Interpreting Students' and Teachers' Discourse in Science Classes: An Underestimated Problem?

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Abstract

This article deals with the problem of the proper interpretation of discourse between students and teachers in classrooms. First, several interpretations of a concrete classroom protocol dealing with the paradigmatic case of static forces are discussed: an "ordinary" teacher's analysis, an analysis in terms of misconceptions, and an analysis in terms of alternative conceptions. Though they represent common ideas from the literature, it is argued that those analyses all in some way misinterpret the discourse. By drawing on Davidson's principle of charity and by distinguishing between belief and meaning, we present an analysis that in our opinion interprets the discourse correctly. Its consequences for teaching are discussed, as well as its foundation in Davidson's philosophy.

The mainstream of present research in science education focuses on students' ideas about natural phenomena and on the relation of such ideas to scientific concepts and theories (Pfundt & Duit, 1994). It is done by studying written responses on questionnaires, transcripts of interviews or classroom discourse, etc. Numerous studies have pointed to the conclusion that students' ideas are often insufficiently taken into account by teachers and textbooks. It is also argued that this might at least partially explain the often very poor learning outcomes of science education as far as real insight is concerned. To improve matters, many researchers have nowadays adopted the constructivist stance that knowledge is personally and/or socially constructed on the basis of existing knowledge, and have begun to study individual and social learning processes to clarify how knowledge is constructed in science classrooms (Duit, Goldberg, & Niedderer, 1992). In our own work, we focus on the interaction of teaching and learning processes. It is our experience that it is often difficult to interpret classroom discourse, let alone interpret it unambiguously. Adopting the constructivist stance has not helped us in overcoming these difficulties, as it only implies that knowledge is personally and/or socially constructed on the basis of existing knowledge (Driver, Asoko, Leach, Mortimer, & Scott, 1994). It does not throw light on the question of which new knowledge will be constructed on the basis of which existing knowledge. And it leaves unanswered the problem of how to properly and reliably interpret what has been constructed, both before and during education. Also, Lemke's (1990) suggestion to uncover "thematic patterns" in classroom discourse, useful as it may be, takes for granted that a prior interpretative problem, namely, what students and teachers mean by their words and how they understand each other's words, has already been solved.
In our opinion, this methodologic problem of how correctly to interpret students' and/or teachers' utterances, be it as answers to questionnaires or as transcripts of classroom discourse, needs more attention. To discuss this problem further, both theoretically and methodologically, we think it appropriate to start with a concrete example of a classroom discourse. As such, this example is not meant to represent a piece of empirical research, but only to provide a concrete base from which our theoretical and methodologic position will gradually be unfolded. Therefore, in the third section, we analyze this discourse according to how we interpret current positions in the literature. Then, in the fourth section, we point to some deficiencies in those analyses, which involve at the same time a critique of the underlying positions. Subsequently we present our own analysis and compare it to the previous ones. We will thereby have elaborated our theoretical position at a concrete level. In the fifth section, we discuss and compare some of the consequences that the various analyses have for teaching. In the final section, we theoretically justify our own analysis by drawing on Davidson's philosophy (1980, 1984, 1990).

A Concrete Example of a Classroom Discourse

The example with which we will illustrate our line of reasoning is taken from a series of lessons on mechanics. One reason this example has been chosen is that it deals with the paradigmatic book-on-the-table situation, which shows up in one form or another in many publications (Minstrell, 1982; McDermott, 1985; Clement, 1993), so that comparisons with the literature can readily be made. Another, more important reason is that we consider it to be a representative example of communication problems as they occur in classrooms. As a consequence, it allows us to illustrate our view on the problem of interpretation in an ecological setting. We hope that just this one example will serve this purpose.

In the previous lesson, the students watched a specially developed video about forces that act when cycling. The following transcript begins with the teacher, who intends to summarize and elaborate on the video by means of the well-known air track. His introductory question, in which he asks for the forces acting on the glider when it rests on the not-yet-operating track, is meant simply to remind the students of the supposedly well-known static forces that are acting in that situation. Then the following discussion occurred, which took about 20 min.

Teacher: The video has been about forces that act when cycling. Well, here [points to the glider on the track] I have a kind of bicycle. Let me now first ask what forces are acting on it. Just try: What forces do you think are acting at this moment? Are there any forces acting?

Eric: Gravity.

Teacher: Gravity, Eric says. What if gravity were the only force, what would happen then?

Eric: Then it would go down.

Teacher: Then it would go down. Ernie, what other forces could be acting?

Ernie: Eh . . . well . . .

Teacher: What prevents it from falling down?

Ernie: The track.

Teacher: Right, the track. So the track has to supply a counterforce to prevent the glider from falling down. Just for the sake of completeness: Eric, which direction has gravity?

Eric: [joking] Upwards.
Eric: No, downwards.

Teacher: So, Orson, the force of the track is upwards. Right?

Orson: Well, otherwise it would fall down.

Teacher: Otherwise it would fall down, he says. So, if it did not rest on the track and I dropped it, then only gravity would act and it would fall down. If the track wants to stop it, then it will have to push the glider upward.

Jane: But the track does not push, does it?

Teacher: The track does not push.

Jane: No . . .

Orson: Well, the track is just there.

Jane: . . . It's just there.

[Some students are mumbling things such as, "Don't make such a fuss. Just accept it."

Teacher: If you drop it, it will fall down; a force will act upon it.

Jane: Okay. If you put it on your fingers . . . I can't take it off. [The teacher cannot get the glider off the track, and takes a small weight instead.]

Teacher: Okay. If you put it on your fingers . . . I can't take it off. [The teacher cannot get the glider off the track, and takes a small weight instead.] It's the same with this thing [the weight], isn't it? If you drop it, it will fall down. Now I want to stop it [places the weight on the tips of his fingers]. Since it is such a small weight, you don't feel much. But if you put a heavy weight on your fingers, you will feel it.

Jane: Okay.

Teacher: That is because you will have to exert a counterpressure. So you do have to . . .

Jane: Sure, if you're doing that yourself.

Teacher: If I place a heavy weight here, then my fingers will go down. If I want to keep it in place, I will have to push it upward. The track will do that too, it's just that we don't notice that. We don't notice that the track does it, the track doesn't move . . .

Carl: Yes, but the track can't push upward, can it?

Teacher: . . . But the track in fact does it as well.

Carl: Yes, but the track can't do that, can it?

Teacher: Oh yes, it can do just that.

Carl: You can push upward with your fingers, but the track can't.

