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Teacher-pupil interaction: a study of hidden beliefs in conclusion phases

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This article is a contribution to the characterization of teacher-pupil interactions during scientific inquiry. Attention is paid to conclusion phases, as it is at this point in the interaction that a pupil's production is to be accepted or rejected. Sixteen sessions taught by eight teachers in junior high and high schools were recorded, transcribed and analysed. In interpreting the teacher-pupil interactions, the presence of hidden epistemological and pedagogical beliefs in the conclusion phases have been discerned. The conclusion phase corresponds to a dogmatic (vs. constructivist) view of science and the teaching of science if the pupil's production is judged for its veracity in relation to the teacher's scientific knowledge (vs. its validity in relation to knowledge shared by both pupil and teacher). A discussion follows on the conditions for the teacher's building a relationship between this aspect of his practice and his beliefs. The impact of this research on teacher training is also considered.

Introduction

The French curriculum encourages junior high and high-school teachers to create teaching situations in their classrooms that will be favourable to pupils taking part in the building of scientific knowledge. Thus, two kinds of teaching situation are put forward: project-based teaching and pre-set task-based teaching. In project-based teaching, called “Paths to Discovery” in Junior High-School (Ministère de l’Éducation Nationale 2002) or “Guided Personal Work” in High School (Ministère de l’Éducation Nationale 2001), it is the pupil who determines the subject for study, and his research question. However, in pre-set task-based teaching (Ministère de l'Éducation Nationale 1997) it is chiefly the teacher who determines the field of study and the pupil’s activity. Pre-set task based teaching comes from research on the teaching of science (e.g. Joshua & Dupin 1989, Larcher *et al.* 1990, Kaminski 1991). This deals with various themes such as electrocinetics, geometric optics, and the particulate model. In both kinds of teaching (project teaching and pre-set task based teaching) the pupil is active and a producer of knowledge. If the pupil’s role is changed in relation to transmissive teaching, so is the teacher’s.

Several researchers agree that it is not easy for a teacher to take on this new role, whether he/she be a beginner or experienced (Vérin 1998, Morge 1998, Keys and Kennedy 1999, Luft 2001). When the pupils participate in the building of knowledge, the way the session will develop is partly unknown, and puts the teacher in an uncomfortable situation. The teacher guides the pupils without directing them. He/She helps them to reason without giving them the solution. He/She takes the pupil’s point of view into account whilst still keeping to the objectives he has set for himself. He/She gets pupils to express their beliefs whilst at the same time preventing the other pupils from being affected by them. He/She must cope with answers from his pupils which are frequently unexpected, and hard to manage. This teaching is also

based on epistemological and pedagogical beliefs which are not those commonly held by teachers.

Better knowledge of the teacher's role in these scientific inquiry classes may help to encourage teachers to implement such classes. The aim of the qualitative research presented in this paper is to gain a better understanding of a precise point in the teacher-pupil interaction, namely, the conclusion. Conclusion is the point in the interaction when a pupil's production during inquiry is to be accepted or rejected. The management of these conclusion phases is peculiar to the management of inquiry situations. Indeed, in transmissive teaching, the knowledge given by the teacher does not need to be checked publicly. So this research contributes to a better understanding of the peculiarities of the management of inquiry situations. In order to situate the study in the field of research on interactions, several studies on this theme that can be put in three categories are presented.

Three major research orientations in teacher-pupil interaction

Research on teacher-pupil interactions in science teaching can be put in three categories, depending on whether the studies concern the teacher's discourse, the pupils' and teachers' verbal behaviour, or the structure of the teacher-pupil interactions.

In the first category, teacher-pupil interaction is seen as an alternation with the teacher and then the pupil talking. In this case, it is the person him/herself who is the prime criterion for analysis of the interaction. Several writers, adopting this angle, have focussed on the analysis of what the teacher says (e.g. Zeidler and Lederman 1989, El Hajjami *et al.* 1999, Newton *et al.* 2000, Rodriguez and Thompson 2001, Cameron 2002). Just one aspect of teacher-pupil

interaction is analysed. Researchers want to understand what, in this discourse, is likely to have an effect on pupils' learning. These studies have shown, for instance, that the mastery of the scientific content in the teacher's statements, the epistemological beliefs conveyed by these, and their clarity and coherence differ from one teacher to another. The results of this research can open up new avenues for reflecting on teacher training so that this may foster a greater awareness of the notions and values the teachers transmit and the way in which they transmit them.

A second approach to teacher-pupil interactions consists in noting different verbal behaviour in pupils and teachers with a view to devising grids for analysis of interaction. (e.g. Flanders 1970, Postic 1977, Duffy *et al.* 2001, Scantlebury *et al.* 2001, Yip 2001, Sche and Fischer 2002). In this case, interaction is seen as several different forms of verbal behaviour, which are first isolated before being integrated into an analytical grid. Often, the dynamics of the interaction, its structure and the relationship between the different moves are not taken into account. Attention is paid to what the teacher and the pupils say, but not to the reasons for them saying it, the circumstances surrounding their participation and the way they affect the interaction. Unlike the aforementioned research, this research takes into account what both the protagonists (the teacher and the pupils) say. These tools for analysis can, for instance, be used to survey the impact of a reform or of training on teaching practices, to measure the percentage of how much the teacher or the pupil talks according to gender, or to establish a correlation between class interactions and pupils' performances or their attitude to science. Research in this field therefore aims to devise observation grids for verbal behaviour and to use these tools to carry out quantitative studies. This research has shown that there is a correlation between, on the one hand, some aspects of the teacher's verbal behaviour in the

classroom (for example, he sets the pupils problems, he is understanding and friendly), and, on the other hand, the pupils' performances and their attitude to science.

