | | lesson 1 (time of classroom talk in each class) | | | | | | Class of talk | NI/A | I/A | I/D | NI/D | | Time in minutes | 2.22 | 7:39 | 10.44 | 2.48 | | Percentage | 10 % | 32 % | 46 % | 12 % | |  |  |
| |  |  |  |  |  | | --- | --- | --- | --- | --- | | lesson 2 (time of classroom talk in each class) | | | | | | Class of talk | NI/A | I/A | I/D | NI/D | | Time in minutes | 7.51 | 9.17 | 11.22 | 1.47 | | Percentage | 26 % | 31 % | 37 % | 6 % | |  |  |
| |  |  |  |  |  | | --- | --- | --- | --- | --- | | lesson 3 (time of classroom talk in each class) | | | | | | Class of talk | NI/A | /A | I/D | NI/D | | Time in minutes | 3.58 | 8.17 | 2.55 | 1.51 | | Percentage | 23 % | 49 % | 17 % | 11 % | |  |  |
| |  |  |  |  |  | | --- | --- | --- | --- | --- | | lesson 4 (time of classroom talk in each class) | | | | | | Class of talk | NI/A | I/A | I/D | NI/D | | Time in minutes | 6.22 | 16.11 | 10.42 | 0.33 | | Percentage | 19 % | 47 % | 32 % | 2 % | |  |  |
| |  |  |  |  |  | | --- | --- | --- | --- | --- | | lesson 5 (time of classroom talk in each class) | | | | | | Class of talk | NI/A | I/A | I/D | NI/D | | Time in minutes | 6.40 | 12.30 | 6.00 | 0.31 | | Percentage | 49 % | 26 % | 23 % | 2 % | |  |  |

## Issues arising from the 'Synoptic analysis'

This section answers the following sub-RQs (refer to section 5.1), subsequent to the TI (b):

1.2b What features of Authoritative and Dialogic types, does the implementation of the analytical framework provide?

2.1b What indicators on the potential of the Authoritative and Dialogic types of talk to support pupils’ learning, does the implementation of the analytical framework provide?

Again as in the chapter on the first stage of this second case, the synoptic analysis will not reiterate the same characterising of Authoritative and Dialogic talk as has been done for the first case. I shall try again to conceive the features of these kinds through the discussion of the different categories resulting from this analysis. The stage prior to the intervention showed Dialogic incidents in every recorded lesson, but this stage witnessed more Interactive Dialogic talk (exceeding the percentage of the Interactive Authoritative talk in some lessons as the statistic illustrates) with incidents of Non-Interactive/Dialogic talk that the first stage was short of. As the examples of talk characterised by the analytical framework have been chosen to represent all the classes of talk in each lesson, the results from the deep analysis include both Authoritative and Dialogic types. This section of the synoptic analysis shall be allocated to both types. It would not go into the details of what has made both types of talk, but it will follow their characteristics through the other three questions of:

1. How has the teacher practiced the transition toward more Dialogic talk? (RQ, 1.2);
2. How has the teacher managed the shift between the different classes of talk? (RQ, 1.2);
3. How does the Authoritative/Dialogic talk seem to support/not support pupils' learning? (RQ, 2.1)

In this section, the three issues are investigated and discussed in light of the different examples of talk analysed by the framework.

### How has the teacher practiced the transition towards more Dialogic talk?

The teacher's attitude to listen to the pupils and give them the chance to ask; this attitude has resulted in different examples of Dialogic talk in the first stage. Her awareness of the classification of talk into different types after going through the TI has influenced her to trying to practice more Dialogic talk. The few examples of Dialogic talk initiated by the teacher in the first stage were from the simplest level according to the figure of levels shown below. They were confined to the type of talk where the teacher explores the pupils' views in surface without going into the details of these views or try to challenge or develop them. The picture in this stage is different though, with examples ranging from the simplest to the more complicated levels of Dialogic talk.

|  |  |  |  |
| --- | --- | --- | --- |
| Levels of Dialogic talk | Lowest level - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - Highest level  Low-Dialogic talk- - - - - - - -Mid-Dialogic talk - - - - - - -- High-Authoritative talk  Exploring pupils’ ideas Exploring pupils’ ideas Challenging pupils' ideas  in surface in detail | | |
| Frequency of follow-ups | Dominated by comments | Dominated by elaboration | Comments and elaboration persist |
| Pattern of discourse | The (I-R-C0) and the (I-R-EL-R-C0) sequences persist | The (I-R-EL-R-EL…C0) sequence persists | The (I-R-C0,EL-R-C0,EL …C0) sequence persists |
| Pupils’ participation | More pupils with less contribution | Fewer pupils with more contribution | Fewer or more pupils with more contribution |
| Features of the talk | -Neutral stance of the teacher  -Openness to the pupils’ superficial ideas  -No persistence of the elaborative voice  -Pupils share less control over the talk | -Neutral stance of the teacher  -Openness to the pupils’ profound ideas  -Persistence of the elaborative voice mainly through the elaboration follow-up  -Pupils share more control over the talk | -Neutral stance of the teacher  -Openness to the pupils’ profound ideas  -Persistence of the elaborative voice through the initiation and the follow-up moves  -Pupils & teacher share control over the talk |

*Figure ‎12.2: The levels of Dialogic talk*

The first task for this section is to follow how the teacher guided the Dialogic talk into its different levels by going through some examples. In case 1, attention was directed to examples of talk that showed dialogic features and yet they were judged as Authoritative. Similar practice is also seen in this case, but in the opposite round away. Here, there are some examples that are to be classified by the CA as Dialogic, and yet they show some authoritative features. How these authoritative features have appeared and what the resultant practice looks like, is the substance of the second part of this section.

#### Guiding the Dialogic talk into different levels

In overview, the teacher's practice shows that she was guiding the talk in the way that encourages and supports the pupils' participation. The pupils' engagement and their contributions to the topics in discussions differed between the levels of the Dialogic talk. The analysis points to the dominance of the Dialogic talk from the lowest and the midst levels. Dialogic talk with the highest level was less frequent in this case compared to the first one. Although this teacher showed a Dialogic attitude to listen to the pupils ideas since the first stage prior to the intervention, she succeeded, in this stage, in practicing more Dialogic talk and developing its level, but not to the extent of trying to negotiate and challenge the pupils' views, apart from rare incidents. Here are examples of Dialogic talk from the lowest, midst and highest levels:

**- The simplest level: Exploring the pupils' ideas in surface**

The following example (Les.2, Ex.2), shows an Interactive/Dialogic talk with the purpose of exploring the pupils' views of the role of the battery;

|  |  |  |
| --- | --- | --- |
| 1.T | .. Based on your discussions, what's the role of the battery in your opinion? Yes | I |
| 2.S1 | The battery just pushes the electrons, then the electrons- It just give orders to the electrons to move | R1 |
| 3.T | A good probability. Good. Her opinion is that the battery only gives orders to move. Let's hear other views, yes | C0  I |
| 4. S2 | The battery moves the charges, the electrons | R2 |
| 5.T | So, the battery gives^ electric charges? | I |
| 6.Sg | No | Rg |
| 7.T | Does the battery produce^ charges? | I |
| 8.S3 | No | R3.1 |
| 9.T | So, what's its role? | EL |
| 10.S3 | Move the charges | R3.2 |
| 11.T | Move the charges, helps in moving the charges. Ok, beautiful.  Are there other opinions? | C0  I |
| 12.S4 | I say it produces charges | R4 |
| 13.T | Produces charges. So her opinion that it produces charges, beautiful. This is a second opinion. Let’s see other opinions, yes resistance, what do you think? | C0  I |
| 14.S5 | It gives charges cause it has positive and negative charges | R5 |
| 15.T | And the battery produces these charges and provides it to the current. Beautiful opinions. Now, we'll try to work on two activities to see if the battery produces the electric charges or basically it just move them? | C0 |

When the teacher posed the high level question speculating the role of the battery, the immediate response she got was going around the battery as a pusher; an idea that is considered unusual in its context. The teacher asked for another opinion, and again another pupil insists on this scientific view that reflects remarkable thinking about the battery. It seems that the teacher wanted to make sure that the pupils mean really what they say; that the battery is a pusher. So she asked the questions in turns 5 and 7 in which she stresses the words; gives & produce, and again she gets the same answer from a larger group of pupils. In turns 12 and 14, however, two pupils talked about the contradicted view to the battery as producing electrons.

Building on this characterisation, it can be referred to different elements that for and by which the talk took its lowest Dialogic level;

* The purpose of the talk of exploring the pupils' ideas without elaborating the details of these ideas, which points to the openness of the talk to the pupil's superficial views only;
* The persistence of the neutral stance of the teacher which appeared in the dominance of the comment follow-up, and which have kept the teacher away from approving or disapproving the pupil's thoughts

**- The midst level: Exploring the pupils' ideas in detail**

In this level, the teacher was trying to get into depth with the pupils' thinking. She was keeping on elaborating their answers for more clarification, as the example (Les.1, Ex.2) below shows;

|  |  |  |
| --- | --- | --- |
| 1.T | Give me examples of electric circuits? Think about the class here? A circuit, and tell me about its components if you can? Yes electric circuit () | I |
| 2.S1 | The laptop () | R1.1 |
| 3.T | The laptop# | C0 |
| 4.S1 | It's firstly, (…?) the electric charges come from the plug and they move through the wire that connects the laptop with the source, which is the plug | R1.2 |
| 5.T | The laptop, so now is this a circuit? | EL |
| 6.S1 | Not a circuit -- | R1.3 |
| 7.T | You've said now that the plug is the source and we connect it to the laptop (B). Is this a circuit? Why did you say it's not a circuit? | EL |
| 8.S1 | Because it's jus between two, the circuit must (…?) | R1.4 |
| 9.T | Between two things - means the current doesn’t go around in a circuit. If it's doesn't go around, how does it move? | EL |
| 10.S1 | It goes back and forth | R1.5 |
| 11.T | It goes back. So this is S1's opinion that current goes back and forth. This is an opinion that I want you to write in your notebook… | C0 |

Although this example starts with a question that looks of a scientific content as it asks for examples of electric circuits, it invites, in fact, the pupils to engage their personal experience in giving these examples. Basically, the teacher has not explained at this stage yet the details concerning the electric circuit; its components, essentials, functions…etc. In asking this question, she was relying, actually, on the pupil's previous experience with electric circuits, whether from everyday life or from school experience, the thing that contributes to assigning high quality to this question. Meanwhile, it seems that the teacher was aiming to identify the pupil's knowledge or preconceptions of electric circuits through their explanation of the examples they provide.

