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FORUM

Changing our minds: a commentary on 'Conceptual change: a discussion of theoretical, methodological and practical challenges for science education'

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Abstract This paper begins with a consideration of some important themes dealt with in the paper by Treagust and Duit. These include the relationship between research on conceptual change and educational practice, the significance of emotion and identity in the process of conceptual change, and role of cognitive conflict in motivating change. I then argue that the authors implicitly assert the importance of spoken dialogue as a motor for conceptual change, but do not give it the proper, explicit recognition that it deserves. I first use their own data of transcribed talk to make this point, and then go on to elaborate my case by drawing on other research. Talk amongst students and teacher–student talk are both considered. My conclusion is that while more empirical research is needed to understand how dialogue is involved in conceptual change, available evidence shows very clearly that the role of talk and social interaction is so significant that it cannot be ignored. It is therefore necessary for theoretical accounts to deal with both social (i.e. communicative) and cognitive aspects of conceptual change.

Keywords Conceptual change · Educational practice · Emotion · Identity · Discursive processes

Introduction

I was invited to make this commentary as a sociocultural researcher, and that is the perspective which I have taken. Treagust and Duit's paper was presented to me as one embodying the 'classic' conceptual change perspective—by which is usually meant a view which is focused on processes of individual cognition and does not take much account of social and cultural factors or the discursive processes of knowledge construction. In fact, the paper offers a much broader and open-minded discussion than I expected, and one which has certainly improved my own understanding of the field. Moreover, I do not consider a sociocultural account of conceptual change, development and learning incompatible with a recognition of the cognitive aspects of those processes. I therefore offer my

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critical commentary in the spirit of a collaborative striving for what Treagust and Druit call an adequate ‘multiperspective’ on this important educational topic.

Some key themes in Treagust and Duit’s paper

In their abstract, the authors set up their paper with the contention ‘that conceptual change perspectives still have the potential to significantly improve instructional practice’ although ‘actual practice is far from what conceptual change perspectives propose’. They begin the paper by summarising what research has shown about students’ conceptions as they enter science education: that they typically have ideas about natural phenomena that are ‘not in harmony’ with scientific accounts; and those ideas are fairly resistant to change. Moreover, studies have shown that many teachers also do not have scientific conceptions of phenomena—in fact, they may share their students’ views. Much conceptual change research has, directly or indirectly, been motivated by a concern to help students (and teachers) move from pre-scientific to scientific ways of accounting for the natural world. The authors describe how various approaches—influenced by epistemological or ontological perspectives—have been developed to deal with this issue. They describe how a classic pedagogy derived from this research is for teachers first to become aware of what ideas students have about a phenomenon and then offer information which will make students dissatisfied with their existing account, so that they are willing to change their conceptions to match the requirements of scientific understanding.

Treagust and Druit go on to describe how, in recent times, conceptual change researchers have begun to appreciate the emotive aspects of understanding. It is recognised that people may have conceptions which resist change because they accord with their personal identities, and/or with the views of the social groups which matter to them. (The authors do not mention this, but clearly religious beliefs interact with rationality when it comes to making sense of the world.) As they explain, changing a conception has to be something a student wants, at some level, to do. The outcome of the growing realisation of the various personal and contextual factors which encourage or inhibit conceptual change has, as the authors explain, led researchers to try to construct a ‘multiperspective’ or more complex model for addressing this topic. They suggest that ‘only such frameworks can sufficiently model teaching and learning processes’ and describe how they have used a framework based on four different perspectives.

In their discussion of how students can be encouraged to reflect on their own understandings, they refer to a protocol they used in their own research which includes the question ‘How would you explain that to a friend?’ In interviews based on this protocol, students were asked to draw and verbalise their predictions about, for example, the refraction effects of a glass block, and were encouraged to give their reasons for their views. The researchers transcribed the interviews and used that data to decide if the conceptions students described were ‘intelligible’, ‘plausible’ or ‘fruitful’. Using this data and analysis, the authors provide a very good analytic account of the nature and extent of the understandings of students in their study, at least as expressed in the interviews. Some extracts from the transcripts are included in their paper to illustrate the ways students represented their ideas, and how they fitted into the three categories of ‘intelligible’ and so on. I was glad to see that the words of both the interviewer and the interviewee are included in some of the extracts. One, reproduced in full below, comes from an interview with a student called Dana, who was asked to explain why some pencils appeared bent when viewed partly though a glass block.

