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RESEARCH REPORT

Talk and learning in classroom science

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This paper examines what is important about talk between learners during school science and, having identified this, suggests how we can ensure that what we consider important happens. By looking at the interaction between teachers and learners talking about science, it is possible to indicate ways in which learners can be helped to continue this learning conversation with one another when teacher support is withdrawn. Strategies for teaching and learning are examined. The paper reports on the findings of a research project designed to teach children how to negotiate their ideas about science concepts through rational dialogue. Children's development of scientific concepts in classrooms is undertaken through structured activity and mediated through oral language. Children must move forward simultaneously in their use of specialized vocabulary and in their understanding of current scientific explanations, models and ideas. New language and new ways of using language are learned by doing, which means for children, primarily speaking and listening. Children's understanding of science can benefit from teaching them to understand that spoken language is a powerful tool for thinking together.

Introduction

Children arrive in school classrooms with a range of speaking and listening skills learned by social interaction. They have a unique vocabulary and understanding of words in use in different contexts developed through their experiences. As well as this variation in vocabulary, each child brings an individual conception of the world around them to school science. For teachers, the challenge is to find out what children think and to organize ways of helping them to question their own ideas and those of others, extending and clarifying uses of words at the same time.

Primary science teachers have found great value in eliciting children's ideas (Monk and Osbourne 2000, Scott 1998, Sutton 1992). Children may hold a range of misconceptions and partial understandings. Opportunities to identify and articulate what they already think directly benefits children's development in science (Gibbons 2001). Children also benefit indirectly from such learning conversations. They may usefully gain an awareness of the value of reflection, and can be encouraged to develop a capacity to question their own thoughts and those of others.

Children working in groups can learn from one another. Collaborative learning is, at best, not simply a transmission of information – especially since such information may not be well founded or accurate – but engagement in dialogue in which children have the confidence to carry on the sort of supportive, questioning discussion they experience when working with a teacher. Children learning science in schools simultaneously experience learning in many areas. They can learn how to

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enquire, reason, to consider evidence and information, to make deductions, to share and negotiate their ideas with others, and to make decisions. Teachers can further help children to do this by raising their awareness of speaking and listening as a tool for thinking together, and of internal dialogue as a way to think more clearly alone.

School science and spoken language

Children bring to their school learning of science the powerful tools of language and previous understanding. The science they 'know' and the language with which they communicate this are inextricably linked. They may be familiar with using talk to ask questions, describe, explain, convey information, evaluate and make predictions; all of which are features of science discourse. When we as teachers ask them to explain their ideas about the world, what they think is created and presented for us to hear in words. Children's conceptions may be firmly or tenuously held. Either way, the chance to talk about them can provide stimulus to question what is said. Focused and significant practical experience can then provide alternative evidence around which to reconstruct meanings.

For young learners, there is the hurdle of scientific vocabulary. Words like 'condensation' and 'evaporation' when first encountered may be so rarely heard that they are difficult to retain and recall. Words like 'arachnid' made ambient by the media may be more easily assimilated. Words used colloquially may generate misunderstanding; for example, 'the greenhouse effect' is commonly reported as a modern phenomenon threatening the planet with global warming; however, life on earth would not have arisen without it. A related problem is that of learning new uses for familiar words. For example, 'force' to a child may be synonymous with aggression: 'dark' may be a colour tone: 'north pole' may be where there are polar bears. Sutton (1992) points out that even when carefully defined for the purposes of science learning,

> The meaning of words varies from person to person as well as from context to context [. . .] there is always a fuzziness at the edges, and that is an asset, not an imperfection. (p. 63)

Sutton goes on to show how exploring the use of words like 'energy' and 'power' (for example) allow insight into what shade of meaning of the word best conveys understanding of the science concept under discussion. In classrooms, discussing vocabulary allows the private meanings held by children to be made public, so that the class can work towards a common understanding.