Teacher: Let me take something else, something more flexible than metal. [Fetches a piece of foam rubber and puts it in front of him.] Here goes. So I will now try to convince you that the track really exerts an upward force. That is, I did agree with Orson, Jane did not; let's see whether we can come to an agreement. [Puts the small weight on the foam rubber, which gets pushed in a bit.] If I put this thing here, the foam rubber gets pushed in, doesn't it? Well, actually I need something a bit heavier. . . .

Jane: Oh, well I do believe you as it is.

Teacher: Do you? So you do actually believe that. [Laughter.] So, the foam rubber will get pushed in if you put something heavy on it. And if we don't put something heavy on it, but push it in and let go [does so with a finger], what will happen then?

Jane: Then it will come up again.

Teacher: Then it will come up again? Why's that?

Jane: Well, because there's nothing on it.
40 Teacher: Sure, but what does it do then, when it comes up? Then it pushes upward, doesn’t it?
41 Jane: What?
42 Teacher: [Somewhat more pressing.] Then it pushes upward, doesn’t it?
43 Jane: No, then it just gets back to its original state.
44 Teacher: [Some students seem to suggest that Jane is just being stubborn.]
45 Jane: No, I don’t think that has got anything to do with it.
46 Teacher: Don’t you? I push the foam rubber in, put something on it, and the foam rubber pushes it upward. Then that is an upward force.
47 Jane: Well, I think that’s really very strange.
48 Teacher: Do you?
49 Jane: Yes. That is not . . . well . . . no, that is not a force. I don’t think it is really a force.
50 Teacher: If you want to push something up, then for that purpose you will have to exert a force. And now [pushes the weight into the foam rubber and then lets the foam rubber spring back] it is pushed in and it pushes the weight back up.
51 Jane: Okay.
52 Teacher: But you don’t think that’s a force.
53 Jane: Right.
54 Teacher: You don’t think that’s a force. For it is the same, isn’t it? And do you consider this to be a force, when it falls down?
55 Jane: Sure, that’s gravity.
56 Teacher: So, the downward motion is due to a force, but if it moves up [lets the weight again move up from the foam rubber] then that is not due to a force?
57 Jane: Right.
58 [Laughter from the class. The teacher remains serious.]
59 Teacher: What if I now . . . I throw it upward, like this.
60 [Jane also begins to laugh about the awkwardness of the whole situation.]
61 Teacher: Is that a force or not?
62 Jane: [Laughing.] It is, of your hand it is.
63 Teacher: Of my hand it is. And now I let the foam rubber do it [again does so] and then it is no longer a force.
64 Jane: [Still laughing a bit.] Right.
65 Teacher: What, then, is the difference?
66 Jane: [Serious again.] Well, that motion just goes all by itself. That’s just the way things go. [Laughter.] Well, I really do think that’s strange.
67 Teacher: So because it goes all by itself, that is why according to you it is no force. If it now of itself gives a slap, then that will be a force.
68 Jane: Yes.
69 Teacher: I see. Well, so it seems that we haven’t been making much progress. I do think there will be a force if you push it in, and Jane still doesn’t think that that is a force. I’ll leave it at that for a while. For the time being, everybody may think about it as he wishes. I would like to know, however, what the others do think about it.
70 [Of the others, most indicate that they agree with the teacher, while no one indicates agreement with Jane. Some students, among which are Orson and Carl, are in doubt.]
71 Teacher: Alright. Let’s leave it at that for now. Perhaps I will be able to convince you at a later time. According to me, the difference between the foam rubber and the metal is that it can’t be noticed that well that the
metal is springy. But also the metal has got some spring that allows it to push back. So the metal is harder and—but now I speak for myself—it gets pushed in, but it does spring back and thus exerts a counterforce. Okay. It is sort of funny, though, that we still don’t agree.

Before discussing this transcript in more detail, we first want to mention two points on which we hope everybody will agree. The first point concerns the situations in the context of which the discourse takes place. We detect seven such situations: the glider rests on the track (1); the weight falls down (24); the weight rests on the teacher’s fingers (24); the piece of foam rubber is pushed in a bit by the weight (34); the foam rubber comes up again after it has been pushed in (36–38); the weight moves up after it has been pushed deeply into the foam rubber (50, 56, 63); and the weight is thrown upward by the teacher (59). The second point concerns the (very experienced and good) teacher: he is open-minded and takes his students seriously (17, 34, 56, 58, 67); he tries to react appropriately and improvises the best he can (24, 28, 34, 36, 63); he nevertheless fails to achieve what he wants and honestly admits that (69, 71). Now, how can we understand this transcript, and what can we learn from it?

Several Analyses of the Previous Classroom Discourse

The “Ordinary” Teacher’s Analysis

We think that many an ordinary teacher will recognize situations as described in this transcript from his daily practice and analyze them more or less commonsensically as follows (see, e.g., Bell, 1994). The teacher is doing his utmost to make himself clear to his students. In particular, he is doing everything he can to take away Jane’s objections (24, 34, 46, 63, 71). Jane, however, keeps on uttering confused remarks (18–20, 39, 43, 66), probably because she does not yet understand Newton’s laws well enough (15–16, 26–27).

In this analysis it may even be said that the teacher gives too much attention to Jane. The other students clearly indicate that Jane is just being a bore (21, 44, 58), probably because most of them have understood the teacher’s explanation from the start (70). Perhaps Jane has not done her homework or has not paid close enough attention to the video in the previous lesson. At any rate, she had better do some extra studying to understand the teacher’s explanation next time.

From the point of view of classroom management, a teaching advice based on this analysis could be not to give so much attention to students like Jane. And by all means, if teachers wanted to convince students like Jane, the best advice would probably be to take them aside and explain Newton’s laws precisely in some detail.

Analysis in Terms of Misconceptions

A somewhat different analysis consists in the statement that Jane has misconceptions, i.e., ideas that are in conflict with correct ideas of physics. Whereas she holds, or at least does not protest against, the correct idea that gravity acts downward on the glider at rest (1, 2, 9, 10), she erroneously holds the idea that the track does not push (16). On the other hand, when a heavy weight is put on your fingers, she agrees that you will have to exert a counterpressure (24–27). Whereas she correctly holds that when the weight falls down, its downward motion is due to gravity acting upon it (54, 55), she has the misconception that when the weight moves up from the foam rubber, its upward motion is not due to a force exerted by the foam rubber (56, 57). She again correctly holds that when you throw the weight upward, its upward motion is due to a force exerted by your hand (59–62).
Thus, one may conclude the following: Jane knows about the existence of gravity, and that it acts downward on everything. In some apparent cases, such as a weight on one’s fingers, she knows that a counterforce is needed; but in less apparent cases, such as the glider on the track and the weight on the foam rubber, she has the misconception that no counterforce is needed.

