RES-00023-0939: Dialogic teaching and the development of understanding in science classrooms: End of award report

1. Background
This research has involved a detailed analysis and characterisation of teacher-student interaction in science classrooms, at both primary and secondary level, ‘Dialogic teaching’ has been defined by the originator of the term as collective, reciprocal, supportive, cumulative and purposeful (Alexander, 2006, p. 28). Taking this view as a starting point and drawing on our own relevant prior research and that of others (e.g. Wells (1999) on ‘dialogic inquiry’), our aim has been to see how the concept of dialogic teaching relates to the actual talk and interaction of science classrooms and in so doing draw theoretical and practical implications.

An a priori assumption of our work has been that the discipline of science brings with it distinctive epistemological features which shape the nature of science learning and the teaching required to support that learning. A key feature is that it inevitably involves the juxtaposition of everyday and scientific views. For example, from an everyday point of view ‘energy’ is often talked about as being a ‘real substance’ (contained, for example, in chocolate bars) which gets used up during exercise. From a scientific perspective, energy is an abstract, quantitative accounting device. Furthermore, scientific concepts exist in an interlinking matrix of ideas: the concept of energy is closely linked to the concepts of force, work, power, entropy and so on. Bearing these features of scientific knowledge in mind, we consider that the meaningful learning of science must entail making links between different points of view. This involves recognising the similarities and differences between everyday and scientific views; understanding the links between different scientific concepts; appreciating how the same scientific concept can be applied in a range of quite different contexts. Our fundamental interest in dialogic teaching is in its potential for supporting this kind of meaningful learning.

2. Objectives
The research addressed the following specific questions:
1. What is ‘dialogic teaching’ in a science classroom? That is, can we characterise teaching strategies which most effectively engage students in extended dialogues and assist their learning and understanding of science?
2. What can the analysis of classroom dialogue through a series of related lessons tell us about the ways such dialogue contributes to students’ emergent understanding of specific scientific concepts or processes?
3. Do teachers of science at upper primary (KS2) and lower secondary (KS3) levels typically engage in different types of dialogic interaction with their students, use specific strategies, or represent scientific knowledge in different ways? Are any such differences of pedagogic significance?
4. How can the specification and exemplification of dialogic teaching contribute to educational theory and inform the professional development of teachers?

Some obstacles and issues arising in pursuit of the objectives are described in Section 7 of the End of Award Report Form.

3. Methods
The research was carried out in five primary schools and three secondary schools, involving six primary teachers and six secondary teachers. Video/audio recordings of short teaching sequences (total duration 3-5 hours) were made in both primary (Year 5/6/7) and secondary
(Year 7) classrooms. Two of the secondary schools and three of the primaries were in Milton Keynes, with one secondary school and two associated primaries in Calderdale. There were no significant problems of access. The teachers involved all volunteered to participate in the project and all were considered by local advisers and their peers to be ‘good practitioners’. The secondary teachers were science specialists; of the primary teachers, only the research consultant Lyn Dawes (who was both teacher and researcher) had a science teaching background. The lesson topics were selected through discussion with each teacher and based on the regular curriculum. They included some conceptually demanding topics, with some common to both primary and secondary curricula. By an accident of fate (a changing primary/secondary transition age in Milton Keynes), we were able to observe Year 7 students being taught by both primary and secondary teachers. Lessons were planned by the teachers and in accord with our original plans we made no interventions as to how lessons were taught or students’ learning assessed.

3.1 Data collection
All the teachers’ talk in the target lessons was recorded, as they interacted with whole class, small groups and individual students. Talk amongst a group of students in each class was also recorded. We interviewed a sample of students in each class immediately after lessons and several weeks later to elicit their understanding of the science concepts taught. We also gathered any available written work. The data gathered thus consisted of:
(i) pilot video recordings of four lessons;
(ii) video-recordings, focusing mainly on the teacher, of 12 sequences of 3 lessons;
(iii) video/audio-recordings of target students working together during lessons (at least one group in each class);
(iv) students’ written work (along with teachers’ assessments) from the 12 classes;
(v) any other assessment data (such as end of unit tests);
(vi) recorded interviews with teachers and students in all classes involved;
(vii) stimulated recall sessions with three teachers (2 primary, 1 secondary);
(viii) audio recordings of teacher meetings.

Approximately 120 hours of classroom talk (video and audio of group work) and 20 hours of interviews with teachers and students were recorded. Relevant data has been transcribed.

3.2 Data analysis
The two most significant influences on the conceptualization of ‘dialogic teaching’ used in our analysis of classroom communication are Alexander (2006) and Mortimer and Scott (2003). However, they employ the term ‘dialogic’ in rather different ways. For Alexander, ‘dialogic teaching’ describes a whole pedagogic approach, underpinned by specific principles, which can be enacted through a range of possible discursive strategies (he provides a list of 47 indicators) and involves organizing the classroom environment in appropriate ways. He uses the term to distinguish teaching which actively engages students in a coherent cumulative, process of learning with ways of teaching which do not. In contrast, Mortimer and Scott (2003) use ‘dialogic’ to define the nature of some teacher-student interactions. Its use is associated with their concept of communicative approach, which is defined by characterising the talk between teacher and students along two dimensions: interactive-non interactive and authoritative-dialogic. In interactive communication both teacher and students contribute actively, while in non-interactive communication only the teacher speaks. Thus in interactive episodes the teacher typically engages students in a series of questions and answers, whilst in non-interactive teaching the teacher presents ideas in a ‘lecturing’ style. The authoritative-dialogic dimension is concerned with whether the teacher focuses solely on the school science point of
view or opens up the interaction to ask students for their points of view. During authoritative episodes, the concepts and conventions of science are the clear focus of the teaching. These may be at points where the scientific ideas are first introduced, or where scientific ideas are reviewed or summarised. During dialogic episodes different points of view are represented. Students might be encouraged to express a variety of everyday views, or the teacher might summarise different everyday and scientific views expressed during a lesson. These dimensions generate four classes of communicative approach (as set out in Annex 2). There is no implication in Mortimer and Scott’s scheme that any one of the four types of communicative approach is intrinsically superior. Like Alexander, they argue that the crucial issue is how and why a teacher uses the approaches at any particular stage in a lesson or series of lessons.