Once the starting point of the learner is evident, teaching science is to do with ensuring that observations and the ideas they generate are subject to enquiry. That is, children's 'why?' questions are focused into queries that can be speculated about and investigated to generate answers and further questions. The understanding of science concepts is tied up in words, with which we define, explain, build models and employ metaphor to convey our current thinking about the world around us. Working with young learners involves using children's speaking and listening skills as the basis for development of understanding. Gibbons (2001) advocates arranging for children to be able to generate:

> stretches of discourse in contexts where there is a 'press' on their linguistic resources, and where for the benefit of the listener they must focus not only on what they wish to say but on how they are saying it. (p. 260)

This interesting scenario implies a way in to learning through dialogue *between children*. The importance of talk between teachers and learners in classrooms has long been recognized (Barnes 1976, Edwards and Mercer 1987, Mercer 1995). The importance of talk between children is also well documented (for example, Bennett and Dunne 1992, Kutnick and Rogers 1994). The difficulty for teachers lies in ensuring that children can engage in 'stretches of discourse' about concepts and thoughts that are new and unfamiliar to them, in which their grasp of vocabulary is fuzzy, with others at the same 'newcomer' stage of competence.

The relationship between thinking and collaborative talk is emphasized by, for example, Joiner, Littleton, Faulkener and Miell (2000) and Rogoff (1990), and crucial aspects of collaborative talk specifically in the science classroom by, for example, Driver (1991), Rix and Chantrelle (1997), Selley (1999), Sherrington (1998), Adey and Shayer (1994), and the SPACE (1992) research reports.

This paper sets out to look at what happens between teachers and learners talking about science, and to indicate ways in which learners can be helped to continue their invaluable dialogue when teacher support is withdrawn. The following sections deal with:

- children's ideas about science;
- what it is that science teachers do;
- what happens when groups of children work together;
- what group talk best supports science learning; and
- how we might create conditions in which this sort of talk happens.

To support the discussion, findings from a classroom research project are included. This is the Thinking Together project, established with the aid of the Nuffield foundation to investigate whether teaching children ways to talk together could raise achievement in science and mathematics at Key Stage 2. Further information on this project can be found in Dawes (2001) and Mercer et al. (1999).

Children's ideas about science

Children hold spontaneous concepts about the way things work. Detailed accounts of typical 'alternative conceptions' (Leach and Scott 1995: 45) have been compiled. The examples in this paper have been collected by Year 2 Bachelor of Education students at De Montfort University (2002) working with children aged 5–7 to elicit their ideas. If misunderstandings remain unchallenged they may hamper the child's learning, creating confusion and interfering with new ideas. There are three sorts of misunderstandings, each of which requires a slightly different teaching approach to support the child's development.

i. Misconceptions. Example: How are shadows formed?
The light is so bright that your body reflects it back and makes the shadow.
Generated by observation and imagination, the child's concept may account for or describe their personal experience.

ii Partial understandings. Example: Why will a sponge float?
Light things that are full of air float.
Generated by observation and experience, the child's concept may account for some situations but may not be generalizable.

iii Alternative word meanings. Example: Can you describe what we mean by force?
Force is strong.
The child's conception of a word's range of meanings may be limited or confused. Word meanings are generated by social interaction. New uses of everyday words may be difficult for learners to accommodate.

Misconceptions, generated in childhood, may last a lifetime, even when alternative rational explanations are understood and accepted. For example, personal observation continues to convince me that the moon is bigger when it is near the horizon – 'nearer' to the earth – although I am aware that this is actually not the case. It is not difficult to understand how misconceptions occur and are reinforced. The speed at which a ceiling bulb lights up when turned on at a wall switch creates the idea that electricity moves extremely rapidly, although it actually moves at a snail's pace. Such misconceptions may be unimportant on a daily basis, but for the scientist, the teacher of science, and the child learning science, what is known must be constantly open to question. Concepts are never proven, but always subject to investigation and verification. Science is to do with enquiry. Scott (1997) has developed a framework identifying forms of pedagogical intervention in science classrooms, to show how teachers direct and sustain interactions through a 'Teaching Narrative'. The purpose of the Teaching Narrative, through the medium of talk is to develop scientific knowledge, support meaning making by individuals, and promote continuity between learning conversations across time. Children's talk is contained and made significant within the narrative. In classrooms of rarely less than 20 children, the teacher works with the children to present ideas, ask questions, share findings and new ideas, and consolidate new uses of familiar and unfamiliar words. Such processes lead children from spontaneous concepts to taught concepts which themselves are open to enquiry.