An analysis in terms of students having misconceptions is not uncommon. Especially during the first stage of the conceptual change research paradigm, many publications appeared in which all kinds of misconceptions were investigated, predominantly by means of questionnaires (Pfundt & Duit, 1994; McDermott, 1984; Halloun & Hestenes, 1985). In line with this, the transcript may also be seen as a kind of questionnaire consisting of seven items corresponding to the seven situations in the context of which the discourse takes place. Each item asks whether gravity or any other forces are acting. From Jane’s answers to this questionnaire, one may also conclude, as is often done in such investigations, that we have one of the many examples of a student who reasons inconsistently and holds wrong epistemologic commitments (Hewson, 1985), as she does not seem to be aware of the fact that the laws of physics are supposed to be generally valid (Finegold & Gorky, 1991).

One way to bring out the difference between analysis of the ordinary teacher and analysis in terms of misconceptions relates to the estimation of students such as Jane. Whereas in the former analysis Jane could be considered a student who has not paid close enough attention or is just being a bore, or for whom physics simply may be too difficult, in the latter analysis Jane is considered a student with an excellent attitude. In fact, it is the other students’ attitude to just accept what the teacher says (21) that must be considered detrimental to real insightful learning, because it is precisely this attitude that leads to the survival of misconceptions. After all, as may be safely conjectured on the basis of the research on misconceptions, many of the other students will hold the same misconceptions as Jane does.

Teaching advice based on analysis in terms of misconceptions would therefore be to challenge both Jane and the other students to bring their misconceptions forward. As Van Heuvelen (1991) put it: “Instead, students should become active participants during lectures in constructing concepts, in confronting preconceptions that are misconceptions, in reasoning qualitatively about physical processes, and in learning to use concepts to solve problems.” Related advice is given, e.g., by McDermott (1984), who wrote: “Experience has shown that merely presenting the correct information, either orally or in written form, is seldom effective in helping students overcome misconceptions. Specific difficulties must be directly confronted and deliberately addressed.” Labudde et al. (1988) noted that “new knowledge should be explicitly contrasted with prior knowledge in order to remove inconsistencies, to ensure the coherence of the students’s new knowledge and to minimize interference from conflicting knowledge.” Champagne et al. (1980) argued as follows: “We propose that instruction in classical mechanics can be improved by continuously encouraging students to reject an Aristotelian system of beliefs and to adopt a Newtonian paradigm. The main strategy of this approach, which acknowledges the pre-existing belief system of the students, is to compare and contrast the two paradigms.” Therefore, from this perspective, real insight can only result from a combined process of learning correct ideas and unlearning misconceptions.

Analysis in Terms of Alternative Conceptions

Yet another type of analysis maintains that Jane has ideas that are in conflict with accepted ideas of physics, but adds that it is not at all surprising that she has those ideas: “In some cases, prior knowledge acquired by informal learning or through cultural transmission of ‘folk knowledge’ is inconsistent with the formal knowledge to be acquired during schooling. This is
particularly likely in the natural sciences, where prior experiences, though categorized as naive from a scientific perspective, provide reasonable explanations to guide daily behaviour” (Anderson, 1992). Researchers that adhere to this analysis prefer to call students’ ideas preconceptions or alternative conceptions instead of misconceptions, because, as Dykstra et al. (1992) put it: “These alternative conceptions manifest themselves as useful commonsense beliefs about the world.” Thus, instead of emphasizing that from a scientific point of view students have incorrect ideas, they try to frame the alternative conceptions that students seem to live by in their daily life. Concerning students’ ideas about force and motion, for instance, Gunstone and Watts (1985) framed intuitive rules such as: forces are to do with living things; if a body is not moving there is no force acting on it; if a body is moving there is a force acting on it in the direction of its motion, etc. In relation to the problem at hand in our transcript, Clement (1993) formulated the “deep seated” alternative conception of “static objects as barriers that cannot exert forces.”

With this analysis, one will interpret the transcript as showing such intuitive rules at work in Jane’s reasoning. This interpretation then also requires the additional conclusion that students may reason inconsistently across contexts. For example, this rule associating force and direction of motion may be used by Jane in some situations, but not in her reasoning about the weight’s upward motion from the foam rubber. This apparent lack of consistency is a matter of considerable debate. One often tries to make this additional conclusion plausible by noting that from an everyday life perspective, there is no need for coherence or general applicability across a wide range of situations. Sometimes it is simply taken for granted. Grandy and Hamilton (1992), for instance, wrote about students’ theories: “Of course, these theories are often incomplete, incoherent and misguided.” Champagne et al. (1980) wrote accordingly: “Their preinstructional belief system has a loose structure, displays little interconnectedness, and lacks an overlying formalism. In consequence, the belief system is highly flexible and can accommodate new information locally without producing any conflict with other parts of the system.” Others, however, have argued for the existence of more consistent patterns in students’ alternative ways of reasoning (see, e.g., Viennot, 1985, 1994; Finegold & Gorsky, 1991; Engel Clough & Driver, 1986; Dykstra et al., 1992).

So far, this analysis has only focused on one side of the coin, i.e., on students’ conceptions. In teaching, however, as the transcript shows, the interaction between teacher and students is essential. Focusing on this interaction from the perspective of alternative conceptions, the previous transcript can in some sense be viewed as a clash of two worlds, somewhat similar to the clashes of incommensurable world views that Kuhn (1970a) has written about, for example. On the one hand, Jane reasons from her frame of reference; on the other hand, the teacher uses the Newtonian concept of force. He reasons consistently from this Newtonian framework, because his knowledge and epistemologic commitments are such that he knows that the laws and concepts of physics must be generally applicable across situations. One could say that the teacher and Jane are more or less living in different worlds. They do not see the same objects and events, because observation is theory-laden. In each world, different concepts are used, being part of different kinds of knowledge, with different characteristics and problem-solving procedures (Reif & Larkin, 1991).

With this analysis, it is quite understandable that Jane and the teacher do not understand each other and that the teaching process fails. Anderson (1992) wrote: “These well-entrenched alternative conceptions (or misconceptions from the viewpoint of the scientist) can have profound effects on the students’ capacity to accept and internalize scientific explanations that may be contradictory to prior experience.” Gunstone and Watts (1985) pointed to the importance of language in this respect: “The issue of language is difficult and complex. Students use language which is meaningful to students; teachers use language which is meaningful to teachers. There
are a range of important teaching implications to be derived from an understanding of language and its role in learning.”