When the teacher asked for examples from the class, an expected answer would have been a battery connected to a bulb as these components were there in the front bench of the lab. S1 did pick something from the teacher's bench, but it was not the simple circuit of the battery/bulb. She picked the example of the laptop which surprised the teacher initially. The teacher was then repeating the answer with a face expression indicating that she was thinking about it. S1 interrupted the teacher's comment to provide an explanation of how the electric current moves to reach the laptop. The teacher provided then an elaborative question to examine with more detail S1's view. S1 herself, without any negative evaluation from the teacher, changed her mind by stating that this is not a circuit. The truth is that her attempt to explain the route of the current from and to the laptop has confused her. So, she was not actually negating the idea of the laptop as a circuit when she said, hesitantly; 'Not a circuit (turn 6). She was, in fact, thinking loudly, about it. With a Dialogic attitude, the teacher kept probing S1's ideas, by asking her to apply, explain and generate hypothesis. S1, in response, was trying to analyse; to recognize how the elements behind the example of the laptop work together in relation to what she knows about electric circuit.

Building on this characterisation, it can be referred to different elements that for and by which the talk took its midst dialogic level;

* The purpose of the talk of not exploring, but explaining in detail one pupil's view which points to the openness of the talk to the pupil's profound ideas and its potential to invite for more contribution from that pupil;
* The less frequent rate of the initiation move apart from the main one;
* The neutral comments that kept the teacher away from approving or disapproving the pupil's thoughts;
* The persistence of the elaborative voice of the teacher which appeared in the dominance of the elaboration follow-up and which has resulted in giving the participated pupil more control in guiding the talk (I-R1.1-C0-R1.2-EL-R1.3-EL-R1.4-EL-R1.5-C0).

**- The highest level: Challenging the pupils' ideas**

This advanced level is distinctive with the depth extent with which the teacher tries to identify the pupils' thoughts. This appears usually in the teacher's tendency to challenge the pupils' answers in order to get into more depth to the pupil's thinking about the discussed issue, as the following example (Les.1, Ex.1) illustrates;

|  |  |  |
| --- | --- | --- |
| 7.T | So the static electricity…(B).  Do you agree with S1? All of you agree with her? () Yes alternating current | C0I |
| 8.S2 | Static electricity exists in every material | R2.1 |
| 9.T | Exists in all materials, how? | EL |
| 10.S2 | Cause we know that any matter is neutral having protons and electrons. There're atoms and because a matter consists of atoms, then it has negative electrons and positive protons | R2.2 |
| 11.T | It has charges, so every matter generally # | C0 |
| 12.S2 | and also it doesn't move, means static electricity | R2.3 |
| 13.T | Ok, but electrons don't move (whiz?) around the nucleus? | EL |
| 14.S2 | Yeah, they go around but - I mean - they don't move in the whole material… | R2.4 |
| 15.T | …what we call it electricity or moving charges, does it move inside the atom itself or move from one atom to another? | EL |
| 16.S2 | Moves from an atom to another | R2.5 |
| 17.T | This is S2's opinion. Good S2. She said that static electricity… | C0 |

This excerpt is part of an episode that starts with the teacher asking for the difference between dynamic and static electricity. The first pupil to respond provided an answer that demonstrates an expected misconception regarding the confining of static electricity to insulators only. After taking a justification from S1 and making her answers obvious to the class through a number of turns, the teacher invited for contradicted opinions. It is then when another pupil; S2 in this excerpt, declared her objection to S1's partial answer regarding static electricity. She followed her objection by offering the other sensible possibility that static electricity exists in insulators and conductors as well. More than this, the teacher asked for a justification, S2 offered a precise scientific view, the teacher challenged it by trying to confuse S2 in relation to the movement of charges, but S2 responded to this challenge by providing a brilliant analysis in differentiating between the movement of electrons inside the atom itself, or that from one atom to another.

Building on this characterisation, it can be referred to different elements that for and by which the talk took its highest dialogic level:

* The purpose of the talk of not just exploring the pupils' ideas, but of going on to justify these ideas and explain the scientific background behind, which points to the openness of the talk to the pupil's profound ideas and its potential to invite for more contribution from more than one pupil;
* The persistence of both; the comments and elaboration from the side of the teacher that appear frequently through the pattern of the discourse (I-R1.1-EL-R1.2-C0,EL…-EL-R1.3-C0-I-R2.1-EL-R2.2-C0-R2.3-EL-R2.4-EL-R2.5-C0);
* The pupils' bigger share of control over the talk in providing the more in depth explanations that might be compatible with the scientific view which results eventually in the pupils themselves providing the correct view without the need for the teacher to do so.

#### Dialogic talk with authoritative features

In trying to practice more Dialogic talk, there were incidents when the teacher seems to be alternating between authoritative and dialogic behaviours. It was confusing, therefore, to make a judgment about the classification of such talk. Such judgment, in fact, is opened to be debated because of the tension between the dialogic and the authoritative features that these incidents of talk manifest and approaching this tension in relation to the context in which this talk is taking place.

The first example here (Les.2, Ex.1) starts with a follow-up move reflecting a Non-Interactive Dialogic talk, through which the teacher was summarizing the offered views of the wires as an essential element for the electric circuit to work. In this excerpt, the teacher initiated the talk to pursue the discussion of this point that started by the end of the lesson before:

|  |  |  |
| --- | --- | --- |
| 1.T | …Is it necessary to have wires in the circuit? The answer of the Voltmeter group was no. It can be without the wires themselves, but... Other opinions. The group of electric potential. Do you wanna add anything to their answer? | C0  I |
| 2. S1 | It needs wires | R1.1 |
| 3.T | So in general the wires. So, it can't be a piece of iron? | EL |
| 4. S1 | It can be. But the wires are made of iron. Means a conducting matter | R1.2 |
| 5.T | It has to be a metal, a conductor. Ok, this is an opinion.  Ammeter group, do you have other opinions? | C0  EL |
| 6.S2 | It doesn't have to be wires. It's necessary to be a conductor, but doesn't have to be wires or the matter itself is solid. That matter can be a liquid or I mean | R2.1 |
| 7.T | Liquid like what? | EL |
| 8.S2 | like water | R2.2 |
| 9.T | Water! | C0 |
| 10.S2 | Water if being added to substances that help on conducting electricity, it will be a good conductor | R2.3 |
| 11.T | Excellent your group.  Ammeter group did mention indeed – Ammeter group has said that it's necessary to be, yes a conductor matter, but it's not a basic condition that the matter is a solid or wires. It's not necessary.  We've talked about the existence of a liquid... | Ev  C0 |

After commenting on the contribution of one of the groups from the previous lesson, the teacher was stimulating the other groups to offer other opinions if they have different views to the issue in discussion. Going through the excerpt starting with the high quality question in turn 1 till S2's contribution in turn 10, shows unquestionable Dialogic talk. Turn 11, however, raises a considerable doubt about this judgment. In a first glance, the word excellent in this turn suggests that the teacher was waiting for this answer and once she got it she approved it instantly; an act characterising usually Authoritative type of talk. Based on deeper thinking about the broad context of this excerpt, however, I have classified this excerpt as Dialogic, because of the following considerations:

1. The act itself of listening to the groups' views about this particular point has started from the lesson before. Through a dialogic practice, the teacher did listen to three groups' views, and the three were going around the same thought reflecting a scientific view indeed. In spite of this, the teacher did not provide any kind of evaluation.

2. It is just in turn 11 when she spoke out the word 'Excellent'. Giving the context in which this word has been uttered, listening to the teacher's intonation and watching her expression, draws a picture of an excited teacher with unexpected response from a pupil; an excitement that appeared naturally in her reaction. So, she wasn't really planning to evaluate the group's contribution yet.

3. But then, she did, and the discussion has ended up with an evaluative move. I am arguing, however, that this move cannot set aside the dialogic practice of all the long talk that started from the lesson before. This judgment can be also supported by the teacher's subsequent reaction in turn 11. She held back after uttering the 'Excellent' comment, and did not keep on the evaluative move. Instead, a neutral utterance is heard of;

''Ammeter group did mention indeed – Ammeter group has said that it's necessary to be, yes a conductor matter, but it's not a basic condition that the matter is a solid or wires. It's not necessary. We've talked about the existence of a liquid''

In this short neutral move, the teacher was reviewing actually the pupil's view not as part of her organization of the talk (as in turn 5, for example), but rather for closing the open discussion and starting to direct it to certain end. This is, in turn, what makes it a Non-Interactive Dialogic type of talk. The authoritative attitude dominates then the rest of this episode through a chain of I/A, NI/A and I/A talk. We can actually summarize what was happening in the episode that this excerpt is part of in the following scenario of; the teacher listening to a number of ideas; eventually, a pupil initiates a remarkable point; the teacher get excited about it; she picked it up, review the pupil's account of it and it is then when she shifts the talk to the authoritative direction to explore that point and tries to make it clear to the whole class. Within such scenario, this excerpt was more probable to be classified as Dialogic although showing an authoritative feature.