While they have similar roots and interests in pedagogic effectiveness, the two conceptions of ‘dialogic’, having developed independently, are difficult to reconcile into one analytic scheme. Nevertheless, we believe our analysis does justice to both lines of research, and that our search for dialogic teaching in the science classroom is, in general terms, in accord with Alexander’s conception. Within the analysis of the data itself, we have drawn on Mortimer and Scott’s framework and have referred to Alexander’s indicators. Descriptors of types of teacher-student interaction generated in earlier research (described in Mercer, 1995; 2000; Dawes, 2004; Mercer & Littleton, 2007) provided an additional resource, and new descriptors were also generated.

Our analysis has been mainly concerned with identifying processes of interaction, within and across the related series of lessons. The methodology called sociocultural discourse analysis (Mercer, 2004) has been employed. This highlights the historical, contextualized and purposeful nature of classroom talk and involves both qualitative and quantitative methods. The qualitative analysis consisted of a detailed examination of video and transcripts, using AtlasTi. We created analysis tables for each series of three lessons in which we noted any learning objectives stated or implied, distinguished episodes within lessons, and identified themes that were pursued across episodes and lessons (see example in Annex 1). We then identified particular communicative approaches and patterns of interaction within episodes (including the use of artefacts). Detailed case studies were compiled with indicators of dialogic teaching, and related language features noted; for example, expression of student’s everyday ideas about science concepts (revelation), students’ and teachers’ juxtaposition of everyday and scientific views (interanimation) and turning points in the talk which indicate transition between authoritative and dialogic discourse. Quantitative analysis (not complete at the time of writing) uses concordance software to identify collocations and the frequency of use of technical terms and other key words.

4. Results

The analysis so far has generated:

a) a ‘case study’ account of sequences of three lessons recorded as a cohesive, temporal sequence of discourse;

b) a selection of episodes of classroom interaction which include dialogue of special interest, whether in terms of the content of the talk, its discursive structure, or other salient features;

c) analyses of interactions in these episodes, which attend not only to content but also to the organization, structure and content of the particular set of lessons in which each is embedded;
d) inferences about the impact of dialogue on learning outcomes;

e) descriptions of interactive strategies used by teachers to engage students in extended
dialogue.

As an expedition which set out to look for dialogic teaching in science, we have captured
some examples of interaction which clearly demonstrate how teachers can enable students’
voices to be heard to good effect and use dialogue to guide their construction of scientific
knowledge and understanding. On the other hand, we have also found that much of the talk
maintained established, conventional patterns of teacher-student interaction.

4.1 Research Question 1: What is ‘dialogic teaching’ in a science classroom? That is, can
we characterise teaching strategies which most effectively engage students in extended
dialogues and assist their learning and understanding of science?

Through the analysis of our data we have characterised dialogic teaching of science in relation
to four ‘key features’: (1) Working on knowledge; (2) Shifts in communicative approach; (3)
Teacher actions; (4) Student engagement. These are listed below and elaborated in Annex 3.

1. Working on knowledge
This first feature concerns how the teacher and students work on knowledge. Thus, dialogic
teaching in science involves:

a. enabling students to make their own ideas, understandings and questions explicit at
appropriate points during a teaching sequence.

b. developing the scientific point of view.

c. the bringing together and juxtaposition of different points of view.

d. making links between explanations and events.

e. temporal management of the construction of knowledge.

f. handing over responsibility to students in using and applying scientific ideas.

Examples of the ways in which teachers manage the construction of knowledge over time are
shown in Annex 5, Examples 1e.

2. Shifts in communicative approach
Dialogic teaching involves shifts between communicative approaches in accordance with both
lesson plans and emerging circumstances. A key aspect of interactive/dialogic communication
is that the teacher does not provide immediate evaluation of students’ ideas. Examples are
given in Annex 5, Examples 2b. In nominated output 2, Sequence 4.5 illustrates a teacher’s
strategic switching between dialogic and authoritative communication within one lesson. In
dialogic teaching, authoritative and dialogic communicative approaches are reciprocating in
nature as one gives rise to the other. Thus the dialogic exploration of ideas leads to some
form of authoritative resolution, whilst an authoritative presentation of ideas demands
subsequent dialogic exploration.

3. Teacher actions
In using different communicative approaches to work on knowledge in the ways specified
above, the teacher:

a. organises teaching activities to address specific purposes.

b. monitors and refers to students’ understandings.

c. asks for reasons and justifications for views

d. encourages students to comment on each others’ points of view.
e. responds to students’ understandings.
f. allows sufficient time, and adjusts the pace of lessons, for exploration of views to take place.
g. creates an encouraging and open working atmosphere.

Examples of 3c and 3g are given in Annex 5.

4. Student engagement
As dialogic teaching progresses all or most of the students should become active participants as they:

a. articulate their own points of view.
b. refer and respond to the points of view of others.
c. take extended turns in whole class and small group interactions.
d. raise questions relevant to the developing subject matter.
e. attend to whole class interactions even when not directly involved.