Int.	O.K. Can you think of any simple analogy that would help you explain to a friend why those pencils appear to be bent?
Dana	No. I don't think I'd be able to explain it 'cause I don't know myself.
Int.	Right, did Mrs ... use an analogy when she taught you this?
Dana	Umm ... She used a car type of thing with wheels when it was changing from a piece of carpet to paper.
Int.	And what happened when the wheels went from carpet to paper?
Dana	It bent because one wheel got onto the paper before the other one and one is rougher than the other surface.
Int.	So what happened to the wheel that got onto the paper first?
Dana	It went faster so it turned.
Int.	O.K. So one wheel was going faster than the other was it? What happened when the other wheel got onto the paper too?
Dana	Then it just went straight from there.
Int.	O.K. So the direction of the wheels changed because the speed changed did it?
Dana	Mmm.
Int.	Does that fit in, in any way with light?
Dana	Yes, because light changes faster in air than it does in water.
Int.	Alright, let us come back to your sketch. What will happen when the beam of light hits the surface between the water and the air?
Dana	It would probably be bent that way.
Int.	Did the wheels help you work that out?
Dana	Yes.
Int.	Did you initially remember the wheels?
Dana	No.
Int.	Alright, so when you didn't think about the wheels you had no idea what happened to the ray of light?
Dana	Uhhu.
Int.	When you think of the wheels, you can work out which way it bends?
Dana	Yes.
Int.	You are happy with that?
Dana	Yes.

The authors comment that 'Dana's answers to the subsequent beam tracing problems using glass blocks and prisms were among the best of the 39 students interviewed', although previously 'the teacher had placed Dana in the bottom 25% of the class and Dana had failed the Optics unit.' They add that, at the start of the interview, Dana had seemed quiet and not very interested. But when the researcher reminded her of the teacher's analogy 'she became enthusiastic and talkative'. They suggest that 'the introduction of the analogy led to her becoming dissatisfied with her initial answer [and so she] changed her vague ideas into a correct response.' Their explanation, then, is in terms of Dana bringing together two different sets of ideas and resolving her dissatisfaction with their difference—in other words, a cognitive, individualistic account. Later in the paper, they broaden this explanation to take account of what they call 'the affective domain', which they relate to an instance of a teacher's use of encouragement and praise for students' efforts. And much later in the paper, they discuss the significance of 'cognitive conflict', concluding that research findings are inconsistent on whether such conflict is an efficient motor for conceptual change (though they do quote studies which show that it is a facilitator). Surprisingly, perhaps, there is no discussion here of the post-Piagetian notion of 'sociocognitive conflict', to which I will return.

The final part of the paper is mainly concerned with the relevance of conceptual change research for instructional design and pedagogy. In their conclusion, they emphasise the value of observational and interview data for relating the empirical reality of science education to particular theories of conceptual change; and they suggest that normal classroom practice remains largely uninformed by what conceptual change research has to offer. Overall, the paper offers a clear, interesting and educationally relevant discussion of a wide range of studies of conceptual change.

A missed destination: the significance of dialogue

As I read Treagust and Druit's paper, I had an experience which might be likened to that of hiking along the shore of a lake and seeing a sailing boat tacking across the water. Sometimes the boat's course converges with mine, so that I think the crew are heading for a similar destination; but it regularly veers off, apparently heading elsewhere, before once again appearing to temporarily share my destination. Eventually, I see that the crew are indeed bound for somewhere else. The destination I thought that I might share with Treagust and Druit was the conclusion that conceptual change cannot be understood without considering the role of dialogue. Much of the research the authors discuss is, at least indirectly, about people sharing ideas, considering them and changing them through spoken interaction. They acknowledge that students' views are shaped by their membership of communities; they emphasise the need for teachers' interactions with students to be based on appropriate conceptions of conceptual change; they describe pedagogic interventions in which, through dialogue, a teacher causes a student to become dissatisfied with an existing conception and so revise their ideas. They mention the potential significance of a teacher praising students' efforts.