In the second example for the purpose of this section (Les.4, Ex.3), the nature of the pupils' answers appears as to pushing the teacher's reaction to be alternating between authoritative and dialogic:

|  |  |  |  |
| --- | --- | --- | --- |
| 1. T | My question again; what's the kind of energy transform in the electric bulb? Yes S1 | I |  |
| 2.S1 | Light | R1.1 |  |
| 3.T | Light. Where did the light come from? I'm asking about the energy transform, the word transform, always mean by it from ^ to ^ | F | ^ Affirmation tone |
| 4.S1 | From kinetic | R1.2 |  |
| 5.T | From kinetic. The energy transfers in it from kinetic into what? | F |  |
| 6.S1 | From gravitational potential to kinetic | R1.3 |  |
| 7.T | The energy changed from gravitational potential into kinetic. This is S1's opinion | F |  |
| 8.S1 | No, may be from electric into kinetic | R1.4 |  |
| 9. T | Another opinion, from electric into kinetic. It's ok I write both of them (B). Yes S2 | F | (B) T writes on board uttered opinions |
| 10.S2 | From Kinetic into electric | R2 |  |
| 11.T | S2 is saying this time from Kinetic into electric.  In the bulb. I'm asking about the bulb (). Yes direct current | F  I | () T is smiling and the expression of astonishment is obvious in her face |
| 12.S3 | From gravitational potential into light | R3 |  |
| 13.T | From gravitational potential which refers to a fall () into light! Yes | F | () T is acting the fall with her hand with a surprise smile & expression in her face |
| 14.S4 | From electric into light | R4 |  |
| 15.T | From electric into light. Excellent (). Let's see on which of these opinion (written on board) you agree upon; the first one …the second…the forth ()  So what's the secret behind all these opinions? Did the gravity caused the fall of the bulb and so it glow?! Did…. So the energy will transfer from… | F | () T is showing an approving Expression  …()group of pupils iterate: No for all the first opinions and shout: yeah, this is right for the last opinion |

This excerpt starts with the teacher asking what she was regarding as a simple question about the transform of energy in electric bulb. When she initiated the question in turn 1, S1 offered part of the correct desired view, and the teacher elaborated S1's first response to develop it. However, S1 surprised the teacher with two new incorrect views, and which are strange in their context, the thing that motivated the teacher to guide the talk into a dialogic route and asked for more opinions. She got further strange answers with which she could not really hide her astonishment that appeared in her smile, wondering facial expression & tone, and some indicators of indirect negative evaluation like the ones in turn 11 (In the bulb. I'm asking about the bulb) and turn 13 (From …which refers to a fall). When the correct view was offered lastly, the teacher could not control her excitement, and spoke out the word 'Excellent' in turn 15.

The scenario here is similar to the one in the previous example, which in spite of its ending with evaluation; it is still characterized as Dialogic. Although each example has its own distinctive context, the two gather under the same general context; a teacher trying to promote more Dialogic talk in her teaching as a result of some training. In both examples, she guides a Dialogic talk in which she listens to pupil's different opinions and commenting without evaluating them. For a reason specific to the context of each example, she cannot hide her excitement with the correct answer for which she provides an immediate approving response 'Excellent'. But then, she holds back and gives a space for reviewing these opinions by stating them or asking the whole class about the opinion they support. Without that approving word, the excerpt is undoubtedly Dialogic, but with it, confusion happens. A context-based justification has specified the judgment of the example in lesson 2, and so does here. Given the simplicity of the question, the weirdness of the presented opinions and the low cognitive level they reflect, the class reaction to these opinions and the later reaction of the teacher to very detailed opinions of high cognitive level regarding the same question, in addition to all what has explained about how did the teacher react through this excerpt; all of these supports the judgment of a Dialogic rather than Authoritative talk.

### How has the teacher practiced the shift between the different classes of talk?

In approaching how the teacher has managed the shift between the different classes of talk, I analyse examples of the shift between the four classes, giving that all the four classes appear in every analysed lesson in this stage. Going into the details of the shift will, expectedly, shed light on the shift within the two Authoritative and Dialogic binaries. This section offers two examples; the first reflect a smoother shift between the different classes, where the second demonstrates what seems to be a more complicated shift as the classes of talk appear to interfering each other:

#### Smooth Shift

In the following example (Les.1, Ex.1), there is a five-steps shift between the four classes;

|  |  |  |
| --- | --- | --- |
| 1.T | What do we know about the dynamic electricity? And what's the difference between this kind and the first one? Yes current intensity | I |
| 2.S1 | The dynamic electricity moves in conducting materials but static electricity doesn't move in conductors, it is in insulators | R1.1 |
| 3.T | So, it has to be an insulating material () | EL |
| 4.S1 | Cause it doesn't move freely | R1.2 |
| 5.T | Doesn't move freely. Beautiful. Doesn't move freely…  And dynamic electricity? | C0 …  EL |
| 6.S1 | Moves freely in conducting materials | R1.3 |
| 7.T | So the static electricity…(B).  Do you agree with S1? All of you agree with her? () Yes alternating current | C0  I |
| 8.S2 | Static electricity exists in every material | R2.1 |
| 9.T | Exists in all materials, how? | EL |
| 10.S2 | Cause we know that any matter is neutral having protons and electrons. There're atoms and …, then it has negative electrons and positive protons… | R2.2 |
| 16.S2 | …Moves from an atom to another | R2.5 |
| 17.T | This is S2's opinion. Good S2. She said that static electricity exists in ….  But If I ask you, is there an evidence, an experiment or something in which we saw static charges but in a conductor? Yes heat… | C0  I |
| 20.S4 | …Van De Graaff generator | R4 |
| 21.T | Excellent, Van De Graaff generator….we've said what its (metal ball) kind is? | Ev , I |
| 22.Sg | A metal – A conductor | Rg |
| 23.T | What's its kind? | I |
| 24.Sg | Conductor… | Rg |
| 27.T | …Didn't I consider it in this case or didn't I consider it as charges that stand still on the surface of this matter?.. So they are not just on the surfaces on insulators, but they're also on…the conductors. When do they move from the surface…? | Ev  I |
| 28.S5 | When been touched by another matter,… | R5 |
| 29.T | Excellent. So, when it's been touched…  Ok, in this case, Is it right to say that the static electricity are…in insulators? | Ev  I |
| 30.S1 | No. No they're there | R1.4 |
| 31.T | Where? | EL |
| 32.S1 | In all the matters | R1.5 |
| 33.T | In all the matters. Conductors and insulators. Good… Does everyone agree…?... | Ev , I |

I went through small part of this example previously when discussing the highest level of Dialogic talk of challenging pupils' ideas (p.12). The whole example shows a five-steps shift between the communicative classes; I/D (1-17) -N/D (17) -I/A (17-27) -NI/A (27) -I/A (27-…). As explained before, the Dialogic part started with the teacher asking for the difference between dynamic and static electricity. S1 provided an answer that shows an expected misconception regarding the confining of static electricity to insulators only. S1 also talked about dynamic electricity in conductors. It is correct scientifically, but then it is an expected thought to relate dynamic charges to conductors. The teacher chose, therefore, to pay a little more attention to discussing the view about static electricity. After taking a justification from S1 and making her answers obvious to the class through a number of turns, she opened the chance to other opinions. It is then when another pupil; S2, declared her objection to S1's partial answer regarding static electricity. She followed her objection by offering the other sensible possibility that static electricity exists in insulators and conductors as well. She continued in justifying her idea, and she stood to the teacher's attempt to challenge this idea as explained before (p.12).

Following the Interactive/Dialogic part, came the Non-Interactive one that is assigned most commonly to the purpose of reviewing the presented views. Two ideas have been presented, but the NI/D part reviews the details of the second pupil's idea only. The first pupil's idea has been reviewed and made clear to the class through the talk in turn 5 and the skipped turns after. Such an observation regarding the review of pupils' ideas through Interactive parts has been actually noticed in several episodes. It can be considered as part of the teacher's role in orchestrating the CT.

After getting this brilliant contribution from S2 and summarizing it, the teacher chose to lead the talk towards the scientific account. Instead of approving the second correct opinion of S2 directly, the teacher chose to do it slowly and indirectly, so the pupils can conclude themselves that this is the correct view. She did so by;

* opening an Interactive/Authoritative discussion about evidence that shows practically that static electricity exists in conductors (i.e. Van de Graaff generator)
* providing a summary for how this evidence supports the aforementioned point through a Non-Interactive/Authoritative talk
* shifting the class of talk again to be Interactive /Authoritative by giving back the turn to the first pupil who has showed the misconception about static electricity. She controlled the talk intellectually, in the way that led S1 to correct herself the misconception she early showed.

In summarizing the 5-step shifts in this example, it would be useful to follow the purposes, the content, and the kinds, quality and patterns of moves of the Authoritative part in regard to the Dialogic part:

* Purpose of the talk: Through the Dialogic part, the teacher implemented a dialogic practice in identifying, explaining and reviewing major pupil's ideas. In the Authoritative part, she picked up the correct view, worked on it by relating it to old scientific information through a certain scientific example, and developed eventually the desired scientific idea.
* Content of the talk: A theoretical scientific subject matter was the focus of both the Dialogic and the Authoritative parts. However, the Dialogic part was opened to the personal views, where the Authoritative part was all directed to the scientific view. There was also a shift in the content from being theoretical only in the Dialogic parts to be supported by empirical content through the Authoritative talk for the aim of convincing the class with the correct view.
* Kinds, quality and pattern of moves: As evaluative moves were absent from the Dialogic part (see p.14), they just dominate the follow-up move through this part (I-R3-I-R4-EV-I-Rg-EV-I-Rg-EV / I-R5-EV-I-R1.4-EL-R1.5-EV). In terms of the quality, it seems that the dialogic practice has opened the chance for high quality question to be posed by the teacher, and high quality answers to be offered by S2. The Authoritative part, though, has been short of high quality moves because, simply, the talk has taken place to just develop S2's idea that has been already justified and explained through moves of high quality in the part before.

This example is distinguished with the harmony in shifting between the types of the talk; a shift that entailed a gradual growth of the purposes, starting with pupils' opinions regarding certain scientific content and ending with the scientific precise view. It entailed a managed control from the side of the teacher between confining her follow-up moves to just commenting or extending pupils' contributions, and practicing her intellectual control in evaluating such contributions.