Finally, research in the third category studies both the structures of teacher-pupil interaction, and the elements which it is composed of (e.g. Lemke 1990, Franceschelli and Weil-Barais 1997, Polman and Pea 2001). Unlike the previous categories, it is concerned with the dynamics of teacher-pupil interaction, each element in the interaction being situated, and linked up with others so as to give a picture of its structure and to define the context for each move in the interaction. This research, which is generally qualitative, has shown that the teacher and the pupils resort to conversational routines which recur frequently, thereby enabling each speaker to find his place in the interaction rapidly. For example, the structure 'Question – Answer – Evaluation' (QAE) (Lemke 1990) is a very frequently used routine in teaching. Similarly, the ambiguous question is a way for the teacher to encourage the pupil to express his ideas clearly (Franceschelli and Weil-Barais 1997). As for Polman and Pea (2001), they have found a four-stage structure in teacher-pupil interaction in project-teaching situations:

> 1) Students make a move in the research process with certain intentions, guided as well as limited by their current knowledge. 2) The teacher does not expect the students' move, given a sense of their competencies, but understands how the move, if pursued, can have additional implications in the research process that the student may not have intended. 3) The teacher reinterprets the students' move, and together student and teacher reach mutual insights about the students' research project through questions, suggestions, and/or reference to artefacts 4) The meaning of the original action is transformed, and learning takes place in the students' zone of proximal development, as the teachers' interpretation and reappraisal (i.e., appropriation) of the students' move is taken up by the student. (ibid., p.227).

Our research can be put in this third category. Unlike the research conducted by Polman and Pea (2001), which is concerned with project teaching situations, our study deals with pre-set task teaching, which the French Ministry of Education asks to be implemented. More precisely, the interaction when a pupil's production is to be accepted or rejected has been focussed on. What modes of control are used, what epistemological and pedagogical beliefs correspond to these modes of control and who may use them have been established. As will be seen in the course of this paper, these questions cannot be answered without being familiar with the production which is being controlled, the question asked of the pupil, and the knowledge available to the pupils involved in the interaction. In other words, the conclusion phases, and the reading of the beliefs these hide can only be achieved by situating them in the context in which they appear during the interaction.

Methodology

Eight teachers volunteered to take part in this research. Of these eight, two have been teaching for about twenty years, whereas the others are trainees. The teachers work either in junior high-school or in high school. The methodology has been organized in a four-stage iterative process. First, the preparation stage, when the researcher and the teacher devise a teaching session composed of a sequence of tasks. The researcher suggests instructions for the teacher on interacting with the pupils. Secondly, the teacher records the class using a miniature microphone and a portable tape-recorder. Thirdly, the recording is transcribed and analysed by the researcher in order to gain a better understanding of the interaction and to explicit the epistemological and pedagogical beliefs underlying it. Fourthly, the results from this analysis are used to refine the instructions given for the following preparation stages. The

epistemological and pedagogical beliefs which are linked with these interactions enable the researcher to account for certain constructivist orientations in interaction during the preparation stages with the teachers. Thus the descriptors for interactions and their relationships with underlying epistemological and pedagogical beliefs have been built up gradually, throughout this iterative process. The beliefs are inferred by the researcher. We are not dealing with the teacher's beliefs which can be accessed in a questionnaire or an interview, but those beliefs which are hidden in the teacher's interactive practice. A relationship between certain teaching practices and the pedagogical and epistemological beliefs to which they correspond will be established. The question of the relationship between this aspect of practice and the teacher's beliefs will be discussed at the end of the paper. In this analysis, we make a distinction between epistemological beliefs and pedagogical beliefs. Epistemological beliefs correspond to beliefs about the nature of science, that is to say for instance, scientists' activities, the nature of the scientific knowledge they produce, and the way in which this knowledge is produced. Pedagogical beliefs correspond to beliefs about the teaching and learning of science, in other words, the way the pupil learns scientific knowledge, the way the pupil's conceptions are taken into account, the definition and attribution of the respective roles of teacher and pupil and the definition of the knowledge the pupil is to learn, and so on. The aim is not to determine whether it is the epistemological or the pedagogical beliefs that shape practices, but to determine which epistemological or pedagogical beliefs the practices observed correspond to.

The recordings are carried out in a natural situation as the teachers involved are working with their own pupils in exactly the same conditions as for the rest of the year. A total of fifteen sessions on very varied themes, as seen in table 1, were recorded, transcribed and analysed.

[insert table 1 about here]

The analysis of the first transcripts brought us initially to differentiate between the QAE pattern in recalling knowledge, and the QAE pattern in inquiry. The nature of the productions and the way they are checked is different in the two cases. The analysis of interactions in inquiry then allowed an interaction mode based on the expectation of the right answer, corresponding to a dogmatic conception of scientific knowledge and the teaching of this, to be pinpointed. By gradually altering the instructions given, certain features of a teacher-pupil interaction mode which is compatible with a constructivist view of science and the teaching of this could be described.

Differentiating between the QAE pattern in recalled knowledge situations and in inquiry

The first transcripts of the classes show a predominance of the QAE structure. This structure appears in two different teaching situations: checking previously established knowledge, and inquiry. To get pupils to recall knowledge (cf. extract 1), the teacher asks a question, for example: ‘What is the atom composed of? ‘. The pupils give several answers: ‘It’s round‘, ‘It’s got a small nucleus in the middle‘, ‘It’s got neutrons and protons‘, ‘It’s got ions‘. And the teacher accepts or refuses these answers: ‘Yes it is, in the nucleus’, ’No, not ions.’

Extract 1, Session B

1 Teacher 1 [T1]: The nucleus. Well then. Perhaps we ought to see what we already know about the atom. What is the atom composed of? Who can tell me what the atom is composed of?