Talk is the medium of preparing children for, and generating, new understandings. Teacher talk is designed to support learning. This paper goes on to consider how well children can support one another's learning in science through talk. There are problems. Children's newly conceived ideas and uncertain conceptions of words use are shaky foundations for learning conversations. Group work may be very difficult for children faced with having to articulate personal ideas to a not especially supportive audience. Insecurity can be a barrier preventing some children speaking at all, while others talk not of science but irrelevancies.

Talk in a whole class setting

This section considers links between two different kinds of teacher intervention: scaffolding, and initiation–response–follow-up (IRF) exchanges.

Scaffolding

The metaphor of 'scaffolding' was introduced by Wood et al. (1976) in order to identify what happens when a teacher works with learners attempting a task that initially seems beyond them. With the support or scaffolding of the teacher, learners can move through achievable stages to complete a task, and may then be able to complete a similar task unaided. The teacher assists, ensuring that the learner engages with one thing at once, most often through talk. Scaffolding happens when the teacher 'serves the learner as a vicarious form of consciousness' (Bruner 1985: 24); that is, the teacher's words support the learner's thoughts and actions. This process seems to help the learner create a pattern of thinking for future use. It is most often reported in interactions of teachers and individual children (Scott 1998: 69) presumably because it is a very subtle process, requiring a knowledge of the learner's state of readiness to learn or zone of proximal development (Vygotsky 1962). Successful scaffolding is a joint achievement for teachers and learners. True scaffolding requires a concentration on probing the personal meanings of words, ideas and opinions, and the underlying reasons for meaning generated by individual experience.

Initiation–response–follow-up exchanges

The sort of 'already-known answer' questions that teachers ask are a distinctive feature of classroom interaction. The IRF structure (Sinclair and Coulthard 1975) has become widely accepted as 'the essential teaching exchange' (Edwards and Westgate 1994: 143). Historically it has been much criticized by researchers observing classroom talk. Criticism, for example, includes the belief that IRF exchanges:

- inhibit children working out meanings for themselves;
- reduce children's level of competence in spoken language;
- limit the possibilities for discussion;
- treat pupils as subordinate;
- ensure that teachers to claim all knowledge; and
- promote a cat-and-mouse guessing game in which children are easily caught out (Edwards and Westgate 1994, Fisher 1992, Wells 1986).

An understanding of classroom talk requires a re-examination of these claims, in which it is evident that the primary function of IRF sequences has long been misunderstood. Perhaps the basis for the profound misunderstanding of IRF as a teaching method lies in an endemic negative attitude to teachers – what Cuban (1986) calls 'teacher bashing': and in the consequent misperception of the teacher's purpose:

> Most teachers' questions are intended to find out whether the pupil questioned knows what the questioner clearly knows already. (Edwards and Westgate 1994: 40)

Teachers actually use IRF exchanges for a range of purposes, such as to check for understanding and elicit misconceptions. Gibbons (2001: 267), for example, details an interesting IRF variant that she calls 'Teacher-guided reporting'. She says:

> The teacher's role is crucial [. . .] her interactions with individual students provide a 'scaffold' for their attempts, allowing for communication to proceed while giving the learner access to new linguistic data [. . .] teacher-guided reporting encourages learner language to be *pushed*. (Gibbons 2001: 267)

To illustrate the point that research looks harshly at teachers and in doing so misunderstands the primary purpose of teacher talk, we can consider a passage in which Wells provides a transcript and his commentary on an IRF exchange. A child, Lee, brings a conker to show his teacher. After nine exchanges, the teacher asks Lee to identify the type of tree it will grow into and Lee provides the answer horse chestnut. Wells says:

> Lee's topic is appropriated by the teacher as she imposes her perspective as the basis for her questions – questions to which she, of course already knows the answers. Under the constraints that she thus imposes, Lee's utterances decrease [. . .] he is reduced to providing a simple labelling response to a question on a topic that he hadn't wanted to talk about. (1986: 88)