Specific teaching activities
The effectiveness of particular pedagogic strategies and activities is contextually determined. The same literal request for views on a phenomenon by two teachers may generate quite different types of responses because one teacher has established a normative environment in which students’ speculative responses are known to be welcome, while the other one has not. Our research supports the view that students are only likely to make more extended and adventurous contributions to dialogue if a teacher has established an environment in which such contributions seem normal. Moreover, dialogic teaching has a temporal dimension. An initial exploratory activity can only be judged as part of ‘dialogic teaching’ when the rest of the sequence is also examined. For example, the case study in nominated output 1 includes an account of an extended discussion through the related topics of (a) the forces acting on a bottle standing on a shelf; (b) the forces acting on a balloon; and (c) a diagram of forces on a whiteboard. These are key elements of the case study sequence and an important question concerns how each enables the key features of dialogic teaching to be addressed. The summary in Annex 6 demonstrates that each covers features relevant to the purpose of the activity and that all features are covered (some more than once) across the three discussions.

4.2. Research Question 2: What can the analysis of classroom dialogue through a series of related lessons tell us about the ways such dialogue contributes to students’ emergent understanding of specific scientific concepts or processes?

This has involved developing detailed records of the learning trajectories of targeted students, looking for evidence of meaningful learning. Student pathways are developed from a range of sources: what the students say in class in plenary and small group settings; written work, sketches and drawings; and how they engage in activities. As an example, key points from the learning pathway of one 12 year old secondary pupil, ‘Josie’, with links to the surrounding teaching, are presented below. This example is based on the case study in nominated output 1, as briefly described above. Part of the research record of Josie’s profile is in Annex 7.

Josie’s learning pathway
1. Josie responds to two images provided by the teacher. For one, of a bottle on a shelf, she states that ‘the only force acting is gravity’ and that ‘the shelf cannot push’. This is in disagreement with her partner who maintains that ‘there are two forces on the bottle – the force of gravity and the push of the shelf upwards which balances it’.
2. In a later plenary Josie articulates her view, ‘Well like, I don’t think that a table can push. Cos gravity pulls, it’s a force...but a table can’t push upwards, it’s just in the way of the erm…that’s all’.

3. In the next lesson the teacher refers back to the debate about the bottle on the shelf and asks Josie ‘What were you arguing about?’ Josie replies ‘That a table can’t push up’. The teacher uses this as a starting point for arguing, with the help of a balloon model, that a table can provide an upward force.

4. After the demonstration with the balloon Josie works with her partner on an activity where they are asked to write down a useful way of thinking about ‘Bottle on a Shelf’. Josie wrote: ‘The table has up-push normal force. Gravity is pulling it down. The table is pushing upwards. The bottle is pushing downwards’.

5. In the next lesson the teacher represents forces with arrows on a whiteboard. Josie and her partner work on an example which shows tomatoes in the pan of a weighing scale. What are the forces acting on the tomatoes? They show one arrow acting down which they label ‘gravity’ and one arrow acting up which they (incorrectly) label ‘tension’.

6. In the plenary following this group activity, Josie contributes to placing the force arrows on the whiteboard. She suggests (correctly) placing the upward arrow, ‘That’s the start of the arrow and that’s where the spring is’ and the downward arrow: ‘It’s sort of in the centre like this’

7. At the end of the lesson sequence Josie is involved in an activity whereby she must give a ‘clue’ to allow a fellow pupil to guess the term ‘up-push/normal force’. Josie states, ‘Like a bottle standing on a shelf has gravity on it and something keeping it up from the table’.

Josie's learning pathway leads from an everyday view through to the correct application of normal force in different contexts. It is clear that specific teaching activities and especially the talk around them have enabled her to take steps in meaningful learning, starting with the juxtaposition of everyday and scientific views through use of the images. Our data show that students follow different learning pathways and so 'meet' the same teaching activities with different perspectives and achieve different outcomes. Nevertheless we have evidence that such interactions (dialogic and authoritative) have the potential to support meaningful learning and together constitute 'dialogic teaching'.

4.3 Research Question 3: Do teachers of science at upper primary (KS2) and lower secondary (KS3) levels typically engage in different types of dialogic interaction with their students, use specific strategies, or represent scientific knowledge in different ways? Are any such differences of pedagogic significance?

As is normally so, the primary science lessons which we observed were mostly taught by teachers without any higher qualification in science. They taught their own class in their own classrooms with little specialist apparatus. In contrast, the secondary science lessons were taught by science specialists, in laboratories with easy access to specialist equipment. These factors impact on the way in which dialogic teaching is played out in classrooms across the two phases. We shall examine this impact in relation to the four key features of dialogic teaching in science.
4.3.1. Working on knowledge

In terms of developing the scientific point of view, differences were observed which relate to the primary teachers’ lack of depth of subject knowledge. For example, in one particular case a primary teacher referred to phases of the moon as being caused by the ‘shadow of the Earth’. Conversely, at least one secondary teacher, with a physics background, commented on her uncertainty with some aspects of a chemistry topic. Secondary teachers, and students, also tended to use more technical vocabulary. We recorded Year 7 secondary teachers using such technical terms as ‘gravitational potential energy’ and explaining a process by saying ‘yesterday, we did the pH scale, so this starts with sodium carbonate, they add ethanoic acid...’. No such usage was recorded in Year 7 primary classes. It was also more common for secondary students to respond to teachers’ questions by reference to a textbook or their own notes, which made the inclusion of technical terms more likely. In interviews, secondary teachers sometimes mentioned the importance of students’ learning technical language, while primary teachers did not.

We have evidence of primary teachers at times distancing themselves from the authority of science (‘Oh dear sounds as though we’re getting into college physics now!’), while secondary teachers were happy to be seen as science experts. However, in terms of the temporal management of the construction of knowledge the primary teachers had the advantage in that they inevitably knew their class of children better and were able to make references to what individual children had said in previous classes. As one secondary teacher commented, ‘given all of the classes that I teach, I barely know all their names, let alone remember what someone said last week’.

4.3.2. Shifts in communicative approach

All four classes of communicative approach were observed in both primary and secondary classes. Nominated output 2 (Sequence 4.5) illustrates the strategic shifting between approaches within a lesson.