2 Pupil [P]: It’s small. It’s got a small nucleus in the middle. It’s got neutrons and protons. Is that right?

3 T1: Yes it is, in the nucleus. And what is there around the nucleus?

4 P: There are ions.

5 T1: No, not ions, but?

6 P: Electrons.

7 T1: Electrons...

This QAE pattern also appears when the pupils are carrying out inquiries. In pre-set task sessions, the teacher gives the pupils a task, which corresponds to the 'Question' phase. Each pupil provides a response to this task (Answer). Then the teacher has to judge this answer (Evaluation). So the difference between the recalling of knowledge and inquiry is not to be found in the structure of the interaction, but rather in the nature of the knowledge involved. Indeed, when recalling knowledge, the question asked by the teacher is for an answer the pupils already know, which is not the case in inquiry. A rejection such as "No, that's not the right answer" does not have the same significance in recalling knowledge or in inquiry. In order to bring out this difference, we have preferred to use the terms 'Task – Productions – Conclusions' to describe the structure of the interactions in inquiry. The conclusion stage is thus a time for interaction when the teacher has to decide whether to accept or refuse a production provided by a pupil in response to a task.

A way to check productions corresponding to a dogmatic conception of scientific knowledge and the teaching of it

The first transcripts from the sessions show that in inquiry, the arguments used by the teacher for accepting or refusing the pupils' productions are authoritative. The teacher judges the pupils' answers to be right or wrong, just as he does when recalling knowledge. He refuses the productions which are different from the solution he has until a pupil provides the right

answer. If this way of checking pupils' productions is well-adapted to recalling knowledge, it is not suitable for inquiry, because of the epistemological and pedagogical beliefs it conveys.

Indeed, from a pedagogical point of view, this mode of interaction encourages pupils to memorise declarative knowledge that is not necessarily interconnected, rather than to build a rational answer. The pupil's cognitive activity thus consists in guessing what answer the teacher expects. Checking knowledge in this way comes from a conception of learning which corresponds to memorising. Here the teacher is the only person with knowledge and power as he is the only one to know the right answer. Consequently, the pupils are excluded from any discussion of the proposals and thus their participation in interaction is greatly limited. From an epistemological point of view, scientific knowledge is here considered as truth in that the arguments used to check the pupils' productions are right/wrong judgements. Giving scientific knowledge a status of truth also gives it an unchangeable and timeless character. So if we follow this conception, then once scientific knowledge has been found, it can no longer be questioned, since it is the truth, whereas from a contemporary epistemological viewpoint, scientific theories are seen as an intellectual construction which can be changed in response to new questions, or to take new phenomena into account (e.g. Popper 1934, Bachelard 1938, Kuhn 1970).

In order to illustrate this, we shall analyse the extract from a class on radioactivity which took place in the following context. After showing his pupils a film, the teacher draws up a list of stable nuclei (C12, N14, O16, Bi209) and a list of unstable nuclei (C14, O14, Po210, Ra226, U238). These lists have been taken from the film and are given to the pupils. The teacher reminds the pupils of the conditions for stability and instability dealt with in the film. They are as follows: there is symmetry between the number of protons and neutrons in the stable

nuclei which have between 1 and 40 nucleons. There is dissymmetry between the number of neutrons and protons in the stable nuclei having between 40 and 209 nucleons. All the nuclei having more than 209 nucleons are unstable. All the unstable nuclei try to become stable. Before the film tackles the passage from instability to stability, the teacher stops it and asks the pupils to imagine how the small unstable nuclei could become stable.

Extract 2, Session B

1 T1: Couldn't you imagine something?

2 P: Well, we could take away a neutron, and put in a proton, and that would make 7, 7.

3 P: That's it, it's got to be equal.

4 T1: So we're going to try to make it equal. What do we need to do to make it equal? What has to be changed?

5 P: A neutron's got to be changed into a proton.

6 T1: A neutron's got to be changed into a proton. Well, we're going to see you can do that. Let's get going. You're going to watch the film. And they're going to give you everything you just said. We're going to try and sort it all out, from what they're going to show you. So you're going to see the pictures, and you're going to try to sort it all out. Off we go!

In extract No 2, we can see that the teacher (6 T1) stops the inquiry as soon as the right answer is produced. This right answer (5 P) is repeated by the teacher (6 T1) and accepted as it is the right answer. 'Well, we're going to see you can do that.' However, the teacher does not comment on the previous answer (2 P) which he avoids dealing with by taking out of it the elements which go with the answer he expects (3 P). By acknowledging that the last production is the right answer, the previous production (2 P) and all the others are judged to be wrong without any scientific argument accounting for this refusal.

The need for the teacher to control pupils' productions

If he is to move towards constructivist management of conclusion phases, the teacher must avoid using authoritative arguments. A first possibility is delegating the control of pupils' productions to other pupils. If the teacher no longer uses authoritative arguments, he is in danger of seeing pupils agree on an incorrect production, as can be seen in the following example: 'You add the uranium atoms to each other'.

Extract 4, Session B

1 P1: You can't put uranium in carbon.

2 P2: Why?

3 P3: No, you can't. Uranium can't be mixed with carbon.

4 P2: Well in that case, the uranium atom will, the uranium atom will go with a stable uranium atom.

5 P1: That's it, I should think that'd be more…

6 P2: You add the uranium atoms to each other .

The teacher cannot refrain from controlling the pupil's productions But this does not mean that the pupils should be excluded from this control. This moment in the interaction must remain the teacher's responsibility. The teacher must always be able to intervene if necessary, in order to control the production himself.

A way to control productions that is compatible with the image of constructed and evolving scientific knowledge

The way pupils' productions are controlled in inquiry is compatible with a constructivist approach if the acceptance or refusal of the production concerns its validity or absence of validity can be considered. A pupil's production is considered to be valid if it answers the question asked and if it is in keeping with the knowledge he can use as reference. This knowledge is the knowledge related to the theme tackled, which has already been temporarily validated by the teacher, and which is available both to the teacher and to the pupils involved in the interaction. It is to be noted that this control is completely different from that used in an interaction based on the expectation of the right answer, when the teacher is looking for the veracity of the production in relation to the scientific knowledge he has at his disposal.