#### Complicated shift

In the second example here (Les.5, Ex.2), there is a shift from the Authoritative binary (I/A-NI/A0 to the Dialogic one (I/D-NI/D). Within the Dialogic one, however, there is a shift to Authoritative talk as follows:

I/A (1-7) - NI/A (7-9) - I/D (10-32) { I/A (24-32) , NI/A (32)} - NI/D (33).

|  |  |  |
| --- | --- | --- |
| 1. T | Let's go back to the question you have (). Yes alternating current | I |
| 2.S1 | How do you expect the brightness of the two bulbs? | R1.1 |
| 3.T | Ok. So, what's your group's answer? | I |
| 4.S1 | Both bulbs have the same brightness | R1.2 |
| 5.T | Why? | EL |
| 6.S1 | Cause we know that the charges move at the same time. The electrons move at the same time, and they go around in a closed circuit. So, it will be the same brightness cause they're passed by the same charges | R1.3 |
| 7.T | Ok, cause the same charges will pass by them. Good. So, the two bulbs will glow with same brightness…The other thing, we've said that these electrons; where do they get the energy they carry from? | Ev  I |
| 8.S2 | The battery | R2 |
| 9. T  10.T | The battery which is formed of… It has a chemical energy that transfers to electric energy that…If the two bulbs are identical, then what…Will it give one bulb more energy than the other? Or…the moving electrons as a number will not be affected, but what happen? The energy is distributed… is it clear?  Ok, regarding the justification, the reason (), how do you explain that the two bulbs have the same (brightness). May be it's simple now, S3 | Ev  I |
| 11.S3 | Both bulbs used up. I mean the battery when moving the charges. I mean the two bulbs use up the same electric current () | R3.1 |
| 12.T | Use up the same electric current. What's the number of this answer? Use up the current. Do you know the meaning of use up? | EL  I |
| 13.S3 | Means it takes… | R3.2 |
| 18.T | …Ok. This is one possible answer. Is there another answer you chose…Which one is your answer?...So, your answer is number 5; the current is the same everywhere in the circuit. Ok. Does anyone have another answer? Yes | C0 …  I |
| 19.S4 | That it's equal. Shared equally | R4.1 |
| 20.T | Shared. Shared the current equally. Ok, we'll see the two answers.  Does anyone have another answer? | C0  I |
| 21.S5 | The current just pass by but doesn't decrease | R5.1 |
| 22.T | Doesn't decrease, ok. This means the same…everywhere in the circuit. Or? | EL |
| 23.S5 | I mean the bulb doesn't take a current. It (current) passes by it (bulb), but doesn't take it | R5.2 |
| 24.T | Yeah, but what does it take from the current? | EL |
| 25.S5 | The electrons, the current # | R5.3 |
| 26.T | The current is electrons. This person (). Imagine this person as Mister electron, what did the bulb take from him to glow? | EL |
| 27.S5 | Current (). Energy. Energy | R5.4 |
| 28.T | What did it take? Energy. In this bag, there is energy. It just took energy. Did it take the electron itself? No, it took an energy that the electron is carrying | Ev |
| 29.S5 | Miss, then the energy --(…?) () | R5.5 |
| 30.T | Will the electron be used up? The electron itself? | EL |
| 31.S5 | Every electron has energy. Every time an electron comes and puts its energy and then goes again to take | R5.6 |
| 32.T  33.T | And goes and take energy. Beautiful. Good S5. So, the number of the electrons, what? …they just pass by taking with them enough energy for the bulb to glow. Where did it take this energy from?...is this point clear?  Here, I have two different answers, which is, Is the current shared? Or it's the same? This is what we wanna know today by studying a beautiful scientific concept… | Ev  C0 |

This is a complicated example in its shift between classes of talk because of its subject matter content and its flow as a talk. The whole example goes around a question about the brightness of two identical bulbs in one circuit. This question contains two sub-questions. An Interactive/Non-Interactive Authoritative talk goes around the first sub-question, in which there is no confusion. The talk about the second sub-question, however, got more complicated that it was very confusing trying to categorize its classes of talk.

In the Authoritative part, the teacher asked about the answer of the first sub-question, took the answer of one pupil, asked her for a justification, the pupil provided a high quality and scientifically correct response, the teacher praised the answer, and the Interactive part ends here. The teacher then controlled the talk to explain into detail the scientific point of view. Part of her lecturing about the scientific view, she wanted to direct the talk to another point, and so she put it in the form of a question. She got the short answer of; ‘The battery’ in turn 8, before she holds again the control over the talk. I considered the talk from turn 7 to turn 9 as Non-Interactive, because the pupil’s answer in the middle came just within the teacher lecturing about the scientific view.

So, this Authoritative talk with its two classes of Interactive and Non-Interactive had taken place within the purpose of working on a scientific problem. The talk in its short Interactive part took the general sequence of; I-R-EL-R-Ev. This pattern tends to manifest through Authoritative classes with mid and low authority, as the teacher keeps elaborating the answers of a pupil to evaluate all her contributions as a whole at the end.

The Non-Interactive part took a long time relatively through which the teacher talked about different points regarding the electric circuit. So, in her feedback about the first sub-question and S1’s responses for, the teacher confirmed the following facts:

* The battery doesn’t produce electrons. The electrons are basically there in the wires
* The number of electrons is the same everywhere in the circuit
* The bulbs take energy to glow but not electrons, and so;
* Energy is consumed in the bulbs, but the number of electrons is not affected. It remains the same

What happened, therefore, that the teacher in her lecturing about the answer to the first sub-question did actually provided the answer for the second sub-question that asks for a justification for the first one. This is one of the moments that the authoritative attitude of the teacher dominates strongly; that the teacher becomes unaware of her planning of teaching. And so, when she moved to the second question, she realized that she already has answered it, as it can be concluded from her utterance in turn 12; ‘’Maybe it’s simple now’’. In spite of this, the pupils, in trying to answer the second sub-question seem like they did not understand what the teacher has already explained as an answer to this question. Instead of having a short Authoritative talk to answer the question and approving the answer; the expected scenario according to the given context, the opposite happened.

A long, confusing and debateable Dialogic talk took place. The context does not indicate that this was the teacher’s intention. However, the first pupil’s response is what has stimulated the talk to take the Dialogic route and the teacher’s reaction to this response is what has defined the dialogic practice throughout it.

As I have explained earlier, the confusion in classifying the talk in this example (in this part specifically) has been driven by the confusion related to the subject matter and the talk’s flow between the teacher and the pupils.

Through the exchange with the first pupil (S3) to provide the justification, the teacher got confused because S3 presented answer different from the one her group has chosen. Actually, she mixed up different alternatives. It can be imagined then that S3 has not understood her group’s choice or she was not even aware of it. The confusion just went on, and the teacher ended up confused between mistaken explanation and correct choice, and so she invited other pupils to participate. This time, she got the wrong choice, and she kept asking for other opinions. The third pupil offered an explanation, not making the selected alternative explicit though, and here where I got confused in classifying the class of the talk.

Within the Dialogic talk that went around the different alternatives of the second question, came S3's explanation that entails different details. For answering the discussed question, the teacher was looking for the correct choice and its explanation in regard to the number of the electrons. In her explanation, S3 repeated the information already mentioned by the teacher about the energy carried by these electrons. The teacher considered the Dialogic talk as opened to the written alternatives assigned to the discussed question and its relation to the number of the electrons, but not the energy. So, although she kept a dialogic practice in taking different opinions regarding the correct alternative, she did not do the same for the talk about the energy with S3. Within the Dialogic talk from turn 10 to 32, came therefore an Interactive Authoritative talk between turns 24 and 32, and a Non-Interactive Authoritative one in turn 32. After this, a Non-Dialogic talk took place in which the teacher was reviewing the two opinions offered by the three pupils who participated in the Dialogic talk. However, this Authoritative talk come as part of the whole Dialogic talk with its two types; Interactive and Non Interactive.

To summarize the detailed account above; in explaining the glow of the bulbs and their brightness, justification can go into two related direction:

* in relation to the role of the current in causing the lightness and the fact about the conservation of the electrons
* in relation to the role of the energy in causing the lightness and the fact about its consumption

In the Non-Interactive Authoritative talk, the teacher talked about the two. When she decided to practice Dialogic talk about the second question, she wanted it to be in relation to the current and not the energy. The Dialogic talk ended up then with a sequence of moves that includes within patterns of Authoritative talk as illustrated in the following sequence: I-R3.1-C0- (I-R3.2-EV-R3.3) -EL-R3.4-C0-I-R4.1-C0-I-R5.1-EL-R5.2- (EL-R5.3-EL-R5.4-Ev-R5.5-EL-R5.6-Ev) ,C0

### How does the Authoritative/Dialogic talk seem to support/not support pupils’ learning?

In the first case, the teacher practiced frequent Dialogic talk to reveal the pupils' ideas concerning the different details of electric circuit. The talk after was dominated by Authoritative type because the teacher wanted to convey the scientific views. It was possible, therefore, to follow the influence of the Dialogic talk on pupils’ learning. For this case, however, such investigation cannot be performed for the Authoritative and the Dialogic types separately. This is due to the frequent shift between the two types throughout the teaching practice in this stage. Nevertheless, I try in what follows to capture the differences that characterise both types in relation to the investigated issues in this section. I follow then some examples on the shift between the different classes of talk to examine their influence on the pupils learning.

#### Pupils' engagement

Again, both the Authoritative and the Dialogic examples show different levels of the pupils' participation following the different levels of both types of talk. While in some Dialogic examples, each pupil take more turns to talk about her ideas (e.g. Les.1, Ex.2: I-R1.1-C0-R1.2-EL-R1.3-EL-R1.4-EL-R1.5-C0), more pupils participate in other examples with less contribution from each one (e.g. Les.2, Ex.2: I-R1-C0-I-R2-I-Rg-I-R3.1-EL-R3.2-C0-I-R4-C0-I-R5-C0). Similarly, some Authoritative excerpts show more contribution for each pupil (e.g. Les.4, Ex.1: I-R1.1-EL-R1.2-Ev-R1.3-Ev-I-R1.4-Ev), where in others, more pupils are participating in the talk but with less contribution (e.g. Les.2, Ex.1: I-R3-Ev-I-R4-Ev-I-Rg-EV-I… Ev).

Nevertheless, the Dialogic examples of talk are distinguished with their ability to engage the pupils intellectually by asking for their personal thoughts, stimulate them to think about the presented views and to offer other ideas on the discussed issues. Besides, more than inviting the pupils to participate with their thoughts of personal and everyday experiences, the Dialogic talk in most of the examples was going around the pupils' ideas regarding a scientific content. Discussing such content means that the pupils are encouraged to think deeply and generate what they think are scientific explanations and justifications.