But Lee did want to talk about his find: he initiated the exchange. He is supported in what he wants to say. That the teacher already knows the answers to her questions does not mean that she is asking them to impose her perspective. She is providing the child with a context in which he can talk about the conker, knowing that she is interested in his ideas. Lee is further assisted in his thinking by being reminded to associate his conker with its parent tree to which he is asked to put a name. The 'simple labelling response' dismissed here at some sort of self-indulgent triviality on the teacher's part is actually of great value to the child. Sharing the words 'horse chestnut' allows the conception of conker as seed of the tree to be consolidated. Naming the tree is an important step. 'Communication about words within schooling leads to the development of scientific concepts by the individual' (Daniels 2001: 51). Daniels bases this on the idea that 'The concept is not possible without the word' (Vygotsky 1962). Teachers use IRF exchanges as mechanism for reaching and developing the child's thoughts.

Teachers are also permanently aware that they learn from the children they talk to. Schon's (1987) labelling of teachers as 'reflective practitioners' did not call such creatures into being, but described what was already the case.

The crucial importance of IRF exchanges – why teachers use them – is that their primary purpose is to encourage learners to talk to one another about the topic they are studying. It is extremely important that this happens, but equally, extremely hard to arrange or make happen. As we have noted in science, new learning may be difficult to comprehend; new ideas hard to conceptualize, especially when vocabulary is unfamiliar. Much of what the child learns in classrooms may never be mentioned anywhere else (through no fault of the child, the teacher or the home). For consolidated learning and development to take place, it is essential that the child articulates what they are thinking. Teacher-led whole class IRF conversations ensure that children explain their ideas, hear the explanations of others, use new words, refer to previous contributions of other children, share comments and information, and generally talk and think together about the learning topic. Left to themselves, children may find it hard to follow a line of reasoning, or work through a problem to achieve understanding. Whole class IRF talk in science can be purposeful, informative and based on the children's ideas that benefit from re-phrasing or elaboration. The function of the teacher is to create a classroom community of discourse to help the children talk about what they think they know. IRF provides a tool for the creation of common knowledge. Its function is not to gratify the teacher by confirming what she already knows – which would be utterly pointless – but to promote and mediate children's learning conversations with one another.

If we now consider these two teacher strategies, scaffolding of learners and IRF exchanges, we can identify what teachers hope will happen when they group children to work together. IRF allows whole classes to talk together, and is a sort of large-scale scaffolding. Teachers faced with 30 or so pupils must try through talk to locate the children within a whole class zone of proximal development, using IRF to engage them in working through small steps of interchange towards a common understanding. This has its merits, but may not adequately address individual misconceptions and variations in thinking. That depends on personal exchange. Therefore, children are asked to work in groups to discuss their science together, with the aim that they will engage in the same sort of productive talk they generate when talking as a class with their teacher. Small groups working on the same investigation, discussing their findings or planning a fair test, can be expected to work within a group zone of proximal development so that all can move forward in their understanding. The next section looks at what actually happens.

What happens when groups of children work together

The potential for group work is that it will allow learners the opportunity to talk to one another and scaffold one another's learning.

Two problems that arise in science group work are as follows:

(a) In groups where all learners are new to understanding the topic in question, the science that is known and the language used are dangerously unfamiliar. Talk is difficult. 'Stretches of discourse' may not happen.

(b) Learners are not teachers, and may not understand the need to provide the smaller steps required to help someone else develop their thinking. They may not know how to provide the 'sensitive intervention' that Mercer (1995) says is necessary for true scaffolding. They are more likely simply to provide the solution to a problem rather than break the puzzle down into manageable bits to assist others.

Yet learners are often asked to work and talk together in science. But group work can be very taxing (Galton and Williamson 1992). Disheartened children at the limits of their understanding may unfortunately lose heart and revert to talking about something less demanding than science, and learning falls away. Considering peer groups using ICT, Crook (1994) says:

> My own observations of children working together [. . .] suggests that the motivation to co-ordinate cannot be taken for granted. Sometimes, the demand to convene collaborative relationships for exploring some knowledge or other can be experienced too much as just that – a demand [. . .] – these experiences can become irritating and unproductive. (1994: 30)

We cannot dismiss dysfunctional groups as a consequence of behaviour problems in young people. The problem is that the social demands of the situation are too high. Even if children do try to assist one another they may have very little idea of how support may be achieved.