4.3.3. Teacher actions

While all teachers organised teaching activities to address specific purposes, we more often observed primary teachers carrying out activities where it was difficult to see how this might help develop the scientific story. Conversely monitoring and referring to students’ understandings, for reasons outlined in 4.3.1 above, was more common amongst the primary teachers. There was also an obvious difference in the pace at which lessons were conducted in the two types of school. This was not a matter of secondary teachers talking more quickly (there were no consistent differences in words-per-minute at similar stages of lessons), but rather that more content was covered in a similar time. The primary teachers had the advantage of being able to spread out in time, with some of the observed lessons taking a whole afternoon and allowing for both discussion and presentational activities. This meant they were more able to adjust the pace of lessons for exploration of views to take place.

It appeared easier to create an encouraging and open working atmosphere in primary classrooms, as the teacher knew the children better and teachers could easily organize students into working groups or a discussion circle (whilst secondary colleagues, working in labs, could only ask them to turn around in their seats). However, not all primary teachers made the most of this advantage. In addition, primary teachers were more likely to make dialogue a topic with children (e.g. by asking children to consider how they talked together) whilst secondary
teaching were rarely observed doing this. This reflects the wider remit primary teachers have for children’s learning, including ‘speaking and listening’ as well as science.

4.3.4. Student engagement

Our data indicate that primary students were more prepared to articulate their own points of view and refer and respond to the points of view of others. As one teacher said, ‘the secondary kids don’t like passing an opinion in case they are wrong’. Another teacher commented on the fear of adolescent students appearing ‘not-cool’ in front of their peers, especially in ‘set’ classes where the students might not know each other very well. A striking difference was the extended time spent in whole-class plenary sessions in primary classes as compared to secondary. In the primary lessons students were able to sit and follow and contribute to quite lengthy plenary discussions (of 20 minutes and more) whilst in secondary the activities tended to be shorter with a premium for the teacher of ‘keeping up the pace’ and ‘moving on’.

Overall, the differences between primary and secondary classrooms were more subtle than we had expected. There was not, for example, obviously more authoritative talk in secondary lessons, and we observed students asking spontaneous questions in whole-class sessions in both. Differences in discursive style between individual teachers were more apparent. Nevertheless, our analysis suggest that primary teachers face significant challenges in generating useful dialogues when they are working at the limits of their scientific knowledge and have only limited practical resources; whilst secondary teachers are challenged by dealing with different groups of children for only short periods of time in formal laboratory situations, and have no clear remit for the development of children’s use of dialogue as a tool for learning.

4.4 Research Question 4: How can the specification and exemplification of dialogic teaching contribute to educational theory and inform the professional development of teachers?

Our specification of ‘dialogic teaching in science’ in terms of the key features set out in Figure 2 (working on knowledge, communicative approach, teacher actions, and pupil engagement) may bring clarity to the muddy waters of what is meant by commonly used terms such as ‘dialogic teaching’, ‘interactive teaching’, ‘active learning’ and so on. Our results support the view that dialogic teaching has the potential to support meaningful learning of science. Teachers in the project who used the most ‘dialogic’ approaches generated learning conversations in which students contributed tentative views, made explicit their ‘everyday’ assumptions and admitted lack of understanding; and dialogue appeared to shift children’s understandings and give them new insights. Dialogic teaching requires the teacher to adopt different communicative approaches: at times encouraging exploration of different views; at other times focusing on the authoritative scientific view. This might involve direct instruction followed by the opportunity for the dialogic exploration of new ideas by students. It also must involve making links between different points of view. In short, dialogic teaching of science must involve strategic shifts between communicative approaches. We hope that identifying the reciprocating nature of communicative approaches over time, through ‘turning points’ in the discourse, makes a new and significant contribution to understanding effective ways of teaching science by making a fundamental link between pedagogy and classroom talk. For example, if the purpose of the teacher is to ‘work on knowledge’ through juxtaposing views, then a dialogic communicative approach is needed; if the purpose is to introduce the scientific view, then an authoritative approach is needed.
Dialogic teaching requires a certain kind and level of teacher expertise. This expertise is built in part on the teacher’s knowledge and insights relating to: particular content areas of science; how the authoritative science perspective relates to everyday views; students’ everyday views about a particular phenomenon; how individual students in this class think about this problem at this time; possible teaching activities to engage students in dialogue around the learning objectives; possible approaches to present the scientific view; productive questions to probe students’ understandings, and so on. The teacher also needs to have the general pedagogical and management skills required to put into practice all of these insights and activities with a group of 25 children. A fundamental aspect of this entails having the professional expertise to create a classroom environment where students confidently express their views and where they will listen thoughtfully to the teacher and to the contributions of others.

Our analysis, admittedly of a small sample, suggests that teachers may have limited explicit understanding of how dialogue may be used strategically. They may not distinguish between dialogic/interactive and interactive/authoritative communicative approaches. Their training may lead them to believe that direct instruction is ‘not interactive’ and therefore not of value. Experience within this research project and from other related professional development activities has been that teachers, once provided with relevant analytic tools and examples, are quick to recognize the possibilities of developing alternative dialogic approaches. Our dissemination of findings is planned to assist this professional development.

5. Activities
We have been working closely with participating teachers to develop lesson plans and teacher training resources. We have also shared findings with practitioners and researchers at conferences and other events listed in Section 2A of the End of Award Report Form.

International presentations:


5. Keynote presentation and paper will be presented to the European Science Education Research Association Conference, Malmö, August 2007

UK presentations


6. Outputs
See the two nominated outputs. Others are listed in Section 2A of the End of Award Report Form. We were encouraged by the Nuffield Foundation and the TDA to approach them regarding dissemination of findings, and will pursue this shortly.