What students have to go through is a conceptual change—a change in world view, somewhat similar to a Kuhnian scientific revolution. A global teaching suggestion that all researchers who adopt this analysis therefore agree on is that one should take into account and be sensitive to students’ views of the world. In the fifth section, we will discuss the main procedures that those researchers have proposed to successfully “overcome the dominance of an alternative conception” (Clement, 1993).

Our Own Analysis

Some Deficiencies in the Previous Analyses

Both the analysis of the ordinary teacher and the analysis in terms of misconceptions start from and end with the point of view of correct physics as the sole norm and perspective from which to talk about teaching. In both analyses the main conclusion is that Jane holds ideas that are in conflict with ideas that physicists have. We think this conclusion is premature. Of course, we agree that Jane does not yet know Newton’s laws, and that she says things that a physicist would not say, or at least not in those words. There would only be a conflict of ideas, however, if it is assumed that she uses and understands expressions containing the word force as a physicist uses and understands them. But is this the right way to interpret her use of such expressions?

A similar remark can be made concerning the analysis in terms of alternative conceptions. Jane is said to reason from an everyday life perspective from which there is no need for coherence or general applicability across a wide range of situations. However, from the way Jane argues, it seems clear that she herself does not experience any incoherence at all, even when she is clearly aware that the teacher explicitly tries to point out to her that she is being incoherent (56–65). In fact, her problem seems to be that she cannot understand that the teacher does not understand her obvious points (20, 43, 66). Is it therefore right to conclude that Jane reasons incoherently?

Both the analysis in terms of misconceptions and the one in terms of alternative conceptions point out that students’ ideas should be directly addressed. Some more specific strategies to stimulate conceptual change are also advocated. Students should be given the opportunity to express and discuss their ideas. The status of their alternative conceptions should be lowered, for instance, by means of conflict, bridging, or analogical situations. We note, however, that the teacher tries to do precisely these kinds of thing. He gives Jane the freedom to express herself (48, 52, 61), uses bridging situations and analogies (24, 28, 50–54, 71), and tries directly to address Jane’s ideas and to arouse a conflict (50, 54, 65). Yet he does not succeed. Why?

Global Structure of the Discourse between Jane and Her Teacher

Let us consider the transcript anew. The first thing to note is that the teacher analyzes his discourse with Jane as their having a difference of opinion about whether “the track really exerts an upward force.” (34, 69). Accordingly, he sees his aim to convince Jane that his opinion is the correct one (34, 71). He does so not by arguing in terms of Newton’s laws, as he probably quite rightly assumes this to be inappropriate at this stage, but by more or less ostensively and comparatively pointing at ever more clearly visible cases of acting forces. In the end, the teacher considers his attempt a failure: “I do think there will be a force if you push it in, and Jane still
doesn’t think that that is a force.” (69). Given that this is how he evaluates the situation and that he probably cannot think of any other way to convince Jane, it is fair of him to state explicitly that for the time being, he will let the matter rest (69). He even emphasizes: “It is sort of funny, though, that we still don’t agree” (71).

Do the Teacher and Jane Really Have a Difference of Opinion?

Is the teacher right in analyzing his discourse with Jane as their having a difference of opinion? We do not think so. Of course, Jane agrees that the glider’s being supported by the track is similar to the weight’s being supported by the teacher’s fingertips, in the sense that in both cases an object’s falling down is prevented. Of course, Jane agrees that throwing a weight upward and letting the foam rubber do it are similar in the sense that in both cases the weight is made to move upward. And of course, the teacher agrees that the piece of foam rubber and the metal track cannot of themselves push something upward or give a slap in the way that we can (16, 29, 33, 67, 68), or that the foam rubber springs back without us having to do anything, that it goes all by itself (66). And without doubt, Jane could also come to agree with the teacher (perhaps along the lines suggested by Minstrell [1982]) that the metal track is like the piece of foam rubber in the sense that it is sort of springy too, but unlike metal in the sense that metal is harder and that its springiness cannot be observed that well (28, 71).

Thus, the teacher and Jane seem to agree on all the similarities and dissimilarities between the various situations. Moreover, toward the end of their discourse, the teacher seems able to sort of predict when Jane will say that a force is exerted and when not (56, 63, 67). Nevertheless, they have an ongoing and unresolved quarrel. If they were asked the question, “Does the track exert an upward force?” or “Does the foam rubber exert an upward force?,” the teacher would answer yes and Jane would answer no (34, 71).

What Is the Source of the Argument between Jane and Her Teacher?

This leads us to the following question: Is it possible that, on the one hand, there really is no difference of opinion between the teacher and Jane, while on the other, their discourse runs aground in a yes–no stalemate? To answer this question, we find it useful, like Gunstone and Watts (1985) to bring in the issue of language (though somewhat differently than they do it, cf. the next section). We do so by assuming that the teacher and Jane speak slightly different languages. In particular, we assume that the expression “to exert a force” does not have the same meaning for the teacher and Jane, i.e., that they do not use and understand that expression, or something like it, in the same way.5 We think this is a reasonable assumption, given that the teacher uses the expression in a Newtonian way and Jane most likely does not yet know the Newtonian language.

Let us begin then by explaining how under this assumption their yes–no stalemate need not reflect that there is a conflict of belief, that they are having opposing beliefs about the world. That is, the teacher’s answering yes and Jane’s answering no to, for example, the question, “Does the foam rubber exert an upward force?” need not reflect that they are making opposite claims concerning the occurrence of a particular kind of event. To explain this, we will have to make further assumptions about the (different) meanings that the teacher and Jane assign to the expression “to exert a force.” We will show that this can be done in such a way, that by uttering the (his) sentence, “The foam rubber exerts a force,” given the meaning he assigns to the expression, the teacher is rightly asserting the occurrence of a particular kind of event, while by uttering the (her) sentence, “The foam rubber does not exert a force,” given the meaning she
assigns to the expression, Jane is rightly denying the occurrence of a (different) kind of event. Concerning the teacher, there is no problem here: By uttering his sentence, "The foam rubber does exert a force," he is, given that he uses the expression in the Newtonian way, rightly asserting the occurrence of an event that would not have happened if the foam rubber had not been there (namely, the weight's upward motion). But what about Jane? Can we also make an assumption concerning her use of the expression, such that in using it thus she is right in saying, "The foam rubber does not exert a force?"