So the teacher's aims in grouping children, to provide them with collaborative partners and opportunities for discussion, may be unfulfilled in practice. Kutnick and Rogers (1994) identify 'drawbacks' of groups and specify a range of 'needs':

- classroom time is needed to develop group skills;
- pupils need time to learn how to work co-operatively;
- teachers need to encourage groups rather than individuals;
- teachers need to assign group tasks; and
- groups need to be carefully structured.

When grouping is simply a seating arrangement, Kutnick and Rogers report the range of problems that arises: children become 'freeloaders' or 'suckers', or gang up on others; rejection and domination create argument; there is polarization between boys, girls, and those of different ability; 'classroom isolates' will be rejected; children talk out of turn, hinder others, are slow, idle, untidy or move out of their seats to disturb other pupils and the teacher (Kutnick and Rogers 1994: 31).

A far cry from the high ideal that children will talk together and, in so doing, jointly construct meaning and understanding. We can note that some researchers seem as fiercely judgemental about children as they are about teachers, and speculate whether this affects their perception of what is happening in classrooms. But if we look behind the pejorative language what we see is children exhibiting distress and anxiety. They seem to have no idea why they are grouped together, or what they or their peers may gain from such an arrangement. Even if they do understand some of why they are expected to work together, they have no sensible strategies for speaking and listening to one another. Children may possess the tools of language, but have not yet learned how to wield them to good effect once adult support is withdrawn. The educational effectiveness of group work depends entirely on communication, but communication in groups is at the mercy of the social interaction between its members. Vygotsky says 'Absolutely everything in the behaviour of the child is merged and rooted in social relations' (Daniels 2001: 18); with no joint conception of why and how to talk to one another to good purpose (educationally speaking), children display their confusion and learning stops.

What group talk best supports science learning?

Science activities are invaluable in helping children to visualize and otherwise experience phenomena that will contribute to their developing understanding of concepts. However, making sense of activities requires engagement with others through talk in order to draw out the significance of the activity or enquiry.

In classroom situations, children are developing an understanding of science concurrently with developing an understanding of language. The sort of language tools used in science are, for example, questioning, explaining, putting things clearly, repeating or rephrasing, predicting, reasoning, evaluating, deciding. But the child's linguistic toolkit may not be so extensive or developed. In addition, children may be completely unaware of the potential power of talk with their peers. They may never have considered talk; they may need to be helped to pay attention to what and how they speak to one another, to become members of what Goodwin (2001) calls 'the articulate classroom'. In doing so, they may come to value what productive talk can do for themselves and for their classmates.

Even when the idea behind group talk is made explicit – 'talk together to decide', 'discuss this in your groups' – there may be no real understanding of how to talk together, or how to discuss things. If we can extend the metaphor of language as a psychological tool for thinking, then we can say that the tools for group discussion do not have good affordance for children. They are not aware that questions such as 'why?' and 'how?' afford the discussion that may help them to share their thoughts. They may require direct teaching of which tools to select to ensure productive interthinking. 'Learners must first "learn" language before they can "use" it' (Gibbons 2001: 267).

How we might create conditions in which this sort of talk happens

As part of the Nuffield Thinking Together project, we taught classes of children how to talk to one another in groups. We provided a core of talk skills lessons that enabled classes of children to generate and agree to use 'ground rules' for Exploratory Talk. What we were concerned with was teaching strategies that, if implemented, could result in educationally effective talk that best supports science learning. As defined by Mercer (1995), Exploratory Talk is talk in which:

- All relevant information is shared.
- All members of the group are invited to contribute to the discussion.
- Opinions and ideas are respected and considered.
- Everyone is asked to make their reasons clear.
- Challenges and alternatives are made explicit and are negotiated.
- The group seeks to reach agreement before taking a decision or acting.