7. Impacts
We have formed new and strengthened existing relations with local authorities and schools and our findings have already been received with interest by practitioners and researchers. We are currently working with the National Secondary Strategy in developing lesson plans for ‘Interactive/Dialogic’ science teaching at Key Stages 3 and 4. These are heavily based on the findings from this project and have been developed by working closely with National Strategy Science Consultants and science teachers. The materials will be available in 2008 and will be disseminated nationally through National Strategy professional development programmes.

8. Future research priorities
An interventional study which raised the awareness of secondary science teachers about effective uses of dialogue and assessed the effects would be valuable. Further research should also examine the nature of the link between dialogic teaching and meaningful learning. The research has already informed a Cambridge proposal currently being considered by the ESRC under the *Targeted Initiative on Science and Maths Education.*
REFERENCES


Annex 1: Examples of analysis networks

Analysis of LizForces101 – Episode 4

Analysis of 1 student’s engagement
## Annex 2: Four classes of communicative approach

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Annex 3: Key features of dialogic teaching in science

1. Working on knowledge
This first feature concerns how the teacher and students work on knowledge. Thus, dialogic teaching in science involves:

a. enabling students to make their own ideas, understandings and questions explicit at appropriate points during a teaching sequence. This may involve students expressing their everyday ideas about some natural phenomenon at the start of a teaching sequence or expressing their understandings of a science concept or the application of a science concept at some later point.

b. developing the scientific point of view. This is the responsibility of the teacher and involves introducing the scientific point of view so that it appears both understandable and reasonable to students, who are meeting it for the first time from the perspective of their existing everyday views.

c. the bringing together and juxtaposition of different points of view. Wherever appropriate the teacher draws attention to different points of view encouraging the students to work upon, or to interanimate, those different perspectives to see how they fit together. This might involve scrutiny of contrasting everyday ideas raised by students or examining any differences between everyday and scientific points of view.

d. making links between explanations and events. In introducing ideas for the first time it is helpful to link ideas to a memorable event which subsequently takes on the role of a prototypical reference point for both teacher and students.

e. Temporal management of the construction of knowledge. Dialogic teaching is not a one-shot pedagogy where new ideas are introduced and the teacher then moves on. On the contrary, it allows for arguments and ideas to be revisited, as both teacher and students explicitly refer to points raised earlier. In this way continuous themes are developed through a sequence of lessons as opportunities are offered for the review, reconsideration and consolidation of ideas by both teachers and students.

f. handing over responsibility to students in using and applying scientific ideas. As the dialogic teaching sequence proceeds the teacher enables the students to take increasing responsibility for talking and thinking with the ‘new’ scientific ideas.

2. Shifts in communicative approach
Dialogic teaching of scientific conceptual knowledge involves shifts between authoritative and dialogic communicative approaches in accordance with the changing purposes of different episodes of teaching. Thus dialogic teaching involves:

a. Authoritative communication. During authoritative episodes, the concepts and conventions of science are the clear focus of the teaching. These may be at points where the scientific ideas are first introduced, or where scientific ideas are reviewed or summarised. Here the teacher is more concerned with ‘closing down’ the discourse to focus on the canonical school science point of view and is less concerned with students’ everyday views.
Interactive/authoritative communicative approaches are often played out between teacher and students through triadic I-R-E (initiation-response-evaluation-) interactions where students’ responses are followed up with evaluative comments from the teacher.

b. Dialogic communication. During dialogic episodes different points of view are represented. Students might be encouraged to express a variety of everyday views, or the teacher might summarise different everyday and scientific views expressed during a lesson. Here the teacher is concerned with ‘opening up’ the discourse to probe a range of different points of view. Interactive/dialogic communicative approaches are often played out through extended chains, I-R-P-R-P-R-P- (initiation-response-prompt-) of discourse, where the teacher acts to prompt further thoughtful contributions from students rather than to evaluate responses.

c. reciprocating communicative approaches. In dialogic teaching, authoritative and dialogic communicative approaches are reciprocating in nature as one gives rise to the other. Thus the dialogic exploration of ideas inevitably leads to some form of authoritative resolution. Equally, an authoritative presentation of ideas demands subsequent dialogic exploration.

3. Teacher actions
In using different communicative approaches to work on knowledge in the ways specified above, the teacher:

a. organises teaching activities to address specific purposes. The key point here is that each teaching activity is ‘fit for purpose’ whether in terms of being designed to reveal students’ thinking, or to introduce a scientific idea, or to allow students to apply an idea, and so on.

b. monitors and refers to students’ understandings. As far as is possible the teacher is aware of the current ideas and understandings of each student in the class and often refers to these via the name of the student (‘John said…’).

c. asks for reasons and justifications for views

d. encourages students to comment on each others’ points of view.

e. responds to students’ understandings. The teacher is responsive to students’ current understandings as the teaching sequence proceeds. This might be achieved through changing short-term learning goals, shaping and re-shaping of teaching activities and so on.

f. allows sufficient time, and adjusts the pace of lessons, for exploration of views to take place. Appropriate provision of time is absolutely fundamental to the success of dialogic teaching. On the one hand students need to feel that there is time for them to sort out and to express their ideas. On the other hand discussion activities must not be allowed to drift.

g. creates an encouraging and open working atmosphere. This underlies any possibility of developing dialogic teaching in the classroom. Students need to feel confident about expressing their views such that both the teacher and other students will listen carefully to them and take them seriously. This might be achieved through: establishing working ground rules for classroom discussion; valuing pupil contributions; modelling active listening; emphasising the quality of interactions.
4. **Student engagement**
As dialogic teaching progresses it is to be expected that all or most of the students become active participants as they:

- *articulate their own points of view.* This might be in response to the bidding of the teacher or via a spontaneous offering. The views expressed might relate to their initial everyday ideas or to developing understandings of a scientific concept.