This reference knowledge can be either theoretical or empirical. In some ways, its role in the classroom is similar to that of the paradigm (Kuhn 1970) in scientific activity. It defines what is shared by the scientific community at a given time, and it is used by this community to check the validity of new knowledge. The different productions are to be judged within the framework of this knowledge. This reference knowledge establishes the boundaries within which the teacher and the pupils may negotiate the validity or absence of validity of the productions. The elements of this knowledge are not listed arbitrarily by the teacher, but defined by the teaching situation itself in relation to what the teacher and the pupils have established prior to this.

The beliefs underlying this form of interaction are the following. On an epistemological level, this mode of teacher-pupil interaction is compatible with the idea of scientific knowledge that is constructed and which is a result of human activity. As the productions are accepted in relation to what has previously been established (reference knowledge) it can be said that they have been constructed, as their acceptability depends on other knowledge having been

accepted. As this constructed knowledge depends on previously established knowledge it can be hypothetical, as it depends on the framework which it refers to so as to be accepted or refused.

On the pedagogical level, this mode of interaction is consistent with a socio-constructivist conception of learning (Vygotski 1934, Doise *et al.* 1978, Perret-Clermont 1986). For the knowledge is constructed collectively in the interaction between the pupils and the teacher, which the theory maintains facilitates the pupils' individual construction of knowledge. Trying to determine the validity of a pupil's production in order to accept or refuse this production is a necessary condition for the co-construction of knowledge. This co-construction in turn facilitates learning. By limiting himself to only mobilising the knowledge available to the pupil with whom he is interacting, the teacher puts himself in the pupil's Zone of Proximal Development (Vygotski 1934).

Now that the epistemological and pedagogical beliefs underlying this mode of control of pupils' productions have been explained, some examples of how it can actually be used are given.

Examples of a production being accepted as valid

For example, returning to number 4 in the previous extract, the teacher had not commented on the answer 'You add the uranium atoms to each other' which the pupils had agreed on. By using the modalities of constructivist control that have just been presented, he could have refused the answer by arguing that it is not compatible with previously acquired knowledge,

as the addition of two large uranium nuclei gives a nucleus with more than 209 nucleons which automatically makes it unstable.

The analysis of two extracts from a transcript of a teaching session on the theme of the particulate model gives another illustration of this way of controlling pupils' productions. The preparation for this session, based on the works of Larcher et al (1990) is taken directly from the guidelines accompanying the curriculum published by the Ministère de l'Education (MEN, 1997: 36-38). The session is for junior high-school pupils and includes four tasks. First, the pupils describe their observations on the compression of nitrogen dioxide (brown gas) inside a syringe blocked with the finger. In the second task, they explain what phenomenon they have observed with the help of a particulate model composed of four properties (a particle cannot be cut, its shape cannot be changed, it keeps the same dimensions, and the same mass). The third task consists in formalising the links between the register of the model and the phenomenological model (e.g. the gas is more compressed = the particles are closer together). Whereas the fourth task consists in completing the model with two new properties: there is an empty space between the particles; the number of particles characterizes the quantity of matter.

This session is taught by four trainees. Before they do it, the trainees are given information about both the session on the particulate model (its objectives, the epistemological beliefs underlying it, the pupils' misconceptions on this theme) and on the conclusions (using authoritative argument, checking previously established knowledge, inquiry, and the characteristics of the constructivist mode of control). Each teacher then tries as often as possible to use arguments of validity to accept or refuse pupils' productions.

After he has observed the compression of the gas in the blocked syringe, a pupil suggests that the quantity of gas has not changed. In extract 5, the teacher asks the pupil to expound his arguments, which will then make it possible for his answer to be accepted. In this extract, the answer 'the quantity of gas has not changed' is accepted as 'the gas can't have got out' because the 'syringe is blocked'. The speakers use reference knowledge, more precisely the experimental protocol, in order to justify this production.

Extract 5, Session L

1 T5: We'll write it all down at the end. Well now, let's look at what hasn't changed. The quantity of gas. Does everyone agree? Why hasn't it changed? Fanny?

2 P: Cos it can't have got out.

3 T5: Because it can't have got out, is that right?

4 P: Yes.

5 T5: Do you think that's right? Joachim?

6 P: Well yes, because it's blocked.

7 T5: OK, the gas can't have got out so the quantity of gas hasn't changed, OK. Then, the gas has stayed inside. Do you think that's right?

This production would also have been accepted if the teacher's interaction had been based on expecting the right answer. But this is not always the case. For as will be seen in the following extract, some productions can be accepted in the case of a constructivist interaction, whereas they would be refused in an interaction based on the expectation of the right answer.

The acceptance of a valid production although it is different from institutionalised knowledge

The following extract is taken from a teacher–pupil interaction during the second task of the aforementioned session. This second activity consists in modelizing the phenomenon of compression seen in the observation activity. The document that is given out to the pupils gives four properties of the particulate model: a particle cannot be cut, its shape cannot be changed, its dimensions and mass stay the same. For this second activity, all the pupils already know the following: the phenomenological descriptions from activity 1 that have been validated by the teacher (the colour and compression of the gas have changed, whereas the nature and quantity of the gas have not changed); a gas can be represented by particles; these particles have four properties. In this activity, a pupil has represented these particles in groups of three or four. In the following extract, the pupils and teacher accept this production as it is consistent with previously established knowledge (from 25 T6 to 38 T6). This production, although it is different from scientific knowledge (particles do not stick together in groups of three or four, but atoms do), is nevertheless valid and acceptable in view of the current state of the pupils' knowledge. The acceptance of a valid production, although it is inaccurate in academic scientific terms, is the sign of pupils' constructing their own knowledge.