As adults we may easily be able to pick out, understand and therefore use the crucial language activities necessary for exploratory talk. For experienced speakers and listeners with an awareness of the importance of joint thinking, the necessary language tools have good affordance. They can be identified. This means that they can be directly taught to children. Unless this happens, it is unfortunately the case that whether group work helps children to understand science is at the mercy of chance. Conversely, if children are provided with ways in to understanding the power of productive talk, they are rapidly enabled to assist themselves to learn. They can request and expect the support of peers to assist them as a 'vicarious form of consciousness'; that is, they can have their talk skills and their understanding of science simultaneously scaffolded by their group mates. They can be in the position of experiencing pupil-guided reporting – a favourable position for generating new conceptions. They can also expect to offer direct benefit to others as they listen, ask sensitive and careful questions, listen for reasons, and articulate their response to the discussion. Whole class IRF is no longer the only chance they will have to use new words and explore lines of reasoning with sympathetic assistance.

Group members are unlikely to begin a science activity and discussion with identical conceptions of the world around them. To learn to enquire systematically and agree on a joint conception is learning science. However, they can begin their activity and discussion with identical conceptions of themselves as speakers and listeners – expert wielders of the tools of Exploratory Talk. In this way, group work is not a risk.

We identified the following as essential language tools and indicator words.

1. Talk awareness. The teacher must be explicit about the high value of group talk. All participants must be aware that the quality of their speaking and listening is of utmost importance. They must understand that the aims for talk and the aims for science learning are of equal status.
   Indicator words: 'Let's talk about this', 'Now we should discuss our ideas', 'Right – who wants to go first?'.
2. Key questions and reasoning. Simple strategies allow group members access to one another's thinking. The key questions, 'what do you think?'

followed by 'why do you think that?', if honestly employed by the group, allow everyone to pool their ideas and the reasons behind them.
Indicator words: 'What do you think?', 'Why do you think that?', 'Because . . .' 'If . . .', 'I think . . .', 'Do you agree?', 'We need your opinion', 'Your reason is?'.

3. Active listening. Listening is not an observer's role, but an open-minded absorption of new information, which must be thoughtfully considered and weighed against what is already known. Active listening in a group involves experiencing new ideas and words, formulating and remembering a response, and articulating these thoughts within the group's rules for taking turns.
Indicator words: 'Go on . . .', 'Please say that again', 'What?', 'Can I say . . .'.
4. Joint decision-making. The group must act as a unit in its decision-making, so that any subsequent problems or successes are shared.
Indicator words: 'Do we all agree?', 'Shall we do that?', 'Have we decided?'.

In teaching Exploratory Talk and providing science contexts for its use, we hoped to help individual learners to 'make sense of the talk which surrounds them, and in doing so, relate it to their existing ideas and ways of thinking' (Leach and Scott 1995: 44). We organized contexts in which the children's minds could be attuned through understanding how to talk to one another. That is, we created conditions for educationally effective interthinking;

> the joint, co-ordinated intellectual activity which people regularly accomplish using language. (Mercer 2000: 16)

The next section details some of the Thinking Together project research findings and the implications for the teaching and learning of science.

Research findings: science speaking and listening

We recorded groups of children talking together during their science and mathematics work in classrooms. Some of the sessions involved using computers. We recorded children who had worked through the Thinking Together talk lessons, and other control groups who had not. Findings from previous studies led us to predict that children could raise their attainment not just through learning about curriculum areas, but by learning how to talk and think together (Mercer et al. 1999). The project collected a range of qualitative data including video and audio recordings, interviews with teachers and children, and children's written work. Quantitative data included, for example, collecting pre-intervention and post-intervention scores from non-verbal reasoning tests for groups and individual children. All recordings were transcribed for analysis; for example, to identify and quantify incidence of indicator words. The transcript exerts presented are used to illustrate points that arose from the data we collected and our analysis of it.

In Transcript 1, 'Blocking out sound', a group of three talk-trained children aged 9 and 10 years are working together at a computer. The software (Granada Science Explorer) provides scenarios that can be used to conduct investigations. In parallel, the children use the Thinking Together's Talk Bug software that prompts them to discuss what they are thinking – to engage in Exploratory Talk. In this section the children have been asked to predict which of 10 materials would be most effective at blocking out sound. Indicator words are italicized.