- *refer and respond to the points of view of others.* Students make reference to what other students have said, possibly stating whether or not they agree with particular ideas and giving their reasons why, and often generating further questions thereby creating continuing lines of enquiry.

- *take extended turns in whole class and small group interactions.* At times the students take extended turns and thereby do most of the talking whilst the teacher, along with the other students, do most of the listening.

- *raise questions relevant to the developing subject matter.* An important indicator of dialogic teaching is that questions are raised not only by the teacher but also by the students.

- *attend to whole class interactions even when not directly involved.* Students are actively engaged intellectually whether or not they are actually involved in discussions.
Annex 4: Summary of key features of dialogic teaching in science

1. Working on knowledge
   a. students make own ideas explicit
   b. developing the scientific view
   c. juxtaposition of views
   d. linking explanations and events
   e. temporal management of construction of knowledge
   f. handing over responsibility to students

2. Shifts in communicative approach
   a. authoritative
   b. dialogic
   c. reciprocating

3. Teacher actions
   a. purposeful
   b. monitors student understandings
   c. asks for reasons and justifications for views
   d. encourages student comments
   e. responds to student understandings
   f. allows time
   g. supportive working atmosphere

4. Student engagement
   a. articulate own points of view
   b. refer/respond to views of others
   c. take extended turns
   d. raise relevant questions
   e. attend to interactions
Annex 5: Examples of dialogic teaching in the classroom

1. Working on knowledge:

Example a: enabling students to make their own ideas, understandings and questions explicit at appropriate points during a teaching sequence.

This might be achieved by:
- asking not just one, but several students for reasons and justifications for their views on why a result (e.g. of a test or experiment) has occurred before proceeding;
- preceding whole-class discussion of particular questions or issues with a short group-based session, in which students can prepare joint responses for sharing with the class;
- offering groups of students a set of alternative explanations for a phenomenon (e.g. on a whiteboard, concept cartoon, or on slips of paper) and asking them to decide which are true/false (and why);
- deferring authoritative demonstrations or explanations of phenomena until the existing conceptions of at least some students in the class have been expressed (and then, where possible, linking the authoritative account to issues they have raised).

Example e: temporal management of the construction of knowledge
A secondary teacher is talking here with a group of students during the second of a series of three lessons on the topic of acids and alkalis.

T: Right you know what you did yesterday with that table?
S2: Yeah.
T: Can you now take the substances and write them against the pH scale. So he had vinegar red, he had soda water orange. Can you do that? Right can you write (inaudible), do you remember that one that went blue? That's called ammonia. Ammonia OK? Against the 7. Right no I'll draw something on the board that you can copy in a minute. Right have a good look at that now please?
(and later)
T: Right OK so start doing that with number 9. Yeah very lightly to start with, good. Yes? Right ok, I'll write something on the board. Right have you matched all the things you got there? Good, can you remember the one I used today that was 10, its called ammonia, ammonia. I'm going to write something on the board now. James can you tell Robert the ammonia name please?
(and later)
T: Right the closer you are to 7, the less of an acid you are. So did anybody get anything yesterday that was pH 6?
(and later)
T: Right I need you to try and finish this in the next 4 or 5 minutes. I want to collect your books in today with any homework you've done. Tomorrow, excuse me? Tomorrow I may let you do the rainbow fizz thing again, but you've got to explain exactly what's going on.
Example e: temporal management of the construction of knowledge
A primary teacher uses a group-based activity to encourage recall and consolidation of knowledge previously gained which is relevant to the forthcoming activity.

T: Right I'm going to start off this week then, usually at the beginning of lessons, you do that thing with your teachers where you recall things that you've done in previous lessons. So um, you'll start the lesson going back over what you've done before, so that you know why you're doing this lesson and what to do next. Usually I would try and remind you of something or get you to say what you think you've done. This time, you're going to do the reminding, because I've totally forgotten what we did in the last two electricity of lessons. So what I'm going to ask you to do with your partner now, for one minute, partners; is talk together to decide what you think the key points were of last lesson; I'm not going to say any more about it than that, and the one before in science. What did we do, what were we trying to either remember or do that was new? Or what did you learn, or how did you learn it? What did you have a go at, what did you find interesting? So that's quite a lot but really I only need one or two sentences from each group.

2. Shifts in communicative approach

Example b: Interactive dialogic: asking for relevant ideas and allowing responses without immediate evaluation

An example from a primary classroom

What do you understand by the word force?
We join the science class right at the start of the first lesson. The pupils are sat at their tables and Mrs Simon begins by posing a question:

1. Mrs. Simon: Today, we are going to talk about forces. What do you understand by the word ‘force’? Any meaning that you can think of…what does the word ‘force’ mean? Think of other words that might explain what the word ‘force’ means. (Several students put up their hands and Mrs. Simon nominates Gareth).
2. Gareth: Hmm…push and pull.

3. Mrs. Simon: Ah…let’s put it down (writes on the flip chart the words ‘push’ and ‘pull’). Anything else that might describe what the word means?

5. Mrs. Simon: Move something (writes on the flip chart).

6. Louis: Like hmm…hold cos’ like gravity [inaudible].

7. Mrs. Simon: Let’s put that ‘hold’ (writes on the flip chart board). Anything else? If you are thinking of a particular meaning – if you are thinking of the word force, then how would you use the word force? Not just in science… ’cos you are not always using it in a scientific way.
During the next 9 turns there is discussion of the idea of ‘forcing or making somebody do something’. Max then offers a different idea:

17. Max: Hmm… like power – like the force of the heat or the power of the heat.

18. Mrs. Simon: Power is the word (Mrs. Simon writes the word on the flip chart). Anything else that might go with the word ‘power’?