In discussing the first example from the first lesson (p.16-19), a misconception related to static electricity and its modified scientific view have been both offered through the Dialogic part (more examples in this regard are observed in Les.4, Ex.2). This can be imagined to take place through an Authoritative talk as well. However, without any positive or negative evaluation from the teacher through dialogic practice, the misconception and its opposite scientific correction remain opened to other pupils self-thought and self-argument. This, to be argued, can support the chance for other pupils' to be intellectually engaged with the discussed issue; the thing that is less likely to happen if the opinions are closed down by approving or disapproving them through Authoritative talk.

#### Quality of questions and responses

The characterization of the quality in the Authoritative and the Dialogic examples of this case illustrates what has been described for the first case. The results suggest again that Dialogic talk supports the emergence of questions and responses of high quality. As it has been explained, Dialogic talk is based most frequently on open questions of high quality asking for the pupils’ thoughts followed by elaborative questions requiring high cognitive processes in analysing and justifying these thoughts and ideas. Some of the pupils' responses come to manifest the required high cognitive skills and some do not. In contrary, most of the Authoritative examples seem to be dominated by questions and responses reflecting low cognitive processes. The quantitative representation below demonstrates these general observations on the quality:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Examples of Dialogic talk | Quality of questions | | Quality of responses | |
| Low | High | Low | High |
| Les.1, Dialg.1 | 2 | 6 | 3 | 5 |
| Les.2, Dialg.1 | 0 | 4 | 1 | 4 |
| Les.3, Dialg.1 | 1 | 2 | 2 | 1 |
| Les.4, Dialg.1 | 0 | 8 | 4 | 5 |
| Les.5, Dialg.1 | 4 | 7 | 8 | 1 |

*Table ‎12.2: Quality of Questions & Responses in I/D excerpts of C2, S2*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Examples of Authoritative talk | Quality of questions | | Quality of responses | |
| Low | High | Low | High |
| Les.1, Auth.1 | 5 | 1 | 4 | 0 |
| Les.2, Auth.1 | 3 | 0 | 2 | 0 |
| Les.3, Auth.1 | 5 | 0 | 5 | 0 |
| Les.4, Auth.1 | 3 | 0 | 4 | 0 |
| Les.5, Auth.1 | 1 | 1 | 1 | 1 |

*Table ‎12.3: Quality of Questions & Responses in I/A excerpts of C2, S2*

The potential of Dialogic talk to invite for moves of high quality in opposite to the tendency of the Authoritative talk to invite for low ones can be best spotted in following the shift in these types of talk within a certain example (e.g. Les.1, Ex.1 (I/D-NI/D-I/A-NI/A-I/A) & Les.2, Ex.1 (NI/D-I/D-NI/D-I/A-NI/A-I/A)). The usual scenario in such examples is: the teacher calls for the high cognitive processes of understand, analyse…etc through her initiation and elaborative follow-ups in the Dialogic part. The different ideas and their explanations would be presented by the pupils through this part. In the Authoritative one, the teacher would ask for low cognitive processes of recalling, recognising…etc to develop and confirm the scientific view only which would has been already introduced through the Dialogic part.

A second observation that has been demonstrated through the first case and repeats again here is the potential of the Authoritative talk to reduce the cognitive level of the starting initiation. The following short Authoritative excerpt (Les.1, Ex.1) demonstrates this observation;

|  |  |  |  |
| --- | --- | --- | --- |
| 17.T | …But If I ask you, is there an evidence, an experiment or something in which we saw static charges but in a conductor? Yes heat | I | H |
| 18.S3 | A conductor () | R3 |  |
| 19.T | We've generated static charges in its place but it was in a conductor. Didn't we ever generated static charges but in a conductor? Didn't we? Yes heat | I | L |
| 20.S4 | Van De Graaff generator | R4 |  |
| 21.T | Excellent, Van De Graaff generator. A conductor, you remember when… | F |  |

This excerpt is part of the example displayed previously when discussing the smooth shift between the types of talk (see p.16-19). It starts with a question of high cognitive level (turn 17). The teacher was aiming at this stage to support a certain idea that has been presented through the preceding Dialogic part. Thus, when she got the unclear response of 'Conductors' (turn 18), she immediately, in turn 19, repeated the same query of turn 17, but this time with a low cognitive level. To understand this change in the cognitive level, there is the need to compare between the two questions in turns 17 & 19. In turn 17, the teacher was asking for unidentified, unclear and may be an abstract evidence or example to support a scientific hypothesis, which gives the question its high quality. In turn 19, though, she gave a hint about specific example that the pupils have went through once, and which was there in the lab. The hint worked out and S4, immediately, offered the answer that the teacher was looking for, and to which she directed the pupils (Van De graaff generator). This indicates the influence of the Authoritative talk to affect the quality of questions and consequently, the quality of responses. This attitude has stimulated the teacher to lessen the high level of the first posed question to a lower level; the act that can increase the chance for the pupils to provide her with the answer she is aiming for.

#### Pupils' conceptual understanding

Investigating the CT for the pupils' conceptual understanding is highly dependent on the extent to which the pupils' thoughts are revealed through this talk. It is more likely, therefore, to follow indicators on the pupils' understanding through Dialogic talk. The data on the shift between the Dialogic and the Authoritative talk in this case also make it possible to examine how the talk has influenced pupils’ learning. In general, the analysed examples in this stage illustrate the potential of Dialogic talk in revealing the pupils' views; mis/alternative conceptions and scientific ones. They demonstrate, meanwhile, that in how the teacher was following the Dialogic talk, the shift to other classes appeared to have positive influence on the pupils' conceptual understanding in some examples and negative influence in other ones. The following examples demonstrate these general observations:

- In many incidents, it was obvious that the Dialogic talk could reveal the pupils' starting points in approaching a certain issue. In one of the examples of Dialogic talk offered previously for example, (Les.2, Ex.2) the analysis showed that a number of pupils recognizing the role of the battery as pusher of electrons rather than a producer in opposite to other pupils who were holding to the expected misconception of the role of the battery in producing the electrons;

|  |  |  |
| --- | --- | --- |
| 1.T | .. Based on your discussions, what's the role of the battery in your opinion? Yes | I |
| 2.S1 | The battery just pushes the electrons, then the electrons- It just give orders to the electrons to move | R1 |
| 4. S2 | The battery moves the charges, the electrons | R2 |
| 10.S3 | Move the charges | R3.2 |
| 12.S4 | I say it produces charges | R4 |
| 14.S5 | It gives charges cause it has positive and negative charges | R5 |

- The shortcoming of the teacher's practice in this stage from Dialogic talk of higher level in challenging and negotiating the pupils presented ideas seems to has its influence in not to support pupils’ learning. When the pupils in the above excerpt expressed their views to the battery as moving the electrons and not producing them, the teacher did not go into the details of these ideas. Instead, she held to the many activities she planned to prove this point. The analysed examples of talk illustrate that in spite of the discussions of the performed activities, the misconception regarding the role of the battery was still persisting in the minds of some pupils. In the following excerpt (Les.4, Ex.2), the teacher was guiding a Dialogic talk about the role of the battery of providing the electrons with energy. Among the presented opinions was the following view that shows how the misconception of the role of the battery in producing the electrons still persists:

|  |  |  |
| --- | --- | --- |
| 1. T | …We've agreed last time that the battery move them. What did the battery do to make them move?... | I |
| 10.S3 | …It's – I mean there is a battery, and there, there is a negative and positive carbon and the charges move. So, one get empty of them, when they move # | R3.1 |
| 11.T | Get empty, deflate of. You mean there will be no charges at all | F |
| 12.S3 | One. Just one. The second will run out and positive and comes to the positive. And the positive, I mean it's – and they move, move | R3.2 |
| 13.T | You're confusing us | F |
| 14.S3 | I mean one takes and the second till- one was empty and the second was umm | R3.3 |
| 15.T | Full of charges? | F |
| 16.S3 | Yeah, and the negative… | R3.4 |
| 17.T | The movement of the electrons stop. Ok. Is there another opinion… | F |

-The teacher's practice of not following up the pupils' ideas in some incidents indicates also how the Dialogic talk in itself cannot influence pupils’ learning positively unless it is reinforced and supported by a meaningful shift to other classes of talk. The following example (Les.2, Ex.3) highlights this point:

|  |  |  |
| --- | --- | --- |
| 1.T | …Let's listen to your designs. The Voltmeter group | I |
| 2. S1 | In the first experiment …we connect one wire to the Galvanometer... | R1 |
| 3.T | Beautiful. Here they used two experiments, one with a battery and one without. Yes, your group | F |
| 4. S2 | The first experiment, we connect… | R2 |
| 5.T | Good, your group | F |
| 6.S3 | We have a galvanometer with a battery and wires, long wires #, and we use the second time the same but short wires and see if - if - and we use a bulb and see which one- I mean lights faster, lights first | R3.1 |
| 7.T | So, if it lights first, what does this indicate? Based on your assumptions, if it's faster. If in one circuit lights faster than the other one, what does this mean? | F |
| 8.S3 | thaaaat - I mean – moving | R3.2 |
| 9.T | Mover of charges? | F |
| 10.S3 | Yeah, and the second producer of charges, So, it's the one who produce, the resource | R3.3 |
| 11.T | Ok. Let me give you a design for a circuit with long wires in a way and two galvanometers… | F , I |

This example looks like a short excerpt. The truth is that it is quite a long exchange of talk as its purpose was not to only explore pupil's ideas, but to give them the chance to explain these ideas. It starts with the teacher asking for ideas on designing an experiment to test two opposing ideas. The teacher listened to a number of group’ designs. In the displayed excerpt, however, I skipped lots of the pupils' talk that was reflecting simple attempts that were not providing any meaningful design. The excerpt displays, though, the whole account of the third group design (starting from turn 6), in which S2 offered an outstanding idea reflecting her group's design. She talked about the idea of the big circuit that I have introduced to the teachers though the TI (section 5.5.4). It is amazing how the group came up with such good idea within few minutes of discussion. Needless to say, that the Dialogic nature of the initiated task has created the chance for such idea to be raised. The teacher responded by elaborating S2's idea, and the exchange between the two lasts for several turns before the teacher ends it (6-11). However, looking at the teacher's first follow-up to S2's response reveals a mistaken resolution of the design. The pupil was not talking about two circuits, but about one circuit to be observed twice under one different condition (the length of the wires). In response to the strange, mistaken reaction of the teacher, S2 got confused and provide an ambiguous answer. The exchange continues with contributions that it are difficult to understand the point behind or what thoughts they exactly reflect. Following this excerpt instantly, the teacher introduced an experiment; already planned by her, and the teaching continued around this experiment. A question to be posed here then is, why did the teacher ask the groups for their opinions, when she has not used them in any way? Why did she disregard the remarkable precise design proposed by S2, and instead of helping the group to refining it, she (with her as a reference in the pupils' eyes) directed the idea towards a total mistaken formation? Such behaviour suggests that the teacher has not practiced the Dialogic talk because she wanted to get ideas from pupils and to develop them after to support the scientific view. Rather, she wanted to use the Dialogic talk as an introduction to the experiment she has planned. The teacher Authoritative reaction in successive excerpts, therefore, has discarded the positive outcome of the Dialogic talk in stimulating the pupils to come up with remarkable ideas.