Extract 6, Session M

1 T6: So he has done 25 little circles and you have, so to speak, stuck them together in groups of three or four, is that it?

2 P: Yes.

3 T6: So I'm not going to do 25 (the teacher draws the pupils' diagrams on the board).

4 P: Yes, but he did three and then four, you can't do that.

5 P: Stop, you can't do that.

6 P: But why did he put four sometimes, you can't do that.

7 P: They're not well balanced, are they?

8 P: It's as if there were two different gases, because they aren't the same. It's not the same flowers, some have three, some have four.

9 T6: Well, I'd like to ask him a question. What do you think a particle is? Is this a particle, or is it just a circle? I'm asking you a question, do you think all this is a particle, or is it just that?

10 P: Ah Ah!

11 P: Well it's…

12 T6: Is all this a particle?

13 P: No, it's the opposite .

14 P: No, each circle is a particle.

25 T6: Yes, he's put 25, I don't know how many I've put.. 8 and 12, I've put 20 altogether. And… OK, there are 20. Now, a particle cannot be cut. Has he cut them?

26 P: No.

27 P: No.

28 T6: It keeps the same dimensions.

29 P: *All together* Yes.

30 T6: And the same mass.

31 P: *All together.* Yes.

32 T6: Its shape doesn't change.

33 P: *All together* No.

34 T6: And it takes up the whole volume.

35 P: *All together* Yes.

36 T6: So.

37 P: *All together.* It's right.

38 T6: I have nothing to say to him. Maybe there are some other possibilities. Are there any other possibilities?

A mode of interaction which enables the pupils to take part in validating the knowledge produced

By changing the mode of control of the pupils' productions, it is possible to have them participate in conclusions. As the pupil also has the knowledge that is made use of in conclusions, he/she can take part in this interaction. This participation should help pupils to progress. Doise et al (1978: 255) have shown that 'subjects can only progress through interaction if they have the notions which enable them to be involved in this interaction...' (translated by myself). We can see an example of this in extracts 5 and 6 which clearly show pupils taking part in the conclusion.

This pupil participation in conclusions is by definition impossible if the teacher looks for the veracity of production (right / wrong compared to his own knowledge). For only the teacher has the right answer and he is the only one who can recognize it when it appears. Extracts 2 and 3 have shown that pupils are excluded from conclusions when the teacher interacts by looking for the right answer.

It should be remembered that even if the pupil takes part in validating or refusing productions, this interaction is entirely under the teacher's responsibility as he has to check whether the validations provided by the pupils are indeed based on their recognizing that they are consistent with reference knowledge, and relevant to the task. Nor should we forget that if the teacher does not control these productions, the pupils might agree on inaccurate productions (cf. extract 4).

The evolution of reference knowledge during a session

In this paragraph, the way in which reference knowledge may change is studied. In all the sessions studied, two different cases of reference knowledge changing were observed. In the

first case, the reference knowledge is completed in the course of the sessions, which corresponds to the case of ‘normal science’ (Kuhn 1970). In the second case, the reference knowledge is replaced by new knowledge, which corresponds to the case of ‘extraordinary science’ (Kuhn 1970).

First of all, the change in reference knowledge in the cases corresponding to normal science is described. Once the pupils’ productions have been accepted and validated by the teacher and the pupils, they change status. These productions become reference knowledge which is added to the pre-existing knowledge. They may then be used to accept or refuse new productions in later tasks. The knowledge constructed by the pupils in the class increases within these dynamics of construction. It is here that the idea of evolving science is conveyed, in opposition to a timeless vision of scientific knowledge transmitted by a dogmatic approach. The following extract is taken from the same session as extract No 5. In extract 5, the pupils and teacher validate the idea that the quantity of gas has not changed as the syringe is blocked. This production, once it has been validated by the teacher and the pupils, will be used as reference knowledge in the following task. In the following task, the pupils are asked to draw the particles in the syringe before and after the gas has been compressed. In extract no 8, a pupil refuses a production as the amount of particles is not the same before and after they have been compressed, whereas it had previously been established in the first activity that the quantity of gas hasn’t changed. The pupil’s production which gives a different number of particles therefore contradicts the reference knowledge.

Extract 8, session L

1 P: If you keep the same quantity of gas, then there have to be the same number of particles.

2 T5: And so?

3 P: So it’s wrong.

4 T5: I don’t think we need bother to count them. She has put two more in situation 2 than in situation 1. Olivier, tell me, did you check this detail? You didn’t count them. So for Léna, the quantity of gas has changed, is that it?

In the second case, which corresponds to extraordinary science, there is not an addition to reference knowledge, but new knowledge replaces it. This case occurs when a teacher interacts with pupils who believe something inaccurate. As long as the pupil’s conception has not been proved invalid, the pupil considers it to be valid, and he explains and predicts the phenomena through this conception. As for the teacher, he has another conception, which is more consistent with academic scientific knowledge. In this situation, the only knowledge which is available to both the teacher and the pupil is the pupil’s misconception, as long as the teacher knows it and is able to notice it. So for a while this misconception will be the reference knowledge shared by the teacher and the pupil. This is the necessary condition for a co-construction of knowledge. In other words, for a while, the pupil’s misconception is considered as reference knowledge during the interaction. This means that for a while, any productions are judged in relation to this misconception. For example, predictions which are consistent with this misconception may temporarily be accepted by the teacher, even if they are wrong, as they are consistent with the pupil’s misconception. Then, if these predictions are in contradiction with the experimental result, but consistent with the misconception used, this misconception may be questioned and replaced by a more relevant representation. Finally, this new representation replaces the pupils’ misconception in reference knowledge, and will be used as a new shared argumentative basis in future tasks.