19. Larry: Like power of the storm.

By the end of the interactions, which continued for another 7 turns, the following list of ideas is on the flip chart:

*Push and pull, Move something, Hold, Make something to do, Power, Strength, Speed.*

**Example b: asking for relevant ideas and allowing responses without immediate evaluation**

An example from a secondary classroom

T: Right ok I'm with you sort of; let me repeat what Kevin said. What - hands down for a minute, let me repeat what Kevin, you'll get arm ache, I'm trying to save your arms, put them down for a minute. Kevin said this person (would have more energy than somebody in a cold place, because the sun makes (Vitamin D). Alright that's one idea. Let’s hold that idea in our heads. Josh?

S2: Um I actually think it's the opposite of what Kevin said, because the sun's rays um, I'm just saying it's just um that its colder, um so they'd be getting the same energy from the sun, but they wouldn't feel the same affect from the sun.

T: That's a good point, so they'll get the same energy from the sun but they won’t feel the same affect. Yes?

S3: I'm not sure if this is right but um, say in a place like Africa, they have quite a few trees, and they kind of give us energy; but in this place like the Artic, they don't have any trees.

T: They don't have any trees, we've got lots of ideas coming out, Georgia?

S4: I think um, my idea is because - I, I think it actually slows a person down instead of giving them more energy, because the sun's heat it will make you feel like you don't want to do anything like.

T: Ok so that's good, the suns energy would make you feel sort of like lethargic and you can't be bothered to move in hot weather, Tom?
S1: Um they have trees, loads of trees where that bloke is, so like um the trees take up most of the energy.

T: The trees take up most of the energy, Cameron?

S1: It's to do with the atmosphere, in a hotter country there's a more dense atmosphere which takes up some of the um (inaudible), so they get as much as a thinner atmosphere in Antarctica or in the Artic.

T: Ok so the atmosphere makes (inaudible). Right first question, lets see if we can take some of those ideas, and try and come up with an explanation? First question for you to think about. Do we get our energy directly, directly from the sun? That's your first question, have a look, before reacting to it just have a think about it.

3. Teacher Actions

Example c: asking for reasons and justifications for views

An example from a primary classroom (electricity and magnetism):

T: Have you got any questions or anything that you'd like to do a bit more about or anything else, can you think of anything? Shall we come back to you about that? Amy's dying, go on then Amy.

S4: Um well we learnt that um we, when we used a um parallel circuit, um with a motor, a light bulb and a battery, the light bulb is really like dim and the motor works, but with the.

T: The series circuit, yeah, yeah?

S4: With a parallel circuit.

T: Are we listening, Sam?

S4: With the parallel circuit um, the, the motor still works like at the same speed as it usually does, but the bulb was brighter.

T: That, that worked very well didn't it? If you all have a look at the picture at the bottom of the board there, that's the picture we drew of the circuit Amy and Callum made. They tried putting a motor in a series circuit with the bulb, and the bulb went really dim didn't it? And then what did you do, put it in a parallel and what happened to the bulb?

S4: It was brighter.

T: And what was your explanation for that? What do you reckon Callum? What do you reckon Amy?

S4: Um that in a, in a series circuit um the motor used, uses more power, and with the parallel circuit it uses less power.

T: You could think of it in terms of resistance as well couldn't we?

S4: Resistance yeah.

[And from the same lesson]

T: OK, now at the moment this metal nail is not a magnet, it's not going to attract anything it's just a nail. If we run an electric current around the outside of it, in theory we ought to be able to turn it into a magnet and be able to pick up a paperclip with it,
when the current is flowing. [...] Will it be able to pick up a magnet? There's two different nails there; what do you reckon, do you think the big ones will work better or the little ones?

CLASS: Big ones.

T: Now is that a guess or have you got a good reason for saying that? Fritzy?

S1: A guess.

T: A guess.

S2: I've got a reason.

T: You've got a reason?

S2: Well I think that the big one will become a magnet, because it's bigger - and actually no, I've changed my mind, it's the little one because the little one is smaller and the more in, more um electricity can go around it, because if it's the big one it will only pick up a little bit.

T: So we, there's two reasons there, and arguing both cases isn't there? Yes Sam?

S3: Um I think the little one will work better because it'll be less, the energy running through it will make it to make it a magnet will be less dispersed than in the big one because there's more things to make a magnet.

Example g: creates an encouraging and open working atmosphere
- making it clear that some parts of lessons are expressly intended to be discussion sessions, in which the ‘ground rules’ permit questions from students, the expression of diverse views and in which answers are not judged as ‘right’ or ‘wrong’;

- getting students to nominate other students to contribute in whole-class discussions (and so avoid the teacher always choosing who should speak);

Example g: creates an encouraging and open working atmosphere by emphasising the quality of interaction
A primary teacher reminds children how and why they should interact in a forthcoming activity.

T: So what's really important?

S: Wait (....).

T: Wait until the other person’s finished.

S: And take your time.

T: Pardon?

S: And take your time when you talk so (unintelligible)

T: Yes and listening, active listening isn't it? Looking at each other. What, not doing so much perhaps, well we are discussing obviously, but we're also going to be working collaboratively, so it doesn't matter whether you're with your best friend or not, in fact I might shuffle some of you up because I think some of you are just too comfortable working with each other, and other people you know? Then are refusing to work with other people which are not being a collaborative learner alright? Collaborative learner means you work with them whether you like them or not quite frankly, yes?
5. Student engagement

Each of the following transcripts refers to these key features:

a. articulate their own points of view.
b. refer and respond to the points of view of others
c. take extended turns in whole class and small group interactions.