To make a plausible assumption concerning Jane's use, we simply make the methodologic suggestion to assign such meaning to her expression "to exert a force," that whenever she would answer yes (or no) to the question, "Does this exert a force?" she is, according to us, right in doing so. Among the situations in the context of which the discourse takes place, there are two in which Jane answers yes: the teacher throws the weight upward; the teacher supports the weight. In the other situations she answers no to the question, "Does this (the foam rubber, the track) exert a force?" We guess that she would also answer yes if instead of the teacher, another living thing supported something or threw something upward, or if a living thing did something else than that (e.g., set another object in motion quite generally, give another object a slap, deform another object, etc.). She even indicates that she would also answer yes in case an inanimate object of itself caused things these kinds of effect (67, 68). Accordingly, we suggest the following assumption: For Jane, the expression "...exerts a force" has application to an object precisely if an event occurs that the object of itself has caused, or if it is an object that could of itself cause something to happen to another object but instead merely supports it.6

If we interpret Jane in this way, we will agree with her that when the glider rests on the track, an utterance of her sentence "The track exerts a force" is not true, simply because the track could not of itself cause something to happen to the glider (e.g., throw it upward). Moreover, by uttering her sentence, "The foam rubber does not exert a force," she is, according to the above interpretation, denying the occurrence of an event that the foam rubber of itself has caused. By her utterance she is not denying that the weight moves upward nor that the foam rubber has been involved in the weight's upward motion, but only, and rightly so, that the foam rubber of itself has caused the weight's upward motion. It is rather the teacher who, by pushing the weight deep down into the foam rubber and then letting the foam rubber get back to its original state (43), in effect has caused the weight's upward motion. We thus conjecture that Jane would have answered yes if she were asked, "Does the teacher exert a force?" That is, if her answer had been yes, this would have counted in favor of our interpretation.

According to this analysis, the conflict that the teacher and Jane themselves think they are having (34, 69) is just an apparent one. If the teacher had known that Jane uses and understands the expression as indicated earlier, he would have assented to, for example, Jane's utterance of "The track does not exert a force." Their discourse runs aground in a yes–no stalemate, not because they really have a difference of opinion, but because both of them wrongly assume identity of meaning with respect to the expression.

Comparison of Our Analysis and the Analysis in Terms of Alternative Conceptions

According to our analysis, Jane does not reason incoherently at all. In fact, we have interpreted her in such a way that we can see her as applying her expression "to exert a force" consistently and rightly to the various situations in the context of which the discourse takes place. So not only does she not reason inconsistently, we also agree with what she believes.

We do not think of the discourse between the teacher and Jane as a clash of two conflicting world views. We rather think of it as a communicative failure. The source of the miscom-
munication is that the teacher and Jane think they are speaking in the same language, whereas in fact they are speaking different (though similar-sounding) languages. Because they are not aware of this, there is a sense in which the teacher and Jane may come to think of each other as living in different worlds. Indeed, both of them may have felt a gap between them or, as ten Voorde (1990) called it, a gulf of ununderstandableness, without being able to bridge it. The teacher may have felt it as his being unable (despite all his efforts) to convince Jane. Jane may have felt it as the teacher's tireless attempts to convince her of something she just cannot believe: “I really do think that’s strange” (47, 66).

In very much the same way, Ramberg (1989) argued that there is a sense in which Kuhn's statement that scientists operating within incommensurable paradigms practice their trades in different worlds can be understood. Ramberg did so by analyzing the problematic notion of incommensurability, about which Kuhn himself (1970b) wrote: “In the transition from one theory to the next words change their meanings or conditions of applicability in subtle ways. Though most of the same signs are used before and after a revolution—e.g., force, mass, element, compound, cell—the way in which some of them attach to nature has somehow changed. Successive theories are thus, we say, incommensurable.” Ramberg (1989, p. 132) suggested not thinking of incommensurability as a relation between theories, world views, social practices, or paradigms, but as “a characteristic of the discourse that results when we proceed as if we are using the same vocabulary, and so interpret others by applying linguistic conventions to which they are not party.” Instead of saying that the teacher and Jane have incommensurable world views, we should rather say that their discourse is incommensurable. From Kuhn and others, we may learn that the discourse between scientists has often been, and often is, incommensurable. Indeed, the changes of meaning that are involved in the transition from one theory to the next may easily give rise to situations in which two scientists, like the teacher and Jane, are not aware that they do not use some of their words in the same way. As a result they may, like the teacher and Jane, experience sheer unsurmountable difficulties in their attempts to understand one another, even to the extent of giving up such attempts altogether. But whereas they may thus come to think of each other as living in different worlds, they may in fact, like the teacher and Jane, be only words apart. We thus also hope to have made it clear that we shy away from literal talk about different worlds, reality being relative to a conceptual scheme, comprehensive differences in world view, etc.

Let us close this section by pointing out what we think is the difference between the way we have brought in the difficult and complex issue of language and the way Gunstone and Watts (1985) did so. They wrote: “Language which is meaningful to teachers may, because of students’ views of the world, have a quite different (even conflicting) meaning for students. If we are not sensitive to this, we can unwittingly reinforce the very views we want to change.”

We agree that language which is meaningful to a teacher may indeed have a different meaning for students. In fact, we have just argued that this is the case for Jane and her teacher. However, this is not because they have alternative beliefs about the world, i.e., beliefs we would want to change (we interpret what Gunstone and Watts call “views of the world” as beliefs about the world). According to us, there simply is no identity of meaning concerning some terms, because scientists have come to assign a rather specific meaning to them. So we would rather say that if one is not sensitive to this, one will unwittingly create apparent conflicts and talk at cross purposes (incommensurable discourse).

In our own analysis, we have not assumed or taken for granted that Jane has alternative beliefs. On the contrary, we have assumed that Jane’s beliefs are quite alright and have thus come to assign a meaning to her expression “to exert a force.” It can be said that instead of assuming identity of meaning we have rather assumed identity of belief. By doing so, i.e., by
finding as much common ground with Jane as possible, we have interpreted her not as having
different views or beliefs, but as speaking a different, although similar-sounding, language.
Given that we are in agreement with her, that there is nothing wrong with her beliefs, we also
see no need to change Jane's beliefs. We do see a need, of course, to make her (want to) add
substantially to what she already knows.

Let us try to bring out the difference in yet another way. Although we think that Gunstone
and Watts (1985) and Clement (1993) were aware that students do not use the word force or
expressions containing it as a physicist does, in their formulations of students' intuitive rules or
alternative conceptions they nevertheless use "force," e.g., students believe that static objects
are barriers that cannot exert forces. What they thus leave unanswered is the question of which
meanings students assign to expressions containing "force." In effect, they also leave un-
answered the question of which beliefs are represented by the intuitive rules or conceptions as
formulated by them.7

We, on the other hand, have tried here to answer the question of which meaning Jane
assigns to the expression "to exert a force." Her holding true her sentence "Static objects are
barriers that cannot exert forces" accordingly represents her (correct) belief that static objects
are barriers that cannot of themselves cause something to happen (e.g., set another object in
motion or give it a slap).