In order to illustrate our comments, a session on electrokinetics is analysed. The situation is as follows. The teacher gives the pupils a device he has assembled. In this device, a battery, a switch, a bulb and a diode are in series. The teacher asks the pupils to determine whether the

bulb will go on when she turns off the switch. The pupils, who already have a conception of electric current reacting in relation to the obstacles it encounters (Closset 1989), will predict that the bulb will go on, as it is placed before the diode and thus gets the current. This prediction is accepted (3 T4) as it is consistent with the conception of current reacting in relation to the obstacles it encounters.

Extract 9, session I

1 T4: Speak nice and loud, and explain to the others, and the others listen to what she is suggesting.

2 P: The light goes on because the current goes from + to -. As the diode is after the light, it doesn't block the current going into the light.

3 T4: OK, can you show us what the current does in the drawing.

... The experiment shows the light does not go on.

4 P: That's because the bulb is broken.

5 T4: Wait a minute. Let's see if the bulb is broken.

6 T4: Look, it's all working alright.

7 P: The wires have been cut inside.

8 T4: Come on, I used the wires with the others this morning, and it all worked.

9 P: But now it's not working.

10 P: So there must be a problem somewhere.

11 T4: There is a problem somewhere. Where then?

12 P: In the way it's wired up.

13 T4: There's a problem in the way it's wired up?

14 P: *Several pupils.* No.

15 T4: So, where is there a problem?

16 P: In what we've said….

The teacher accepts an argument for the prediction based on a misconception of electrical current which she knows she can challenge later on. The prediction 'the light goes on' (2 P) is

accepted by the teacher in relation to a misconception of electric current that she will temporarily take into account. So both the teacher and pupils refer to this conception to judge the validity of the prediction. Once she has checked that the inaccurate prediction does not come from an experimental problem (5 T4, 6 T4, 7 P, 12 P), it is the misconception which is going to be challenged (16 P).

Introducing an inaccurate representation in reference knowledge before replacing it with an institutionalised representation conveys a series of epistemological and pedagogical beliefs. Indeed, the inaccurate conception takes the place of the knowledge that is to be taught, that is to say, it is a 'model' for the pupil that enables him to explain and predict certain phenomena. Thus, the misconception is much more than a wrong idea, as it is a mini explanatory model for the pupil. This function it fulfils accounts for the fact that the pupil finds it hard to change it. On an epistemological level, the beliefs transmitted by this change in reference knowledge are also interesting, for there are significant similarities between this change in knowledge and scientific revolutions. Reference knowledge may be altered, just as scientific knowledge may be. The pupils' beliefs are rejected, as the predictions that they enable him to make are not consistent with the phenomena observed. Science does not evolve in a linear fashion. There are breaks in this evolution.

A way to control productions that encourages the use of scientific arguments in science class interaction

It has already been shown that if the teachers use the strategy of establishing the validity of a production so as to accept it, this enables the pupils to take part in this stage of the interaction.

Using this new mode of controlling productions during interaction has another consequence as it entails using scientific arguments to accept or refuse these productions. By not allowing themselves to use authoritative arguments, the teacher and the pupils are encouraged to use other kinds of argument. Using only knowledge already available to the pupils shows there are different scientific arguments appearing in the interaction which are quite similar to those used by scientists (Hogan and Maglienti 2001).

Taking the example of an extract in which the teacher is going to make use of four different arguments in the same conclusion: she will refer back to a previously established model, carry out two counter-experiments, and use reasoning by absurd. The analysis of the four arguments in this conclusion stage is given beneath. Other modalities for regulating productions have also been brought out through the study of other extracts (Morge 2001): noticing that the production is not related to the question asked, carrying out an experiment, identifying an unexplained part of the interpretation of phenomena and identifying the random nature of a choice made for the interpretation.

The session is on the theme of static electricity. The teacher presents the following experiment to the pupils. An ebonite rod is rubbed up against some cat fur and then put near an aluminium ball hanging from a string. After the ball has been attracted by the rod, it sometimes stays stuck to it whereas at others it is thrown back. The teacher will ask the pupils to explain these phenomena. At the end of the session, the explanation of the phenomena will lead to the model being completed by introducing conduction and induction, two different ways in which objects can become charged.

It is to be noted that the accumulation of the phenomena to be explained in one single task, and the use of just one ball to present the phenomena complicates the task for the pupils, as it does the management of the task for the teacher. In the previous sessions, the pupils and the teacher had established the following model: there is positive electricity and negative electricity; two objects with charges of the same sign repel each other; two objects with charges of different signs attract each other; an object with no charge is electrically neutral; objects can be charged by friction; it has been decided in an arbitrary way that ebonite, when it is rubbed, has a negative charge, and Plexiglas when it is rubbed has a positive charge; a positive charge is represented by a +, and a negative charge is represented by a -. The phenomena of attraction and repulsion observed at the beginning of the session and the model established during earlier sessions are the reference knowledge.

To explain the ball being repelled, a pupil makes the supposition that it took a negative charge when it first touched the rod. The pupil thinks that, in the second experiment, the negatively charged rod will repel the ball, which also has a negative charge. Yet the ball is neutral at the beginning of each experiment.

Extract 10, Session J

1 P: When the ball is neutral, there it is negative, It is negative so that gives electricity to the ball, and then when you put back the cat fur, negative and negative make /

2 T4: Careful, careful, the ball is always neutral to begin with.

3 P: Yes, but as it is negative in the first experiment, it has made the ball negative.

4 T4: No no no, it’s not a first or a second experiment, I could start again right away and you’ll see.

5 P: Here, Teacher.

6 T4: Wait a minute, I’m coming.

7 T4: Look, I’m starting right away.

8 T4: Did you see that, first it was attracted then repelled. There, then we stop it. There, it was attracted, then repelled, then sometimes it stayed stuck.