- The example on the smooth shift explained earlier (p.17-19), however, reflects a different picture (see also Les.2, Ex.1 & Les.5, Ex.1). In such examples, there appear to be a reason in shifting from one class of talk to another, each with its purpose, content and pattern of moves. Within such examples, alternative conceptions would be presented and the scientific view would be developed from these conceptions slowly and gradually by both the teacher and the pupils; the practice that is expected to influence the pupils' conceptual understanding positively.

In next section, the focus on pupils’ learning goes to their resultant conceptual understanding as indicated by the results from the focus group discussion.

## Commenting on the pupils' conceptual understanding using data from the teaching and focus group's setting

This section answers the following RQ (section 5.1), subsequent to the TI (b):

2.2b What evidence is there of pupils’ conceptual understanding, following the observed teaching?

This section is the fourth in analysing the pupils’ conceptual understanding. It examines the pupils’ understanding in relation to the topic of this second stage of the Electric Circuit by analysing the focus group discussion mainly and supporting it with the data from the whole CT and the pupils’ written responses in the bubble dialogue sheets. Again, the points rose in relation to the context of this kind of analysis (section 6.4) regarding the bases governing it and its unit of analysis are to be also taken into consideration in following this investigation.

The data of this stage, as been explained in the previous chapter, was generated after a teacher training intervention, where more Dialogic talk had been encouraged. As pointed out previously (section 12.2), each of the analysed lessons in this case witnessed the four different classes of talk. There were, however, very few incidents of Dialogic talk from the higher levels, that the pupils’ ideas had not been explored deeply and in detail as happened in the first case. Similar to the first case, the five analysed lessons were directed to explaining the simple electric circuit as a whole and how it works in general without going yet into the details of the resistance, voltage, and successive issues of series and parallel circuits. In this case, as referred to before through this chapter, there were more activities on the role of the battery and the role of the charges in carrying the energy throughout the circuit. In different incidents also, the teacher was directing the talk to relevant issues, but which do not relate directly to the taught topic, like discussing, for example; what the structure of atoms is, what the battery is made of, how Van De Graaff generator works, and so on. Overall, less talk on the concerned issues went on, and more around multiple activities.

In what follows, the pupils' understanding is examined in relation to the three concepts of Charge, Current and Energy, and how a simple electric circuit works in view of the three. Here are the main scientific ideas to be examined in relation to the specified categories:

1. Charges: Charges originate in the circuit and not in the battery;

2. Current: When the circuit is connected, the charges are set in motion in all parts simultaneously; Current is not consumed, it is conserved. Current (Intensity) is the same everywhere in a simple circuit.

3. Energy: Battery is the source of energy; Energy is transferred in the circuit. It is not conserved, it is consumed;

4. Electric circuit: Electric circuit works as a system, not locally or sequentially; what is happening at one point in the circuit relates to what is happening at other points (not locally), and it is all happening at the same time (not sequentially).

These ideas are followed within two main categories relating to the individual concepts on one hand, and how the electric circuit works in general on the other hand:

### Electric circuit in relation to Charge, Current and Energy

As explained in section 7.4, although being separated for the purpose of analysis, the three entities are interrelated and needed altogether to explain how a simple electric circuit works. There is the attempt here to examine the pupils’ conceptions of the three entities and if there are any difficulties or misunderstanding that might have affected the pupils’ judgment to the problems presented through the bubbles’ dialogue scenes. In overview, however, the focus group discussion in this case does not provide rich and enough data to be investigated in relation to Charges and Current. The main reason for this is the highly reliance of the interviewed pupils on their conception of Energy in explaining their views to the problems presented by the bubble scenes.

#### Charges and Current

Although there are very few incidents in which the pupils referred to the origin of charges during the focus group discussion, it is quite obvious that they all have the scientific conception of the charges as originating in the wires and not in the battery;

R: Where are the electrons basically?

S1: in the wires…they're everywhere (looking at the group, and everyone is saying: Yeah)

…S3: the electrons are not coming out from somewhere. They're in anywhere. They're there, but basically move because of the battery…

…S1: …the electrons are distributed everywhere in the wire

The assertion tone with which these utterances have been pronounced left no place to ask the pupils more on this point as it was very clear that the battery as a source of charges is not there anymore in their minds. Had this be the case, we might then wonder if this is a reason why charges as a conception, was rarely included in their argument about the lightness of the bulbs in the discussed question as this was a point of agreement and would not be an attribute in defending their different views about the lightness, therefore.

Similarly, the movement of charges has been referred to less frequently. More strangely, it had not been conceptualized as a current; not even in a single incident. The ‘Current’ as a term was totally absent from the pupils’ talk. When referred to implicitly as movement of charges, this was done mostly within the context of the role of the battery in moving them, and based on their existence in the wires rather than featuring it in light of its nature of movement.

S6: at the beginning the electrons move, the battery gives the energy…

S3: …they’re there, but move basically because of the battery. They take energy…

S4: I disagree…cause the electrons there before the green bulb have their energy…it will light instantly cause the electrons are distributed over the matter of the wires and have their energy…

S2: I’m with her cause the charges distribute all over the wire, once we close the circuit, the battery sends…

S6: I agree cause the electrons are there…

Even when the talk seems to describe this movement, it can be easily realized that the description is in terms of the energy. In such incidents, the utterances seem to reflect a sequential thinking in approaching the movement of charges. The overall discussion asserts, however, that the pupils have a sequential reasoning in approaching the energy as will be explained later on, and that in their mistaken articulation of the movement of charges, they were actually talking about the transfer of energy that is to be carried by charges:

S4: basically when the electrons pass by the battery will be provided…will pass by the red bulb which will consume…then move to the green bulb and will take…the electrons will go back then to the battery

(Writings of S4)

Farah: ..the work of the battery is to push the electrons and give them energy…Secondly the electrons move and they’re carrying energy so they’ll pass by the bulb (1) and give it from its energy then pass by the bulb (2)…then go back to the battery

Due to the absence of the current as a concept in arguing about the discussed questions, the data does not provide any evidence on the pupils’ views of the scientific ideas of the current as consumed, and being the same everywhere throughout the circuit. In defending their answers, though, the pupils’ views on the simultaneous movement of the charges had appeared in few incidents;

S3: maybe right, the two bulbs will light at the same time cause like any circuit, if we turned on the switch, the electric circuit works- means that the attraction and repel start working- means that all the electrons moved. I mostly agree now with…

S2: it’s right, they all move at the same time but they don’t all have the same…

S5: they light with the same brightness cause the electrons are there everywhere

Going back to the teaching, it appears that the pupils had not get the chance to develop the idea of the charges in the wire and the nature of their movement specifically, slowly and gradually as happened in the first case. This is because the teacher did not approach it like asking about where the charges in an electric circuit are coming from, and if they move and how. Rather, she guided the pupils to recall and think about the structure of matter to bring to their awareness that charges are there in every matter:

Sa: Static electricity exists in every material

T: Exists in all materials, how?

Sa: Cause we know that any matter is neutral having protons and electrons. There're atoms and because a matter consists of atoms, then it has negative electrons and positive protons

T: It has charges, so every matter…

She then focused on the necessity of the wires to be there in the circuit and if they can be replaced with any other kind of matter:

T: …Is it necessary to have wires in the circuit? The answer of the Voltmeter group was no. It can be without the wires…but... Do you wanna add anything to their answer?

Sb: It needs wires

…S2: It doesn't have to be wires. It's necessary to be a conductor, but doesn't have to be wires or the matter itself is solid. That matter can be a liquid or…

Without discussing it with them, she displayed a video showing the movement of the charges prior and subsequent to closing a simple circuit, and presented the scientific views authoritatively, featuring the movement of charges in the wire before and after the circuit is connected:

T: now let’s have a view inside a conductor…the yellow charges are moving electrons. This is how the conductor looks like, the conductor in its normal state has moving electrons, free-moves free…now when I press current, let’s see…Do the electrons move randomly?...in how many directions?...moves in this direction. Ok, is there any part that will be devoid of charges at any moment?...So the electrons were there, but moved when…so surely they got something that help them to move, let’s have a small activity on this…

Most of the focus in the lessons after moved to performing and discussing a range of activities on the role of the battery in pushing the electrons and providing them with energy. In the lessons subsequent to the five analysed lessons in this study, the topic of electric intensity was discussed, and so the pupils’ views on the current might be expected to change or become clearer. What is of interest here, though, is that the absence of the conception of the current in regard to its movement and features from the pupils’ argument can be followed back to the teaching that witnessed also less focus on current. Moreover, the pupils’ tendency to discuss this movement mostly in relation to the role of the battery only, can be also followed back to the teaching which paid great attention to this point. In the extracts below, although the pupil was discussing the lightness in terms of current and the teacher did approve it, it is obvious that she is directing the talk to discuss the lightness in terms of energy:

Sc: Cause we know that the charges move at the same time. The electrons move at the same time, and they go around in a closed circuit. So, it will be the same brightness cause they're passed by the same charges

T: Ok, cause the same charges will pass by them. Good. So, the two bulbs will glow with same brightness…The other thing, we've said that these electrons; where do they get the energy they carry from?