In their own research, they explore students' conceptions by asking them 'how would you explain that to a friend?'; they use data of recorded and transcribed talk, and argue in their conclusion for its importance. In discussing perhaps the key illustrative extract from their talk data (which I quoted above), they describe how Dana's involvement in the discussion of refraction changed from relative lack of interest to enthusiastic animation. When did this happen? It was during a conversation with the researcher. She didn't recall the teacher's analogy herself, she was reminded of it by her interviewer. Moreover, her interlocutor did not stop there. With a series of questions like 'Did the wheels help you work that out?', 'Did you initially remember the wheels?' and 'Alright, so when you didn't think about the wheels you had no idea what happened to the ray of light?' Dana was led through a classic piece of Socratic dialogue. She was helped to see that she already had all the necessary elements for constructing a scientific conception of the phenomenon in question. Is it so surprising, after this dialogic experience, that her conception changed, as well as her attitude—and that she subsequently achieved more from her studies than had been expected?

So despite their admirable and interesting use of talk data, the authors seem, by the end of their paper, to maintain a conception of conceptual change which does not recognise the dynamic motor of dialogue. They acknowledge that conceptual understanding may be expressed through talk, but not (despite the illustrative evidence of their own data) that talk can affect conceptual understanding. Even their 'multiperspective' does not include any consideration of the social, rhetorical processes of thinking collectively, which now constitutes a multi-disciplinary field of study (as discussed in Mercer 2000). There are methodologies for investigating such processes in educational settings, systematically and rigorously. (Several are compared and evaluated by Mercer et al. 2004a.)

It is our natural habit to express our ideas in dialogue, to test our views against those of others, and to attempt to persuade other people to share the conceptual understandings that we believe are the best. It is of course also normal that we resist changing our minds, if the views we hold are bound up with aspects of our social identities. But, nevertheless, most of us proceed as if we believe that one of the most important ways of changing someone's mind is to talk with them. It seems, though, that cognitively orientated conceptual change researchers stand outside this near-consensus—which of course is why sociocultural researchers like myself are keen to engage them in dialogue.

Having made my rhetorical case for the importance of dialogue, I have to admit that empirical evidence on how it can affect conceptual change has not yet been properly assembled and evaluated. The research has, as yet, a patchy quality, with (perhaps surprisingly) more hard evidence available on the effects of peer group activity than on teacher–student interaction. Nevertheless, there has been some interesting and relevant research on both types of interaction. In the rest of this paper, I will present and discuss some its findings.

Dialogue amongst students as a motor for conceptual change

For Piaget (e.g., 1985), the pathway to development and learning was the process of *equilibration*, a process that involves the reconciliation by individuals of conflict between prior and newly experienced beliefs. Equilibration implies that children need to encounter beliefs that differ from their existing ones, but that, by virtue of not being too advanced, can be related to these. Since the beliefs of the children in a class are likely to display similar (although certainly not identical) levels of understanding, this implies that discussing beliefs with classmates ought to be productive, so long as beliefs differ and tasks are structured to draw differences out. Although Piaget (1932) noted the implication himself, he did not elaborate it further. It was left to his colleagues to consolidate his ideas in the concept of *socio-cognitive conflict*, and initiate a programme of empirical investigation. The earliest studies related to that concept were based on Piaget's own classic tasks, with conservation and spatial transformation (i.e., the famous 'three mountains' task) being particular favourites. Some of these studies (e.g., Doise et al. 1975) compared children who worked on the tasks in groups with children who worked on them individually. These studies reported more progress in the 'grouped' children (as ascertained from comparing tests administered before the tasks to those done afterwards). Other studies, such as those by Ames and Murray (1982) and Bearison et al. (1986), have compared groups where members hold contrasting beliefs with groups where members hold similar beliefs, and/or by related the extent to which differences are expressed in dialogue to pre- to post-test change. These studies provide strong and consistent evidence for the relevance of the expression of differing beliefs for motivating conceptual change.