We refer to Klaassen (1995) for an answer to the question of which meanings students
assign to some other expressions containing "force," for an answer to the question of which
beliefs of students are represented by the intuitive rules as formulated by Gunstone and Watts,
and for a comparison of those beliefs to the "common-sense theory of motion" that Bliss and
Ogborn (1993) presented.

What Does This Mean for Teaching?

In this section, we discuss whether the differences between the various analyses presented
are of any importance for teaching: e.g., do they lead to different teaching strategies? The two
main strategies that are proposed on both the analysis in terms of misconceptions and the
analysis in terms of alternative conceptions are on the one hand the use of conflict situations,
and on the other, the use of bridging or analogical situations. We will first discuss whether these
strategies have application to the case at hand.

The idea behind the use of conflict situations is to confront students with a discrepant event
that will more or less force them to abandon, for instance, the static objects are barriers that
cannot exert forces conception. For us, this strategy is no option. On our analysis this concep-
tion represents the belief that static objects are barriers that cannot of themselves cause some-
ting to happen, and there is no reason to make students abandon this belief. This also becomes
clear when we try to think of a discrepant event that would cause Jane to dissent from her
sentence "The track does not exert a force." Given the meaning that, according to us, she
assigns to her expression "to exert a force," it are events of the following kinds: the track’s
throwing, all by itself, something upward; the track’s giving a slap. Indeed, events of those
kinds would really count as discrepant events, but not just for Jane, of course.

The same sort of comment applies to the other strategy: the use of analogical situations.
Clement (1993), for instance, tries to make students overcome the static objects are barriers that
cannot exert forces conception. He does so by starting from a suitably chosen anchor situation (a
hand pushes down a spring). Via some appropriately chosen analogical situations (a book rests
on a flexible board, a book rests on a piece of foam), he then tries to make students see that also
in the target situation (the paradigmatic book-on-the-table situation), a static object does indeed
exert a force. The first thing to note is that Clement’s anchor situation will not be appropriate for Jane if our interpretation of her is correct. When a hand pushes down a spring, she will, as she understands it, answer yes to the question, “Does the person who pushes down the spring exert a force?” but no to the question, “Does the spring exert a force?” Furthermore, in Clement’s analogical situations and target situation, she will answer no to the question, “Does the flexible board/the piece of foam/the table/the book exert a force?” A second note is that she will, of course, agree that the anchor situation and the analogical situations are similar in the sense that in each situation something (the spring, the flexible board, the piece of foam) is deformed, and that the analogical situations and the target situation are similar in the sense that in each situation it is the presence of something (the flexible board, the piece of foam, the table) that prevents the book’s falling down. And she may also come to agree that the various situations are similar in the sense that the table is a bit deformed and, like the spring, the flexible board and the piece of foam, is sort of springy too. Yet, despite all this, she is still right in answering no to the question, “Does the table exert a force?” as she understands it.

We conclude that Clement’s strategy cannot do the job that he has in mind: to make students overcome the static objects are barriers that cannot exert forces conception, simply because there is no such thing to overcome. There is no need to make them realize that they no longer hold a belief that they held before. Concerning Jane, for instance, there is no need to make her dissent from her sentence, “The track does not exert a force,” but to make her assent to the teacher’s sentence, “The track does exert a force.” Accordingly, we interpret Clement’s finding that students like Jane do indeed assent to the latter sentence as a result of his strategy, not as evidence that they have changed their minds but that they have, at least implicitly, picked up a new use of the expression “to exert a force.”

Of course, also Jane could have learned, and explicitly so, her teacher’s use of the expression. This may become clear when we think about a way that would have helped them out of their incommensurable discourse: “What the participants in a communication breakdown can do is recognize each other as members of different language-communities and then become translators” (Kuhn, 1970a, p. 202). For the teacher and Jane, this would have been a way out. Although they have gone some way in determining in which situations the other holds “This exerts a force on that,” they have not recognized that the source of the differences between them is simply due to their attaching a different meaning to the expression “to exert a force on.” If they had, they could have become translators instead of convincers. The teacher might then have found that Jane uses the expression as indicated in our section of the source of the argument, and would then have agreed with her utterance of “The track does not exert a force on the glider.” He might then also have indicated that he uses the expression in a broader sense, e.g., “x exerts a force on y” if something happens to y (or is prevented from happening) that would not have happened (or would have happened) if x had not been there. Jane would then have agreed with the teacher’s utterance of “The track does exert a force on the glider,” because if the track had not been there the glider would have fallen down. She would then also appreciate that, whereas according to her use of the expression, the similarity between Clement’s anchor situation and analogical situations is irrelevant in the sense that she would assent to “The person exerts a force on the spring” but dissent from “The book exerts a force on the flexible board/the piece of foam,” the similarity between these situations is precisely the mark for applying the teacher’s expression. That is, in each situation there is a deformation of something (the spring, the flexible board, the piece of foam) which would not have occurred if something else (the person, the book) had not been there, and therefore, she would then have agreed with the teacher’s utterances of “The person exerts a force on the spring” and “The book exerts a force on the flexible board/the piece of foam.” Her then being in agreement with the mentioned utterances of
the teacher would not be due to her having changed her mind or to her having learned something new about the various situations, but simply to her then knowing how the teacher uses the expression. It is only in Clement’s target situation that she really might have learned something new, namely, that the table does get a bit deformed when the book is placed on it. Having learned this, it is again just her knowledge of how the teacher uses the expression that would then have put her in agreement with the teacher’s utterance of “The book exerts a force on the table.”

Let us briefly take stock. We have rejected the aim of making students overcome the static objects are barriers that cannot exert forces conception. We have also indicated that students may implicitly come to use, or explicitly become aware of having to use, the expression “to exert a force on” in a new sense. Let us now state what we do consider to be an important aim, namely, to make students see why they should use the expression in this new sense, i.e., what the point is of having available a relation that holds between two objects $x$ and $y$ whenever something happens to $y$ (or is prevented from happening) that would not have happened (or would have happened) if $x$ had not been there. Moreover, this aim, in our opinion, not only applies to the case just discussed. It concerns, more generally, the introduction of scientific terms in a for students meaningful way, as part of their entrance into some scientific theory, namely, to induce in students a need or, at least, good reasons for having available the terms that one intends to introduce.