Sd: The battery

T: The battery which is formed of… It has a chemical energy that transfers to electric energy that…If the two bulbs are identical, then what…Will it give one bulb more energy than the other? Or…the moving electrons as a number will not be affected, but what happen? The energy is distributed… is it clear?

Nevertheless, there were incidents of talk in which the teacher was focusing the talk on the current and its features (see, for example, p.19 -23), which implies that the absence of Current as a concept from the pupils’ explanation- through their written responses to the bubble sheets and their contribution to the focus group discussion- cannot be understood only in light of the less focus paid to this issue throughout the teaching. Another dimension to this might be the mistaken or the unclear view about the transfer of energy that most of the pupils of this group have showed. They were agreeing over the conception of charges, but disagreeing over the energy; its entity and way of transfer. Expectedly then that the different views about the lightness in the stimulated questions are to be discussed more in light of the issue they are disagreeing about (i.e. energy).

#### Energy

In starting discussing their answers to the question of the first bubble dialogue scene, the pupils’ views on energy started to emerge and continued throughout the focus group discussion. These views can be examined in regard to different aspects; some were agreed upon and some were not. All the group pupils, for example, appeared not to be questioning the battery as a source of energy. There are even incidents in which some of them talk about two functions of the battery as pushing the electrons, and providing them with energy, although the overall discussion reveals that the connection between the two functions is not clear in the pupils’ minds. Besides, the pupils showed uncertainly about the nature of the movement and the way with which the energy is transferred, as will be explained later on:

S6: …the battery gives energy to the electrons

S4: basically, when the electrons pass by the battery will be provided by energy

S3: the electrons…are there but they move because of the battery-they take energy from the battery

S6: once we close the battery they just move. I mean it’s the battery giving them the order to move-then it gives them energy

S4: …the lightness of the two bulbs will be less because the function of the battery is pushing the electrons and giving them the energy

(Writings of S1)

Farah: …the circuit will not work if we took out the two batteries because there will be nothing to stimulate the electrons to move

The conception of the energy as transformed to light in the bulb can be implicitly concluded from the pupils’ continuous connection between the energy provided by the battery and the lightness of the bulbs:

S1: … because it takes the larger amount of energy, so it will light brightly

S2: …once we close the circuit, instantly the battery gives the energy and the bulb lights

S3: …because the electric energy will be transformed to light

(Writings of S2)

Farah: because the battery is energy, so if we took one of the batteries out, the energy will decrease and the lightness of the bulb will decrease, therefore

Similarly, the conception of the energy as consumed through the course of the electric circuit work can be heard, explicitly and implicitly, in talking about how the electrons distribute the energy to the bulbs which consume it, and so the electrons need to go back to the battery to refill with energy:

S6: …and it will give it to the bulb. The energy might finish because it’s given to the red (bulb)…

S4: …they’ll pass by the red bulb which will consume the energy enough for it to light…

S4: …the electrons wouldn’t go to the battery, carry energy and go back…they’ll be having energy and will consume it in the bulb…

S3:…with two batteries, the lightness will be more and it will last more

Such a general scientific understanding of energy; its source and some of its features appeared through the pupils’ responses to the second scene that asks about the effect of reducing the number of the sources of energy (the battery) or reducing the number of the consumers (the bulb) in a certain electric circuit. They all agreed that taking one of the two batteries out of the circuit and keeping the two bulbs would reduce the amount of the energy available to the two bulbs, and the opposite in taking away one bulb and keeping the two batteries. They pointed, although less evidently from what has appeared with the first case, to the possibility of the lightness to be the same if the bulbs were getting the ‘enough’ energy’ to light with most brightness:

S4: …the lightness of the two bulbs will be less because the function of the battery is pushing the electrons and giving them the energy, so the lightness of the two…

S1: …the amount of energy for the two bulbs before is more, so the amount of energy will be less when we take one battery out, so the electrons will have less energy

S6: I agree with her because with one battery, the amount of energy will be different

S5: …the brightness of the bulb will increase cause all the energy goes to one bulb only

S6: I don’t think it will be different cause the bulb is taking what it just needs…if it needs more, it will increase (brightness)…so it might increase and it might stay as it is if…(all the group support her, except S2 who insists that it will always increase)

When it came to discussing how much bright each of the two bulbs will be after taking out one battery, the difference in views in relation to the distribution of energy started to emerge. In fact, these different views appeared firstly through the pupils’ responses to the first scene. It became obvious from the beginning that the pupils had different opinions about the lightness of the bulb because of different views on energy and how it is transferred through the circuit, rather than because of their view to current. Here are some extracts of the pupils who did not attribute the difference in lightness to the difference in position:

S6: the solution is not in changing the position because may be there is something wrong with the battery-the battery strength is not enough for the two bulbs

S4: I disagree with S6. I mean it’s not the battery that is not enough for the two bulbs- we might say something wrong with the green bulb and so it doesn’t light…the problem is not with battery cause the electrons carry energy with them and divide it equally between the two bulbs or the devices in a circuit

S6: what she is saying is right, but still, the problem might be with the battery

And here is part of their written responses from the bubble sheets:

(Writings of S6)

Muna: …now take the red bulb out because it is not enough for the battery to work. It has to work to light two bulbs

Salma: I did, but the bulb (green) still doesn’t light

Muna: so the problem is with the bulb itself

(Writings of S4)

Muna: if we changed the position of the green bulb with the position of the red bulb, the green bulb will light brightly

Salma: wrong thinking Muna because the position occupied by the bulb does not affect its brightness

Muna: so why did the red bulb light brightly in reverse to the green bulb

Salma: I think there is damage inside the bulb

Muna: No Salma, I know how it works. When the electrons loaded with energy they move, they pass by the bulb (1) and it will consume energy and remains a little energy for the other…

Salma: You’re wrong Muna because electrons divide the energy equally for both bulbs…

In opposite, other pupils attributed the difference in brightness to difference in the amount of energy reaching each of the bulbs due to their positions:

S1:…the red bulb light brightly because it takes the larger amount of energy…

S3: it is not divided cause the electrons at the beginning will put energy in the first bulb, so the energy in the second will be less

(Writings of S1)

Salma: I think I know the reason… these bulbs need a battery with more energy, so if we took out one bulb and keeping the battery, the remaining bulb would be lightning perfectly

Some pupils seem to be utilizing a sequential model in thinking about the distribution of energy, as the last two extracts of S1and S3 demonstrate. Others appeared to hold to the scientific view that the two bulbs will light with the same brightness, if identical, regardless of the position occupied by them. S4 expected, therefore, that there must be something wrong with the green bulb that it is dim. Some of the group’ pupils seem to support her. When it came to defending this correct view, these pupils as well as the others, appeared to be struggling with what energy exactly is, and how it is distributed throughout the circuit accordingly. For those who showed the mistaken judgment on the lightness of the bulbs, it became obvious that they are having the ‘package’ image of energy and the sequential view in distributing the energy; electrons will fill their packages from the battery, give most of it to the first bulb in accordance to its need and the remaining of energy (and there must be) will go to the second bulb before going back to the battery to fill the package again:

S6: it’s (energy) something that the electron take from the battery so the bulb consume it

S1: …they (electrons) have to take load of energy

S3: they don’t have their energy- they take their energy from the battery

R: so they have to pass by the battery to take their energy

S3: yes cause the battery is the one who push them- they take their load of energy and carry it to the bulb…and the red bulb is the one who lit most bright because it’s the one closest to the battery…

Even for those who gave the correct judgment, they appeared to apply the sequential model when talking about the distribution of energy although they do not seem to mean it as they were insisting that the two bulbs, more than just having the same brightness, they will light at the same time and instantly:

S4: basically when the electrons pass by the battery will be provided…will pass by the red bulb which will consume…then move to the green bulb and will take…the electrons will go back then to the battery

S2: they light with the same brightness and at the same time

S4: if the two bulbs are not identical, then the first one take its need and the second its need

S5: they light equally cause the electrons are there everywhere

In fact, the pupils’ struggle to explaining how the energy is transferred can be seen as to result from their confusion about what this energy is, in the first place. In their attempt to defend the scientific view, the pupils holding to it appeared to be thinking loudly about energy and got to some remarkable ideas. S4 in the first extract seem to be approaching the view of the energy as internal in the electrons, while S2 thinks about it not as a ‘material’ to be carried, but as a ‘form’ to be changing from a kind to another:

S4: I say instantly and I insist in my opinion because basically the electrons are distributed all over and carry their energy because when closing the circuit, electrons will not go to the battery and take energy to go then to the bulb- they’ll be having energy and will consume it in the bulb, then they’ll pass by the battery and take energy

S2: I don’t know- maybe it is that the electrons are distributed all over the wire, so when we close the circuit the energy will be in the process of pushing the charges

These ideas, in response, seem to have hit the minds of the girls from the opposite group, but they still appeared to be twisting them to reinforce their views of unequal distribution of the energy ‘package’, although they look confused in doing so;

S1: electric- the battery is formed of chemical substances- when they break up , the positive goes to the negative. This is a repel and this is the energy

R: attraction and repel means movement of electrons, and they’re saying this is the energy…

S1: I don’t think so. They have to take their load of energy

S3: it’s not electric energy, chemical energy. The battery is a chemical energy…electrons are electric energy

S1: No, they (electrons in the part of the wire between the two bulbs) have kinetic energy not electric

S3: they have energy, but not a lot because they haven’t gone to the battery yet so it’s not enough for the green bulb (the second), while the red lights cause the electrons passing by it are already coming from the battery

Such arguments and views reflect uncertainty about what exactly is the energy carried by the electrons and how it is transferred. As mentioned before (section 7.4.1.3), this is a tricky scientific issue to be tackled, but yet the difficulty in dealing with it can be linked to what happened through the teaching. When discussing charges and Current, I explained that most of the teaching attention was directed to performing and discussing a range of activities on the role of the battery in pushing the electrons and providing them with energy. What is more is that different classes of Authoritative and Dialogic talk went around those activities. One can expect then that the pupils would show a more correct and solid understanding of the energy than the one, demonstrated. It seems, however, that there was a problem with the activities themselves, which affected the quality of related talk, accordingly. It is out of the scope of this analysis to describe these activities in detail, but I could see since I was videotaping the lessons that the pupils faced a difficulty in understanding those activities and mapping their links to the issues in discussion regarding the work of electric circuit. With simple activities, the discussion can be focused to develop the scientific view that the activity is designed for. In more complicated ones, however, the pupils can face difficulties in understanding how the activity works basically; the thing that is expected to draw their attention away from the intended purpose and affect their learning negatively. In the following extract, for example, Sa is asking about an activity suggested by the teacher to test if the battery is a producer or a pusher of charges. The teacher explained that if the battery is a pusher then the pointers of two galvanometers in a circuit will deflect at the same time, but Sa cannot relate this expectation to the assumption of the battery as a pusher.;

Sa: … How do they (the two Galvanometers) move at the same time?