Transcript 1. Blocking out sound

Sandra:	Um. *Can you* hear sound through wood? [Points to wood on list]
Brad:	*I think* – What?
Sandra:	*Can you* hear sound through wood?
Brad:	I imagine you can, *but I think* that–
Kylie:	*How about* glass? [Points to glass on list]
Brad:	No – not glass, *because* of the vibrations. [Gestures to indicate shaking]
Sandra:	From cloth you can.
Kylie:	Yeah, *but* they haven't got cloth here.
Brad:	– vibrations – metal *because* it can't vibrate and – and it's really strong.
Kylie:	[To Sandra] It *is* strong isn't it? [Sandra nods] O.K. Metal.

[The group predicts that metal will be the most effective insulator to block out high-pitched sound. They run the investigation and discover that cork is actually more effective. The computer asks them to say why their prediction was wrong]

Brad:	So *why* do we think it's wrong?
Kylie:	Well, *because*, um–
Sandra:	*Why do* [inaudible]
Brad:	*Because* it's – er–
Kylie:	*Because* it's got a
Brad:	*I know* it's really strong, unless it's tin foil.
Sandra:	Doesn't vibrate.
Brad:	Yes. It doesn't vibrate so easily.
Sandra:	[Inaudible] . . . *Talk about it.*
Computer:	Click on continue when you have agreed on the reasons.
Sandra:	We have – *we've agreed* it.
Brad:	[Inaudible] I don't know?
Sandra:	*Because* it's the lowest.
Brad:	*Why* is it the quietest? *Why* is it–
Sandra:	*Because* you can hear – you can't hear the sound . . .

[The teacher intervenes and asks the group to consider which materials are more compact, and what effect this might have on the conduction of sound]

Comment. The group sets off to accomplish two tasks: to talk together effectively and to use their new understanding of the science concept of vibration creating sound.

The high incidence of indicator words shows that they achieve their aims for talk. This is not perfect exploratory talk – these are newcomers to this practice – but it is inclusive and reasoned, information is shared, and joint agreement is sought. Brad's suggestion of 'metal' as a good sound insulator is considered by the others and accepted. Once they have tested the materials and discover that this is not the right answer they continue to question one another in a brave attempt to understand the problem they encounter, even when all seem to have run out of new ideas.

As for science, we can see some success in the first half of the transcript where Brad recalls and introduces the vocabulary item and concept of vibration. He then suggests that metal, which he describes as 'strong', will not vibrate. This is completely reasonable in the light of the children's recent experience, which was to observe and touch the resonating stretched strings of a violin. The instrument was used by the teacher to make vibration visible (therefore more real and understandable) as well as audible. The children have formed the concept that the physical movement of the string, vibration, is 'why' there is sound. Brad thinks of metal as strong, and cannot envisage the visible motion that he thinks must take place in order for sound to be carried. Ironically, violin strings are made of metal.

The shared misconception is that thin, flexible materials are necessary for vibration and that 'strong' (hard, rigid) materials will not vibrate, therefore making good insulators. The children have no conception of vibration at the level of particles, or how density affects sound transmission. Thus their erroneous prediction, and their inability to resolve the puzzle together. By listening to this conversation, the teacher can identify the point at which the children's conceptions falter, and intervene.

The group seems determined to solve the problem through talk. At this point, their questions could be shaped to generate further enquiry. They may also need to consider differences between materials that can produce sound, and those that can transmit sound. It is possible to conclude that little science is learned, if 'science' is considered to be the knowledge of facts; however, the process of questioning, prediction, investigating, evaluating findings and posing further questions is very evident here. Science as enquiry can be seen to be happening. Subsequent whole class plenary work can help children to gain a better understanding of the physical world from their peers and the teacher.

Transcript 2, 'Blocking out light', involves a second talk trained group of three children from a different school, working on the section of the Granada Science Explorer program to do with light. The problem is to select which type of paper, and the least number of sheets, to block out light. The numbers in the text indicate points that will be brought out in the commentary.

Transcript 2. Blocking out light

The group predicts how many sheets of paper will block light completely.