The research reviewed above is potentially significant for education: conservation and spatial transformation are clearly relevant to science and mathematics. Nevertheless, it is only from around 1990 that studies began to be published that tested Piagetian ideas with reference to curriculum-related topics. In relation to mathematics, support for the Piagetian emphasis upon difference has been obtained in research on rational number (Schwarz et al. 2000) and matrices (Blaye 1990). For science, some of the clearest evidence comes from research conducted by Howe and colleagues which involved groups (pairs or foursomes) working on tasks relevant to elementary concepts, e.g., whether small objects float or sink, the paths that objects trace as they fall through space, and the relative speeds of toy vehicles as they roll down slopes. In all cases, the groups jointly predicted outcomes, observed what happened, and jointly interpreted what they observed. The majority of the studies (e.g., Howe et al. 1990) were with primary school children aged 8–12 years, although some studies included older students (e.g., Howe et al. 1995). In every study, individual pre-tests prior to the group tasks allowed some groups to be comprised of participants with differing preconceptions about the subject matter, and other groups to be comprised of participants with similar preconceptions. Individual post-tests some weeks after the group tasks revealed consistently greater progress after working in groups in which differing conceptions existed. Sometimes the participants who worked in similar conception groups made no progress whatsoever, despite observing the same physical outcomes as the differing groups and being equally engaged in the tasks. A particularly interesting finding is that when the participants in the differing groups also had differing levels of understanding (which was not always the case), the more advanced individuals progressed as much as their less advanced partners.

There is thus is a sizeable body of research on the effects of the expression of different conceptions amongst students on their learning and conceptual understanding in science, stimulated by the Piagetian approach, and producing broadly consistent results. The results are also consistent with a Vygotskian/sociocultural perspective (as explicated by Wertsch 1991), as change seems to depend upon activity in the 'social plane' which permits the expression of contrasting perspectives. Moreover, it is not simply that sociocultural theory implies the developmental importance of children's engagement with different views; it is also that Piaget's account of such engagement seems to depend upon children establishing mutual goals and a shared understanding of the task at hand. In both cases, there is the clear implication that children do not merely interact and exchange ideas—they also have to 'interthink' (Mercer 2000). Note, for instance, that participants in the studies reported by Howe and colleagues (cited above) were required to predict and interpret *jointly*.

It seems, then, that the potential significance for conceptual change is not merely that peers have differing ideas; it is that those differences are expressed during purposeful joint activity. Howe et al. (2007) have recorded the dialogue of primary school children aged 10–12 years, while they worked through extended (3+ weeks) programmes of teaching on evaporation and condensation, and force and motion. The programmes were delivered by classroom teachers, and although they incorporated group tasks modelled on those used in Howe and colleagues' earlier work, they involved whole-class teaching and practical demonstration in addition. They were, in fact, fully embedded in routine practice, and group work was only one component amongst many. Yet the expression of contrasting opinions during group work was the single most important predictor of learning gain. Crucially, this was gain that was detected not simply between pre-tests prior to the programme and post-tests a few weeks later, but also found to be sustained after an 18-month interval.

The work of Howe and colleagues (as with much of the other research summarised above) explored dialogue in the context of tasks that constrained participants to joint activity. Thus, the tasks ensured that the expression of differences was co-ordinated and coherent, as illustrated in the transcribed extract below. It comes from data collected by Howe et al. (1992), and involves a group of 10- and 11-year-olds discussing the relative speeds with which a toy lorry and a toy car will roll down parallel slopes. The slopes had identical paper surfaces and were supported on pegs, whose height determined their angle.

Jonathon: Well, the lorry's heavier, and it gives more. See like it pulls down like. If it's light, it just moves down in its own time, but if it's got a lot of things it'll make it go faster. Also, it's on the higher peg.

Anna: But say it was like going down a water slide, and there was a great, big, heavy person getting down.
Chung: That is different. Skin is different to rubber, and you slide down in water.
Anna: I know, but cars are metal.
Chung: It's rolling on paper, so the lorry'll hit it, and it'll stop. But it's got weight to push it in the start, so I think it'll go faster.

The dialogue in the extract above has some of the characteristics of what has been called *exploratory talk*, a term first brought into the study of peer interaction by Barnes (1976). As characterised by Mercer and Littleton (2007), this is dialogue which involves partners in a purposeful, critical and constructive engagement with each other's ideas. Statements and suggestions are offered for joint consideration. These may be challenged and counter-challenged, but challenges are justified and alternative hypotheses are offered. Partners all actively participate, and opinions are sought and considered before decisions are jointly made. 'Exploratory talk' has some similarities with the notions of 'accountable talk' (Resnick 1999) and 'collaborative reasoning' (Chinn and Anderson 1998).