9 T4: Look, again, here it is attracted then thrown back.

10 T4: Look, here it is attracted and stays stuck.

11 P: Because you're rubbing it gently.

12 P: It's taken a negative charge.

13 T4: No, each time it is neutral to begin with.

14 P: Yes, but as it keeps on being attracted, it has taken a negative charge just like the ebonite.

15 T4: Well then, I accept that it has taken a negative charge.

16 T4: Hey, go and sit down over there.

17 T4: Ok, I'll accept that, but it has been attracted and stayed stuck.

18 P: Because they both have the same charge.

19 T4: Careful, contrary charge signs, the same signs repel each other. Which means it should have been repelled.

20 P: Well, yes, but they have the same charges afterwards.

21 T4: Well if they have the same charges, they should have been repelled and not stayed stuck.

The teacher takes charge of this conclusion stage during which she puts forward four arguments. First, she reminds the pupils, as she already has done several times, that the ball is always neutral to begin with (2 T4). She could have defended this position much more easily if she had had several aluminium balls. For the assertion that the ball is neutral is based on the model, because when the ball has not been rubbed, it is electrically neutral. This modality for verifying productions consists in showing that there is a contradiction between the production and the previously established model. But as she only has one ball, the argument does not convince the pupils who still think that the ball got charged during the first experiment (3 P) which would explain it being thrown back during the second. In order to refuse this answer, the teacher is going to show that the ball can be thrown back straight away in the first experiment (8 T4), and that it can stay stuck during the second experiment (10 T4). These two

counter-experiments constitute new arguments put forward by the teacher. The pupils still do not seem to be convinced (12 P, 14 P). So the teacher will now reason as follows: if the ball were negative at the beginning of the experiment, it would be repelled and not attracted by the rod (15 T4, 17 T4, 19 T4, 21 T4). This reasoning is based on reference knowledge (charges of the same sign repel each other; at the start of the experiment the ball is attracted). The teacher here uses reasoning by absurd based on a false supposition to show that the observation this supposition leads to is in contradiction with the phenomenon the pupils have actually observed.

Conclusion

Conclusion phases have been studied in this article. The conclusion is the moment when the pupil's production is to be accepted or refused during an inquiry-based lesson. Two main ways of controlling productions have been found in conclusions, stemming from two different epistemological and pedagogical beliefs.

The first consists in determining the rightness or the wrongness of the pupil's production. If it is the teacher who judges this production, he compares it with the scientific knowledge he has at his disposal. If the production corresponds to the expected answer, this answer is accepted as it is correct. If it's not correct, it is refused. When it is a case of recalling previously established knowledge, the use of this mode of controlling productions can be justified as, on a purely pedagogical level, it implies assessing the gap between what has been taught and what the pupils have remembered. On the contrary, in the case of inquiry, this way of controlling pupils' productions corresponds to a dogmatic view of science and the teaching of

this. Scientific knowledge is considered as truths to be discovered. The pupils' cognitive activity consists in guessing the answer the teacher expects.

The second way to control pupils' productions consists in ascertaining not the rightness or the wrongness of the production, but its validity. The teacher or the pupils have to determine whether the production is relevant in relation to the question asked, and if it is consistent with reference knowledge. Reference knowledge is the knowledge on the theme which has temporarily been validated by the teacher and which is available to both the teacher and the pupils involved in the interaction. In the course of the session, the reference knowledge will change. It will either be completed by pupils' productions which have been validated during previous tasks. Or it will be changed if the predictions that it allows the pupils to make are in contradiction with the phenomena observed. This way of controlling pupils' productions is consistent with a constructivist view of science and the teaching of this. Controlling that productions are consistent with previously established knowledge introduces the idea of building knowledge. Using this way of controlling productions allows pupils to take part in this process and encourages both pupils and teacher to use scientific arguments.

The diversity of the themes tackled during these classes that were recorded and analysed (radioactivity, electrokinetics, static electricity, and the particulate model...) makes it possible to conclude that the concepts of veracity, validity, reference knowledge and conclusion phases used to analyse a part of the teacher-pupil interactions in a science class are indeed of a transversal nature in science teaching situations.

The results of this research can find applications in other studies using descriptors of teacher's practices. This is true for instance of research on the relationship between teachers' practices

and beliefs. (e.g. Brickhouse 1990, Briscoe 1991, Gallhager 1991, Désautels *et al.* 1993, Richardson 1996, Keys and Bryan 2001, Lederman and Zeidler 1987, Duschl and Wright 1989, Lederman 1999, Haney and Mac Arthur 2002). Using the results in this research field would lead to studying the nature of conclusion phases carried out by teachers in the light of the epistemological and pedagogical beliefs they have. This study has not been carried out in an empirical fashion, but some hypotheses concerning this relationship, based on the results that have just been presented can be put forward.

Discussion: the hypothesis that it is necessary for the teacher to build a relationship between his beliefs and the way he manages conclusion phases

This article has established links between conclusion phases and the epistemological and pedagogical beliefs underlying them. These links have the peculiarity of being implicit, as the beliefs are hidden in the way a pupil's production is accepted or rejected. Moreover, the conclusion phase is a point in the interaction which is peculiar to the management of inquiry situations. So that teachers who are less familiar with this point than of others which can also be found in transmissive teaching (as, for instance, when teachers are recalling knowledge). This peculiarity of conclusion phases raises the question of the building of a relationship between teachers' beliefs and the way conclusion phases are managed in the classroom.