T: They will move at the same time. This is if the electrons start moving at the same moment

Sa: It can’t be at the same time

T: We’ll see. We’ll see. Is it right, because if it (battery) produces, the first works then the second, Ok? If they moved at the same time, this means the two got electrons at the same moment, right? Again #

Sa: How? In one side, the electrons go

T: This is what we wanna see. Do the electrons really move from one side to reach the other one, or they're just there in the circuit? All what happen to them is a pull act^ ()-nothing more than this. You get it? This is what we'll examine. you know the chairs game…at a moment, there will be a voice ordering them to start …

Sa: So, it's the same there

T : This will be happening in the circuit if the battery is a pusher, if the battery is who give the order and make them all move at the same time

Sa: It can't be Miss at the same time cause from the same direction they go. I mean one before

T: Oh S1, this is what I'm saying. We have two ideas, whether the electrons start…you got the idea? (Sa: Yeaaah)

In fact, the teacher could have used a more simple activity like the ‘big circuit’ one, or simplify the activity itself by putting two bulbs instead of two Galvanometers. Similar situation to this was noticed with other activities. In fact, the teacher presented several activities (circuit with two Galvanometers, movement of pens, chair game, magnet and metals), all of which appeared to be linked to the role of the battery whether pushing the electrons or giving them energy. In addition to the difficulties that some pupils showed in capturing those links, there was rarely a deep discussion (Dialogic talk of high level) of the details of those two functions and the connection between them.

In summary, the focus through the teaching here was on the charges as being pushed by the battery and given energy to deliver to the bulbs to be transformed into light and heat. As suggested in the first case (section 7.4.1.3), without bringing it to the awareness of pupils and rejecting it at least, the view of sequential transfer of energy from the battery to a first bulb and then to a second one is expected to persist in some pupils' minds. However, more pupils in this case gave incorrect judgement for the first scene and all of them appeared to rely on sequential reasoning in explaining the transfer of energy. These difficulties cannot be understood just in light of what went on through the teaching in terms of energy, but they need to be thought of in terms of the overall picture of how the electric circuit works that the CT seem to have reinforced.

### How the electric circuit works?

Since the first stage prior to the TI, the teacher in this case appeared to encourage the pupils’ questions/comments and respond to them by listening to them carefully, appraising their contributions and trying to lead them gradually to what, she thinks, answers their questions in accordance with the scientific view. This was the case again in this stage with more Dialogic talk on one hand, and more variety of the four classes of talk each lesson, on the other hand. One might wonders then of what might went wrong that the whole group of the participated pupils dismissed the current totally, and showed, to different extents, a sequential reasoning in thinking about the transfer of energy. This resulted in three of them (including the two of high-attainment according to the teacher’s records) giving incorrect answer to the first scene and insisting on it, although they had been confronted with other contradicting facts. The other three provided the correct answer, but they could defend it, mainly in terms of equal distribution of energy existing somehow in the first round before the electrons pass by the battery to load their package with energy, without being able though to give a convincing and scientific picture of how the electric circuit works. On the other hand, the pupils who gave incorrect judgment appeared to be confused even about the instant lightness of the bulb in a simple electric circuit as their mistaken conception of the transfer of energy appeared to interfering their overall view to how the electric circuit works:

S4: I disagree with…cause basically the electrons found before the green bulb carry energy. If they were not carrying energy when connected, the red will light before the green

S1: will light, but less (green bulb)

R: If it is like you're saying, and we've had a long circuit, will the bulb light instantly or it takes time?

S1: Instantly. Well, the electrons are there everywhere in the wire. So once we close it, the bulb won't light instantly- it needs time

S3: yeah the electrons are there, but they don't have energy so they have to get energy from the battery so after a while it lights, even if short time

S4: it will light instantly cause the electrons are distributed everywhere and carry energy- then they will consume their energy in the bulb then pass by the battery, take their energy and again continue on the cycle

S2: I'm with her cause the charges are…once we close the circuit, the battery sends the energy

Even when trying to lead them to focus on the movement of charges, they still found their way to twist the view to how the circuit works to match their judgement:

R: what S4 is saying that the attraction and repel represent the electric energy, which appeared as kinetic in moving the charges

S1: because of this it needs time…we have a negative pole and a positive, and Miss told us that the negatives will move by an order from the battery…chemical energy to electric…the repel start near the battery- till they arrive, it takes time

S3: maybe right, the two bulbs will light at the same time cause like any circuit, if we turned on the switch, the electric circuit works- means that the attraction and repel start working- means that all the electrons moved. I mostly agree now with…

R: so what would be the problem with the green bulb?

S3: maybe because the electrons don't have enough energy from the battery…they light at the same time, but one will light more brightly than the other cause it got more energy…

S1: It's right that they all move at the same time but not all of them have energy- not all of them have something moving with it ummm- I mean energy is something that can push the charges for work

It is striking to know that a very similar question to the situation presented by the first scene, has been actually discussed in the fifth lesson. One can easily use the talk exchanged around that question to explain why the pupils who hold to the view of equal distribution of energy did so. It gets more confusing, though, to justify the pupils' dismiss of current, as the teacher, in this particular incident, had to focus on the current because the discussed question consisted of two parts, with all the different alternatives were current-related. Here are some extracts of this talk;

Sa: Both bulbs have the same brightness

T: Why?

Sa: Cause we know that the charges move at the same time. The electrons move at the same time, and they go around in a closed circuit. So, it will be the same brightness cause they're passed by the same charges

T: The battery which is formed of… It has a chemical energy that transfers to electric energy that makes the electrons move…If the two bulbs are identical, then what will happen when the electrons pass by? Will it give one bulb more energy than the other? …the electrons, while carrying the energy, they distribute this energy to the two bulbs equally…this is what happens in the electric circuit…the electrons take energy from the battery…but the battery does not produce them, does not produce electrons. The electrons are basically there in the conducting materials…the moving electrons as a number will not be affected, but what happen? The energy is distributed… is it clear?

T: Ok… how do you explain that the two bulbs have the same (brightness)…?

Sb: Both bulbs used up…I mean the two bulbs use up the same electric current

…T: Does it mean that the electrons…for example, there are 5, then they will be used and 4 will remain, they will be used and so

Sb: I mean every bulb, if for example 5, the two bulbs will take one one. And 3 will remain that will go to the battery

…Sc: The current just pass by but doesn't decrease

T: Doesn't decrease, ok. This means the same- the same everywhere in the circuit. Or?

Sc: I mean the bulb doesn't take a current. It (current) passes by it (bulb), but doesn't take it

…T: The current is electrons…Imagine this person as Mister electron, what did the bulb take from him to glow?

Sc: …Energy. Energy

T: What did it take? Energy. In this bag, there is energy. It just took energy. Did it take the electron itself? No, it took an energy that the electron is carrying

…Sc: Every electron has energy. Every time an electron comes and puts its energy and then goes again to take

I found it difficult and confusing trying to relate the views presented through this example of talk to what has the analysis above demonstrated. On one hand, a correspondence can be noticed between some views that the teacher reinforced, and those which the pupils have shown, whether correct (e.g. existence of charges) or misleading (e.g. package-view of energy). On the other hand, the group pupils' appeared not to got the teachers' explanation of this question in relation to current and energy when being confronted to the very similar situation of the first bubble scene. One thing about this example that has been referred to before (section 12.3.2.2), is that although the teacher has controlled the talk authoritatively in the second extract to explain why the two bulbs have the same brightness, the pupils' response to her question afterwards gives the impression that they were not listening carefully. Yet, it can be suggested that the the teacher's talk was not clear enough, or confusing somehow.

In a broader sense indeed, the pupils' difficulties that the focus group discussion revealed, suggest that in spite of the Dialogic talk to disclose their ideas and the Authoritative one to develop the scientific explanation, and the different activities performed and discussed to confirm the scientific view; there was what made the scientific account not clear enough for the pupils. It might be that the limitation of the Dialogic talk of the higher levels along with the teacher lecturing about the scientific views through very long Non-Interactive/Authoritative talk throughout the five lessons, both have contributed to the pupils’ limited understanding. Moreover, in some other incidents, the teacher was guiding the talk away from the main point to discuss in detail different and indirectly related issues:

T: around the protons. This is atom (drawing a simple model of atom). There are…conductor is a matter and we’ve said that matters consist of atoms… But If I ask you, is there an evidence or… in which we saw static charges but in a conductor?

Sa: Van de Graaff generator

T: Excellent, Van De Graaff generator. A conductor, you remember when we talked about its parts. This is a matter (metal ball), we've said what its kind is?... Didn't I consider it in this case or didn't I consider it as charges that stand still on the surface of this matter? It's right that the electrons moved , but at the end they are there on the surface of this conductor. They stand still on its surface…

T: Liquid like what?

…S2: Water if being added to substances that help on conducting electricity, it will be a good conductor

T: Excellent…It's not necessary. We've talked about the existence of a liquid... We've had an electric circuit that contains a liquid. It was a circuit and it worked. In the chemistry chapter we did a practical activity in which we used a liquid... Indeed, in separating-which is, the electrolysis of water. What's the substance we've used?...not Chloride..no not…it was sulphuric acid. In electrolysis…(keeps on summarising the electrolysis of water)

The influence of such out-of-purpose talk can be approached from the same line of argument in discussing the complication of the activities performed and discussed throughout the teaching in this case. That complication, as well as guiding the talk to subordinate routes, might have contributed to confusing the pupils rather than directing their intellectual thinking to what was intended.

A summary of the pupils’ understanding on the different issues discussed above is offered in the conclusion chapter (section 10.1.2).