Without doubt, the expression of differences is one component of exploratory talk, but it is not the only one. However, the emphasis upon joint activity in the research considered above may have guaranteed the presence of at least some of the other features. In which case, it is probably not difference *per se* that is important, but difference in the service of argumentation and, through this, mutually accepted goals. Through this kind of dialogue, children may use talk not only to express different views, but also to resolve their differences. Through resolution they may even find themselves converging upon ideas that go beyond what any of them were capable of achieving individually. However, the resolution of differences is not essential for peer group dialogue to be useful. Groups that do not resolve their differences have been found to achieve learning gains as well as groups that do resolve (Howe et al. 1990). Those researchers also offer evidence to show that sharing, challenging, evaluating ideas during joint activity motivates children to reflect on the subject matter long after the group task is completed (Howe et al. 1992). Thus, within-group resolution is beside the point. The key factor is that children experience dialogue resembling exploratory talk. The increased occurrence of dialogue of that quality has been shown to be significantly related to improved learning outcomes in science, including the more sophisticated mapping of scientific concepts (Mercer et al. 2004b).

Talk with a teacher

In recent research with Jaume Ametller, Lyn Dawes, Judith Kleine Staarman and Phil Scott, I have been analysing teacher–student talk in science lessons in primary and secondary schools in the UK. Drawing on Scott's own previous work on science teaching (as will be explained below) as well as that of Alexander (2006), the research is based on the premises that:

(a) Gaining scientific understanding involves taking on new conceptual frameworks and ways of evaluating knowledge.
(b) The taking up of a scientific perspective quite commonly involves the critical examination of a more 'everyday' perspective on natural phenomena.
(c) This learning process consists, at least in part, of induction into a perspective and a new discourse by a relative expert (the teacher); it is not achievable by 'discovery learning'.

One of our aims has been to describe how differences between everyday and scientific conceptions are manifested in classroom talk, how they are dealt with by the teacher and what implications this has for the teaching and learning of science. We have tried to identify strategies that teachers use to engage students in constructive dialogues relating to their perspectives, assumptions and beliefs about natural phenomena and how these relate to the teaching and learning of science. Our hypothesis has been that teacher–student dialogue can mediate a shift of students' understanding of natural phenomena, from 'everyday' to more scientific conceptions, and so our examination of classroom talk and assessment of learning outcomes has been designed to test this idea. One practical aim is to help science teachers use dialogue to support student learning more effectively.

In collaboration over some years, Mortimer and Scott (2003) have carefully examined the functions of dialogue in secondary science teaching. Their research has highlighted the problems that students often have in moving between everyday and scientific understandings of natural phenomena—and how dialogue with a teacher may be one means for enabling students make a conceptual shift. They offer a matrix for distinguishing different types of 'communicative approach' in teacher-led talk, as shown in Table 1 below:

(Mortimer and Scott have explained this scheme as follows. The *interactive–non-interactive* dimension represents the extent to which the students, as well as the teacher, are actively involved in the dialogue. The *authoritative-dialogic* dimension represents the relative extent to which the students' or teacher's ideas influence the content and direction of the classroom talk. Taken together, these two dimensions allow any episode of classroom dialogue to be defined as being interactive or non-interactive on the one hand, and dialogic or authoritative on the other. Four classes of 'communicative approach' can thus be identified: interactive/dialogic, interactive/authoritative, non-interactive/dialogic and non-interactive/authoritative.

So in a dialogic/interactive episode a teacher might ask students for their ideas on a topic. The teacher might record those ideas on the board for future reference, or ask other pupils whether or not they agree with what has been said. The teacher might ask students to elaborate their ideas ('Oh, that is interesting, what do you mean by that?'). But the teacher would not make evaluations of these ideas, in terms of their correctness, or lead the discussion along a narrow, pre-defined track. Classroom talk becomes more 'authoritative' when the teacher acts more explicitly as an expert, keeps to a given agenda and directs the topic of the discussion clearly along certain routes (which may reflect the structure and content of the curriculum topic being dealt with). In a non-interactive/authoritative episode the teacher would typically be presenting ideas in a 'lecturing' style.