This aim poses a nontrivial educational task, because generally, students’ reasons or need for having available a particular term cannot, at the stage that it is to be introduced, coincide with what may be called the teacher’s or curriculum deviser’s reason to introduce it—namely, that having available such a term is useful in the light of a further development toward a scientific theory. In the case of mechanics, we have not yet given this important task enough thought, and therefore, we now refrain from making any suggestions. (For similar work on radioactivity, however, see Klaassen, 1995.)

We close this section with admittedly a rather brief and superficial discussion of what we consider to be some further consequences of our analysis with regards to teaching strategies. Earlier, we have tried to show that there is no need to make Jane abandon her beliefs, because there is nothing wrong with them. Of course, we do not want to make the general claim that students never need to abandon their beliefs. We do claim, however, that in general students do not have to subtract much from what they already believe (that there is no need for extensive changes of mind), but mainly will have to build on and extend what they already believe. In particular, the subtractions will hardly concern claims about what is the case in situations that students are familiar with, because especially such claims must be so interpreted that they are correct. We rather think that most subtractions concern students’ expectations of what will happen in a situation that they never before have witnessed or paid attention to, namely, when they themselves recognize that what they expected was going to happen does not in fact happen. In such cases students may come to realize that their expectation was implicitly based on some generalization, and that this generalization is indeed valid in most situations they have come across, but not in this new situation. The following example may illustrate this.

In everyday life, a thermometer functions as a sort of extension of our senses, which is used to obtain a more precise indication than our senses allow (taking someone’s temperature) or to communicate to others how warm it will feel (weather forecast). What makes a thermometer a trustworthy instrument for these purposes is that it displays a higher number when it, or something, feels warmer. Although the relations “feels warmer than” and “has a higher temperature than” (i.e., “a thermometer displays a higher number”) of course, have a different meaning in the sense that to establish whether the latter relation holds, one has to use a thermometer, and
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to establish whether the former holds, one's own senses—for daily life purposes they can be exchanged, in the sense that if one relation holds, the other is supposed to hold. Given the mentioned function and use, one can expect that students will expect, before they are going to measure the temperatures of a table's wooden top and one of its iron legs (something they have never done before), that the temperature of the wooden top will be higher. When they then find that the temperatures are in fact equal (perhaps after a recheck with another thermometer), they themselves will of course admit that their expectation has not come true. In this sense, one may say that the experiment poses a conflict. But apart from their expectation, students will not have to withdraw very much. It is still the case that in the situations they had come across before, the thermometer displayed a higher number when it, or something, felt warmer. What they now come to add to this is that there are also situations in which this is not so. So the main point of the experiment is not that students have to abandon something that they held before. Whether there is any use of the experiment in an educational setting depends, of course, on whether it is possible to so embed it in a series of activities that it can be given a further point. It is perhaps possible to let the experiment precede by such activities that the experiment provides students with a clear reason to differentiate between the relations "feels warmer than" and "has a higher temperature than," and that the element of surprise that the experiment induces is very likely to prompt their formation of a particular intention, e.g., to find out why in some situations both relations hold, but in others not (what the similarities and dissimilarities are between the various situations). A still further point then might be, from the teacher's or curriculum deviser's point of view, that it prepares a later treatment of heat flow, etc.

We thus arrive at a rough picture of science learning in which students, in a process that involves changes of intention and meaning, come to add to their conceptual resources, beliefs, and experiential base, with the eventual aim to further characterize and explain more aspects of the natural world.

Justification of Our Analysis: The Problem of Interpretation and the Principle of Charity

In our own analysis, and in particular, in the method we have applied to find out what Jane means by her expression "to exert a force," we have without mentioning so drawn heavily on the philosophy of Davidson (1980, 1984, 1990; see also Stoecker, 1993, for an extensive bibliography). In this section, we explicitly pay tribute by showing the relation between our analysis and his philosophy, and by using his arguments to justify the method used. Thus, we implicitly also argue why we think a teaching strategy along the lines sketched in the previous section offers the best opportunities for insightful learning.

Let us begin by briefly summarizing our analysis of the quarrel between the teacher and Jane. We have argued that it is not due to a difference of belief, to a difference of opinion about how things are in the world. Instead, we have argued that they have a quarrel because they are not aware that they do not assign the same meaning to the expression "to exert of force."

To find out how Jane uses her expression, we have essentially applied the following method. First, detect under which circumstances she selectively holds true her sentences; then, match her expressions to expressions of our own, so that her holding true her sentences and our holding true our matching sentences are systematically caused by the same features of the world. The method may be briefly summarized as follows: Assign such meanings to a speaker's expressions that she comes out as consistent and a believer of truths.

Before justifying this method, we now first make contact with Davidson's work. In our analysis we have implicitly pointed to the role that both the concept of belief and the concept of meaning play in an interpretation of verbal behavior. Davidson noted in this respect that beliefs
and meanings *conspire* to account for utterances: We can know what someone believes if we know what sentences she holds true and what she means by those sentences. But after having pointed at this *interdependence of belief and meaning*, Davidson subsequently noted that it gives rise to a problem, which may be called the problem of interpreting verbal behavior: If we merely know that someone holds a certain sentence to be true, we know neither what meaning she assigns to the sentence nor what belief her holding it true represents.

Davidson also mentioned the same method to solve the problem of interpreting verbal behavior. He mostly did so by considering the situation in which the problem itself comes most clearly to the fore: interpretation from scratch, i.e., a situation in which two people who speak unrelated languages, and are ignorant of each other’s languages, are left alone to learn to communicate. Indeed, in such a situation we would naturally apply the above method.

What justifies the method is the realization that our competence to understand one another’s verbal behavior does not *in principle* consist in knowing one another’s language. In particular, for communication and mutual understanding to be successful, we do not have to assume identity of meaning. The discourse between the teacher and Jane even shows that the assumption of identity of meaning may lead to severe communicative failures and misunderstandings. In this respect Davidson pointed out that in our everyday conversations there are many occasions in which we cannot rely on the assumption of identity of meaning, and yet manage to understand one another. We may think of our ability to perceive a well-formed sentence when the actual utterance was incomplete or grammatically garbled, to interpret words we have never heard before, or to correct slips of the tongue.

What justifies the method is that it enables us to solve the problem of verbal interpretation without having to rely on the notion of an already beforehand shared language. As such, it brings out essential aspects both of our competence to understand each other’s verbal behavior and of the common concepts of belief and meaning as we use them to account for each other’s verbal behavior.