Transcript: from a plenary discussion

Teacher: Does anybody else have something to say? Lyndon.
Lyndon: I reckon like the start of it is scientific but the end is, m, not really, because like it didn't really forced it to turn back he just like had a choice, the wind didn't like push him back.
Ami: yeah but…
Teacher: Ami.
Ami: The reason that, the thing, is because the (weather), if you're going on about it the wind would be blowing up (...) so it's forcing him to go back because it will be pushes to (...)
Ottie: I disagree with Ami because, even though the skipper (...) something he wasn't actually forced by the wind to go back, he made a decision of whether to go back or not.
Ami: If it says the wind was blowing,
Courtney: The wind was blowing but it wasn't telling, it wasn't actually blowing him back in (...) shall I risk the ocean, so he got a choice.
Ami: Well because he's got to go back, otherwise, if it's a gale, like it says ]
Courtney: No he hasn't got to go back.

Transcript: from a small group discussion about a concept cartoon (David is one of the Talking Heads)

Lyndon: no, no if you put it on like, if you put it on somewhere and lifted it up, the string would be pulling on the ball as well as the thing
Courtney: well that's what you think.
Lauren: I had put not sure. Did you agree with David?
Jessica: I agreed with a baby because I think the string can't pull and then it's stopping the ball from falling.
Courtney: yes, I think that David is right. Simply because I think that the string is supporting the ball. Lyndon, what did you choose?
Lyndon: I put, I think David is wrong. I disagree with David, I think the string can pull.
Courtney: why did you think Carol was right?
Lyndon: because like, it sounds as if they are working together as, like, that is the string is holding it in one place, not like morning around the room, rather is keeping it upwards.
Courtney: did you all agree with box 1?

Transcript: from a small group discussion about practical work results

Courtney: it goes down (...) the weight, it goes down in the water.
Lyndon: why did you put it there?
Student:: that one, and that one, (they are looking at the table of results.) They are all going down in water.
Jessica: why does it go down, though?
Courtney: no idea.
Lyndon: because there's not as much gravity in the water (...)
Courtney: (...) say what you have just said, it’s interesting.
Jessica: it's interesting?!
Courtney: why do you think the weight varies, goes down in the water? Maybe it is because there is not as much gravity in the water.
Lyndon: there is no gravity in the water, there is gravity but not as much (...) that’s why when you dive, there is like a bit of gravity.
Annex 6: Realising the key features through specific teaching activities

The following three teaching activities are taken from the case study set out in nominated output 1. They are key activities from the teaching sequence and the analysis below shows how each of these activities was played out in terms of the key features of dialogic teaching of science.

Activity 1: Concept Cartoon: Bottle on Shelf

In nominated output 1 the image of a bottle on a shelf is used to focus attention on whether or not a shelf can provide an upward force on the bottle. In terms of the key features of dialogic teaching of science, the discussion proved to be very effective in the following ways:

1. Working on knowledge:
   a. enabled students to make their own ideas, understandings and questions explicit at appropriate points during a teaching sequence, particularly during the initial exploration of students’ views.
   c. involved juxtaposition of different points of view.

2. Communicative approach:
   b. supported an interactive/dialogic communicative approach

3. Teacher actions:
   a. teaching activities to address specific purposes.
   b. monitored and referred to students’ understandings.
   c. asked for reasons and justifications
   d. encouraged students to comment on each others’ points of view.
   f. allowed sufficient time, and adjusted the pace of lessons, for exploration of views to take place.
   g. created an encouraging and open working atmosphere.

4. Student engagement
   a. articulated their own points of view.
   b. referred and responded to the points of view of others.
   c. took extended turns in whole class and small group interactions.
   d. raised questions relevant to the developing subject matter.
   e. attended to whole class interactions even when not directly involved.

Activity 2: Teaching model: squashing the balloon

A balloon is used as a model by the teacher to persuade students that a table surface can push upwards. The discussion about the balloon proved to be effective in that it:

1. Working on knowledge:
   b. enabled the teacher to develop the scientific point of view.
   d. made links between explanations and events.
   e. temporal management of construction of knowledge

2. Communicative approach:
   a. supported an interactive/authoritative communicative approach
3. Teacher actions:
   a. addressed a specific teaching purpose.
   e. responded to students’ understandings.
   f. allowed sufficient time, and adjusted the pace of lessons, for exploration of views to take place.

4. Student engagement
   e. prompted students to attend to whole class interactions even when not directly involved.

Activity 3: Use of whiteboard: Where do the force arrows go?
The teacher resourced the next phase of the discussion by representing the forces involved on a whiteboard. This discussion proved to be effective in that it:

1. Working on knowledge:
   a. enabled students to make their own ideas, understandings and questions explicit at appropriate points during a teaching sequence.
   b. developed the scientific point of view.
   c. involved juxtaposition of different points of view.
   f. handed over responsibility to students in using and applying scientific ideas.

2. Communicative approach:
   a. supported an interactive/authoritative communicative approach
   b. supported an interactive/dialogic communicative approach

3. Teacher actions:
   a. organised teaching activities to address specific purposes.
   b. monitored and referred to students’ understandings.
   c. asked for reasons and justifications
   d. encouraged students to comment on each others’ points of view.
   e. responded to students’ understandings.
   f. allowed sufficient time, and adjusts the pace of lessons, for exploration of views to take place.
   g. created an encouraging and open working atmosphere.

4. Student engagement
   a. articulated their own points of view.
   b. referred and responded to the points of view of others.
   d. raised questions relevant to the developing subject matter.
   e. attended to whole class interactions even when not directly involved.

| Key features     | 1a | 1b | 1c | 1d | 1e | 1f | 2a | 2b | 3a | 3b | 3c | 3d | 3e | 3f | 3g | 4a | 4b | 4c | 4d | 4e |
|------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Concept cartoon  | ✓  | ✓  |    | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  |
| Balloon          | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  |
| Whiteboard       | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  |

Key feature coverage across activities
Annex 7: Learning/teaching pathway: Josie

Supplied as hard copy