From this scheme, Mortimer and Scott make two important points:

(a) There are different types of teacher-talk, which vary in the extent to which they position the teacher as 'expert' and the extent to which they offer possibilities for substantial contributions by students
(b) These different types of talk do not represent better or worse teaching strategies in any absolute sense; the quality of the teaching depends on making the right strategic choices; and the different types of talk can function in complement.

Table 1 Four classes of communicative approach (Adapted from Mortimer and Scott 2003, p. 35)

	Interactive	Non-Interactive
Authoritative	Interactive/ Authoritative	Non-interactive/ Authoritative
Dialogic	Interactive/Dialogic	Non-interactive/Dialogic

There is no implication that classroom talk need always be 'dialogic' (in Mortimer and Scott's sense): there will be occasions when the teacher may quite justifiably not be interested in exploring pupils' ideas and taking account of them in the development of the lesson. The teacher may feel the time is right to focus on scientific content, to introduce some new question or concept, or to redirect students' attention to the phenomena under investigation. The key is in the teacher's application of a varied repertoire of ways of using language as a tool for teaching and learning.

We can look at what this kind of discursive variety looks like in practice through the extract below. It was recorded in a whole-class discussion in an English primary school. This followed a group-based session in which the children, in groups of three, had discussed a set of statements about the solar system and tried to decide if they were true or false. The sequence consists of two parts, taken from recordings made at the beginning and end of the whole-class discussion.

Sequence 4.5: Class 5 talk about the moon

Teacher: Keighley, would you read out number nine for us?
Keighley: (*reads*) 'The moon changes shape because it is in the shadow of the earth.'
Teacher: Right, now what does your group think about that?
Keighley: True.
Teacher: What, why do you think that?
Keighley: Hm, because it's when earth is dark then, hm, not quite sure but we think it was true.
Teacher: Right, people with hands up (*to Keighley*) Who would you want to contribute?
Keighley: Um, Sadie?
Sadie: I think it's false because when the sun moves round the earth, it shines on the moon which projects down to the earth.
Teacher: (*to Sadie*) Do you want to choose somebody else? That sounds good.
Sadie: Matthew.
Matthew: Well, we weren't actually sure cos we were (thinking) the actual moon (changes) which it never does or if it is in our point of view from earth which it put us in the shadow.
Teacher: That's a good point isn't it, it doesn't actually change, it looks as if it changes shape to us, that is a really good point.

(We move now to later in the same session. The teacher has a large photo of the moon on the interactive whiteboard. She also has on a table a lamp (representing the sun) a globe (the earth) and a tennis ball (the moon.))

Teacher: Right look, if the sun's shining from here there is nothing between the sun and the moon, so from here on earth what we can see is a circle, a big shiny full moon. (*She hold the 'moon' so it is the third object in line with the 'sun' and 'earth'*) Right? That's a full moon; we can see the whole caboodle, if we're here on earth and the sun is over there. However, have a look now, what happens now. If I put the moon here (*she puts the 'moon' between the 'sun' and the 'earth'*) here's the sun, is there any light from the sun falling on this moon that we would be able to see from earth?

Children: No.
Teacher: What would we see if the moon is in that position?
Children: Nothing.
Teacher: Yeah, it would be totally dark. We get a completely black effect because we can't see it, we can only see it if there is light falling on it, and all the light is falling on this side and we're not over there, we're over here. Yes?
Child: If it is like that, the reason we can't see anything really because it is so dark around it.
Teacher: Yeah, it is dark, yeah, the light needs to land on it for us, it cannot shine on itself. So that is when it is the darkest bit of the moon, we can't see it (*returns 'moon' to first position*). That is a full moon, over here relative to the earth, (*moves 'moon' to second position*) and that is when it is dark. However (a *child tries to interrupt*) wait a minute, let's get this right. If we come half way around (*she repositions the objects so that the 'moon' (ball) and the 'earth' (globe) are next to each other, facing the 'sun' (lamp)*) the sun is shining on this bit, but not on this bit, what would we see then?
Children: Half/half-moon.
Teacher: It would look like that. *(points at picture of half moon on whiteboard)*
Children: Yeah/ooh.
Teacher: Yeah, the sun is shining on that bit, but not on this bit we'd see a half moon. (*A child says 'ooh!'*). So that means that the moon is putting a shadow on itself, it is not the earth throwing a shadow on it, or a planet throwing a shadow on it, it is in its own shadow if you like. The shadowy bit is just not lit up by the sun. And from earth we can only see about half of it, while the other half of it is this side. And this is how it works, (*she moves the 'moon' round the 'earth'. A child starts to speak but the teacher continues*) dark, half moon, full moon, half moon, and that is what happens. With those little crescents in between. (*Viola has her hand up*)Viola?
Viola: I've learned something now.
Teacher: Have you? Yeah (*laughs*) I'm a bit worried about what. Go on then.
Viola: I didn't know that, I know that you cannot see the, the other half, but (*pause*) I don't know how to explain it (*laughs*)
Teacher: Maybe you need to give it a chance for it to sink in and think about it, it's quite hard to understand, I find it hard to understand.