Some of the aspects that it brings out is that our competence is essentially a social trait and that the concepts of belief and meaning are essentially of a social nature. It is clear that the method only works in a society of thoughtful creatures that share a natural world. Or, as Davidson put it: The smallest unit in which the problem of interpreting verbal behavior can be solved is a *triangle*, two vertices of which are *thoughtful creatures* that are aware (and are aware that the other is aware, etc.) of the triangle, and the third vertex of which is the creatures’ *shared world of objects and events*, whose properties and existence are independent of the creatures’ thoughts.

Another aspect that the method brings out is that our basic competence is governed by a principle that we cannot do without, and that it is only against the background of this principle that the concepts of belief and meaning have application. The principle that necessarily enters in solving the problem of interpreting each other’s verbal behavior is the following, which Davidson called the *principle of correspondence*: Assign such meanings to the other’s expressions that the other comes out as consistent and a believer of truths (by your own lights).

Our competence can now be characterized as a species of the art of theory (re)construction: What we (re)construct are the meanings we assign to a speaker’s expressions, and to make the speaker make sense, our process of (re)construction cannot be but governed by the principle of correspondence.

Let us close by pointing to some of the limitations of this account and the way that they can be overcome by a further extension of the account. The principle of correspondence uses as a starting point the sentences that a speaker holds true. It is clear, however, that nothing can count as a reason for supposing a speaker holds a sentence true that does not assume a lot about her
intentions, purposes, or values. Indeed, when interpreting Jane, we have tacitly assumed that she did not just want to be stubborn or recalcitrant and that in fact she really intended to make clear why she could not understand the teacher. Otherwise we would not have gone at such length in trying to understand her. Another way to bring forward this limitation is that to solve the problem of interpreting verbal behavior it is necessary not only to take cognitive attitudes such as belief into account, but also to include evaluative attitudes such as desire from the very start, so that the springs of action and intention, namely, both belief and desire, are related to meaning. Davidson in fact argued that the problem of interpreting verbal behavior cannot be separated from the more general problem of interpreting all behavior, both verbal and otherwise, which may be called the problem of interpretation.

Furthermore, the principle of correspondence can only be directly applied to the most basic cases: utterances that are geared to easily detected goings-on, that are accompanied by pointing fingers, etc. The principle does not enable two people to interpret each other's more theoretical concepts and statements. To interpret those, they will depend much on inferential relations, both deductive and inductive, between beliefs. They must assume that the other, like oneself, gives most credence to the hypothesis most highly supported by all available relevant evidence. Another way to bring out this limitation is that beliefs, desires, intentions, etc. are not only identified by their causal relations to events and objects in the world, but also by their relations to one another. Not only the principle of correspondence therefore necessarily enters into solving the problem of interpretation, but also another principle, which Davidson called the principle of coherence: Assign beliefs, desires, intentions, etc., to the other that cohere in the right way.

Davidson's claim is that the general problem of interpretation can indeed be solved by a combined application of the principles of correspondence and coherence. We refer to Davidson (1990) for a substantiation of this claim, which of course depends on a further specification of especially the "in the right way" clause in the above formulation of the principle of coherence. Here we limit ourselves to giving a crude formulation of the principle of charity, as Davidson called the combination of the principles of correspondence and coherence: To make someone make sense, we cannot but interpret her (and adjust our interpretation of her) such that she comes out as largely coherent, a believer of truths, and a lover of the good (all by our own lights).9

The basic conclusion is and remains, finally, that all interpretation depends on our ability to find common ground. Finding the common ground is not subsequent to understanding, but a condition of it. Everything rests on sharing, and knowing that one shares, a world, many reactions to its major features, and a way of thinking with someone else.

Notes

1 Though it is not relevant to our line of reasoning, the following may serve as some further background information. The series of lessons took place in the fourth grade (16+) of a secondary school in which the PLON-curriculum is used (Lijnse, Kortland, Eijkelhof, van Genderen, & Hooymayers, 1990). In this curriculum mechanics is taught in the context of traffic situations. The lessons were closely monitored by an observer to follow and study as closely as possible the teaching–learning processes that took place. The observer made notes about all relevant activities. Discussions between teacher and pupils were videotaped and within groups of pupils audiotaped and subsequently transcribed. The chosen protocol is such a transcription.

2 It is perhaps noteworthy at the outset that it is not our intention to solve the book-on-the-table problem as it is conceived in the literature. According to us, there is simply no such problem (cf. the fifth section).

3 Here, and in what follows, numbers between parentheses refer to the transcript.
To prevent misunderstanding, this analysis represents our view of how, in general, an ordinary teacher who is not familiar with research on students’ ideas could analyze and react to situations like the one represented in the protocol. It is not meant in any way to criticize teachers. In fact, this analysis and reaction seem to be quite sensible from the point of view of the practising teacher. It should also be noted that we do not mean the teacher in the transcript by “the ordinary teacher.”

5 Note that only the teacher actually uses the expression “to exert a force” (34, 50, 71). He also uses (we think as more or less synonymous with it) the expressions “to supply a force” (9) and “to be a force of” (12). Jane, too, uses the latter expression (62). In (63, 64) and (67, 68) their yes—no stalemate concerns an actual question of the form “Is this a force of . . . ?” In (15, 16) and (42, 43), it concerns an actual question of the form “Does this push?” We think that for both Jane and the teacher, to push is a specific example of to exert a force. When henceforth we use the phrase “the expression ‘to exert a force,’” we intend it to be understood as “the actual expression that is used as a synonym to the expression ‘to exert a force’” (e.g., “to exert a force,” “to supply a force,” “to be a force of”). In the same vein, we intend a phrase such as “Jane’s assertion of her sentence ‘The track does not exert a force’” to be understood as, e.g., Jane’s answering no to an actual question of the form, “Is this a force of the track?” Furthermore, it is part of our assumption concerning the expression “to exert a force” that the expression “to push” does not have the same meaning for the teacher and Jane.

6 If the student in the discourse were still available, we could check this assumption and, if necessary, modify it. We would not check it by letting her judge this rather cumbersome, verbal formulation of it. We would ask her, in various circumstances: “Does this exert a force?”

7 A similar comment applies to Lemke’s (1990) thematic analysis. In the “thematic patterns” that he describes, he uses the very words that students and teachers have uttered, and in effect thus also leaves unanswered the question what the relevant themes are.

8 This addition is not meant as a way of relativizing to a particular agent, community, society, paradigm, or whatever. It is rather meant as a reminder of the interpersonal nature of the concepts of belief and meaning.

9 The principle of charity of course also necessarily enters the interpretation of pupils’ speech and actions. In a subsequent article, we intend to discuss in somewhat more detail the implications that an awareness of the sources of the problem of interpretation, and the role that the principle of charity necessarily plays in solving it, should, according to us, have for (research on) science education.

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