To illustrate the question raised by the findings of this research, the example of the two opposed beliefs according to which scientific knowledge is a truth inscribed in nature, and conversely, scientific knowledge is a construction of the human mind may be taken. These beliefs can be operationalized in several aspects of teaching practices. For instance, this article

has shown that these two beliefs correspond to different kinds of conclusion phase. These two opposed beliefs can also be operationalized in different statements made by the teachers when they explain the nature of scientific knowledge to their pupils. In this second example, the relationship between the belief and the practice is direct whereas it is hidden in conclusion phases. A change in the teacher's belief about the nature of scientific knowledge triggered off by a training course for example, is highly likely to bring about a change in the way the teacher will present the nature of scientific knowledge to his pupils. But what about the translation of this belief into the way the teacher manages conclusion phases? As the beliefs conveyed by this aspect of his practice are hidden, as the operationalization of beliefs in the management of conclusion phases is not a simple application of beliefs, as teachers are not sufficiently aware of this point in the interaction, we consider that a change in the teacher's beliefs does not necessarily imply a change in his management of conclusion phases. For this to occur, the teacher would have to be aware of the existence of conclusion phases, he would have to know that epistemological and pedagogical beliefs may be operationalized in conclusion phases, and know how they are operationalized. In other words, we would suggest that the relationship between teachers' beliefs and the management of conclusion phases must be built by the teacher and is not created spontaneously. This point of view is consistent with Lederman's findings, as he explains that "...More professional development activities should focus on teachers' understandings of the nature of science and the ways to translate these understandings into classroom practice."

Accepting this suggestion - the relationship between teachers' beliefs and the management of conclusion phases must be built by the teacher and is not created spontaneously- has several consequences for the way the relationship between teachers' beliefs and practice in general is considered. The first consequence lies in the fact that there may be a gap between the

teacher's beliefs and certain aspects of his practice, especially if this conceals beliefs related to science and the teaching of science. This challenges the idea that a teacher's practices are directly and systematically influenced by his beliefs. Some studies would allow us to think that such a gap does actually exist. Indeed, Luft (2001) has shown that after doing a course called 'Inquiry-Based Demonstration Classroom' '...the induction teachers experienced more change in their beliefs than in their practices, whereas experienced teachers demonstrated more change in their practices than their beliefs'. (Luft 2001: 531). These results show that teachers' practices and beliefs do not evolve synchronically and that therefore there may be gaps between the two.

The second consequence is that the existence and the strength of the relationship between teachers' practices and beliefs do not only depend on the nature of the beliefs in question (Haney and Mac Arthur 2002), but also on the level of the teacher's analysis of his own practices. For, if the teacher plays an active role in the operationalization of his beliefs, it may be apparent that for some teachers, their practices clearly reflect their beliefs, whereas others, who have not worked on this operationalization, give evidence of a greater gap between their beliefs and different aspects of their practice. This would suggest that the existence and the strength of this relationship partly depend on each individual's characteristics (their academic profile, their training, their ability to analyse all their practices and question their consistency with their beliefs). In relation to this, Brickhouse (1990) and Lederman (1999) have shown that there is a greater gap between teachers' practices and beliefs in new teachers than in experienced teachers.

The implications for teacher training

Learning how to manage conclusion phases in teacher-pupil interaction can be a new aim in teacher training. If the idea that the operationalization of beliefs is not spontaneous, but needs the teacher to think about his own practices is accepted, it is not enough to aim to change teachers' beliefs as this will not automatically lead to a change in his practices. It would be more appropriate to devise a training programme in which a reflection on practices is considered as a means to build a relationship between the teachers' practices and the beliefs underlying these. Practices would be the basis for building new beliefs and beliefs would justify the choice of certain practices.

Two training methods which are based both on the hypothesis that the relationship between teachers' beliefs and practices is constructed have been considered, and on the results of our research on conclusion stages (Morge 2003). The first consists in suggesting that teachers should record teaching sessions, analyse the various conclusion stages, question their relevance from an epistemological and pedagogical point of view, and consider new modes of interaction which will then be implemented in the classroom. This is training by a posteriori self-analysis.

A second training method, consisting in the analysis of simulations, can also be used. This is based on the use of a computer programme simulating the management of a class which requires the teacher to take decisions he would have to take in his management of a teaching session. This programme (http://www.auvergne.iufm.fr/ER/lmorge/simodpart.htm) requires teachers to accept or refuse pupils' productions which have been taken from real teaching situations, and put into the programme. Once the simulation is over, the decisions taken by the

teacher are discussed from an epistemological, pedagogical, or scientific point of view. This second method avoids laborious transcribing. Both methods are part of the reflective practitioner's paradigm (Schön 1983).

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Table 1: Sessions recorded, transcribed and analysed

Code	Theme	Teacher	Class level	Length
A	Radioactivity	T1 (Experienced)	11th grade	1 h.
B	Radioactivity	T1 (Experienced)	11th grade	1 h.
C	Sound propagation	T1 (Experienced)	10th grade	1 h.
D	Distillation	T1 (Experienced)	10th grade	1 h.
E	The decomposition of white light	T2 (Experienced)	8th grade	1 h.
F	Geometric optics, the black box	T2 (Experienced)	8th grade	1h. 30mn.
G	The periodic table of the elements	T3 (Trainee)	10th grade	1 h.
H	The periodic table of the elements	T4 (Trainee)	10th grade	1 h.
I	Electrokinetics	T4 (Trainee)	9th grade	1 h.
J	Static electricity 1	T4 (Trainee)	8th grade	1 h.
K	Static electricity 2	T4 (Trainee)	8th grade	1 h.
L	Particulate model	T5 (Trainee)	7th grade	1 h.
M	Particulate model	T6 (Trainee)	7th grade	1 h.
N	Particulate model	T7 (Trainee)	7th grade	1 h.
O	Particulate model	T8 (Trainee)	7th grade	1 h.
P	Particulate model	T8 (Trainee)	7th grade	1 h.