(Mercer and Littleton 2007, pp. 51–53)

In the first part of this sequence we see a teacher engaging with pupils in a way which is *interactive/dialogic* because the teacher engages the children a series of questions which effectively provide an opportunity for the children to express their own ideas. Moreover, the teacher does not make a critical assessment of these ideas as right or wrong, but rather takes account of them and allows the dialogue to continue. Through the use of interactive/dialogic dialogue, the teacher learns about the children's current understanding of the topic of the lesson and is able to use this information in developing the theme of the lesson.

In the second part of the sequence, the talk has a different pattern. Scanning over the sequence as a whole, it is quickly apparent that in the second part the teacher's talk takes up a much greater proportion of the dialogue. She uses these longer turns to explain to the children (with the use of the models of the earth, sun and moon) how the solar system generates the moon's phases. She again interacts with the children, but this time the questions are mainly used for different purposes—to check that the children are following her explanation, to carry out some ‘spot checks’ on whether they have understood its implications, and so on. The dialogue here could be described as *interactive/authoritative*, though it is also *non-interactive/authoritative* in parts. In conjunction with the use of equipment, she uses language to provide children with information about the solar system which is absolutely necessary for their understanding of how it works. A multimodal presentation of this kind is an effective way of doing so—though it is likely that the students fairly rapt attention to her demonstration was enhanced by their earlier opportunities to talk about the moon in their groups and in the previous interactive/dialogic episode. (We might note at the end of the sequence, that one of the students comments ‘I’ve learned something now’, implying an awareness of some conceptual change—one which she cannot properly explain.) In describing and evaluating the teaching in this lesson, it would be wrong to focus exclusively on either the early or the late parts of the dialogue. It is the quality of the dialogue as whole that matters. A teacher can use different forms of ‘communicative approach’ at particular times, as appropriate. The crucial issue is whether the choices a teacher makes are effective for establishing and maintaining a dialogue which supports the development of understanding for as many as possible of the children in the class.

Research on teacher–student dialogue has provided insightful analyses of teacher–student talk and generated useful analytic methods, conceptual frameworks and models of the process. It has also linked ways of talking with positive learning outcomes. Brown and Palinscar (1989) were probably the first to provide correlational evidence that certain kinds of dialogic features were associated with improved curriculum-related learning, and confirmatory evidence has since been provided by my own work (Rojas-Drummond and Mercer 2004) and by Kim et al. (2007). Nevertheless, as I mentioned earlier, compared with the study of peer interaction such research has generated little hard evidence about how, and the extent to which, teacher–student dialogue affects conceptual change. That work is still to be done.

Conclusion

My aim, then, has been to show that Treagust and Druit’s admirable discussion of research into conceptual change lacked one important feature—consideration of dialogue as a motor for conceptual change. While it is clear that we need more empirical research to understand how dialogue affects conceptual change, research evidence shows that the role of talk and social interaction cannot sensibly be ignored. Treagust and Druit close their paper with the view that we need to investigate all kinds of theoretical frameworks, research methods and instructional strategies. I could not agree more. We should be open to conceptual change ourselves: there is no sense in rigidly maintaining partisan positions as ‘cognitivists’, ‘socioculturalists’, ‘constructivists’ or whatever. Perspectives, methods and analytic frameworks which may seem initially at odds could provide complementary insights into how and why human beings change their minds to achieve a better understanding of natural phenomena.

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