Alana:	*I think*, one, *because* black paper – same as I said before – dark and solid.
Ross:	*How much*? How much paper?
Alana:	*I think* one.
Ross:	No, two, two. *I think* about five.
Alana:	*What*? To block out the light completely?
Ross:	But that's 'Bright' (pointing to the 'light meter') – it goes up to 'Bright'.
Dijek:	Ten – ten. [He holds up all of his fingers]
Ross:	Ten – or a five.

Dijek: Ten.
Alana: *I think one, because* it's dark–
Ross: It's not that dark.
Alana: Dark, it's solid and *I don't think* anything would get past it.
Dijek [1]: No – ten would be much better.
Ross: Shh – stop arguing OK, or we can't continue.
Alana: I just want to say this. It's not about – how solid–
– what's much better – it's about using your–
Ross & Alana: Brains!
Alana: – to think. So *what do you think*?
Dijek: Um I say–
Alana: – least number?
Dijek: One.
Alana: *Do you agree*?
Ross: *I agree*.

[The group sets up the test for this prediction]

Ross: OK. So – [Clicks 'on']
Dijek: No! ([That is, no light: children clap their hands]
Alana: We got it right.
Dijek: Black paper.
Ross: Yes!

[The group test other sorts of paper, then are asked to plan an investigation]

Ross: OK. *Talk together* about a plan to test all the different types of paper.
Alana: Dijek, *how much did you think* it would be for tissue paper?
Dijek: At least ten *because* tissue paper is thin. Tissue paper can wear out and you can see through, other people in the way, and light can shine in it.
Alana: OK. Thanks.
Ross: *Because* I tested it before.
Alana: [To Ross] Why do you think it?
Ross: *Because* I tested it before!
Alana [2]: No, Ross, *what did you think? How much* did you think? Tissue paper. *How much* tissue paper did you think it would be to block out the light?
Ross: At first I thought it would be five, but second–
Alana: *Why did you think that*?
Ross: *Because* when it was in the overhead projector you could see a little bit of it, but not all of it, *so I thought* it would be like, five to block out the light.
Alana [3]: *That's a good reason. I thought* – I thought it would be between five and seven *because*, I thought it would be between five and seven because normally when you're at home if you lay it on top, with one sheet you can see through *but* if you lay on about five or six pieces on top you can't see through. So *that's why* I was thinking about five or six.

Comment. First, the talk. As in Transcript 1, in terms of number of turns the children take almost equal turns. They invite one another to make suggestions, and ask for reasons, which are given. They use the word 'think' frequently, indicating that they are aware of the importance of making their thoughts explicit to one another. Alana's talk shows that she is very consciously using the 'formula' she was taught would help her to find out what her group mates think: What do you think? Why do you think that? She obviously finds it useful. Eventually she may assimilate this way of questioning better and overlay it with her own personal style of asking, but since the talk lessons are very much at the front of her mind, she is for now using the exact words she has practised. She expects the other group members to understand what she is asking, and they do. They too have agreed that one of the 'ground rules' for talking in a group is that you can expect to ask and answer such questions. They provide reasons and seek to reach agreement, and are gratified as a group when they are successful.

[1] At this point, Dijek's contribution is evaluated by Alana. It's interesting to speculate how such an exchange might be interpreted if looking at the evaluations of group work that Kutnick summarizes. Is Dijek a 'freeloader' and Alana 'dominant'? Dijek has suggested 'ten' three times without offering a reason. But we see Alana clarifying the aim of their talk as not to do with guess work but to do with thinking together, and offering him the opportunity to try again to say what he thinks, supporting him by reminding him that he must consider the least number of sheets that might block the light. These three children are not close friends; the way Alana approaches Dijek might be considered rather daring; perhaps confrontational. But the children know about productive talk. Dijek recognizes the reminder for what it is: sensitive intervention, or scaffolding. In this, as in most, classes, there is a wide range of ability and aptitude, not just in mathematics and science but in the ability to recall and implement talk skills. Dijek is here offered assistance.

[2] Alana will not accept a spurious reason. She is sure that Ross can be more thoughtful. He shows that this is so. In this transcript we can also discern an IRF structure, and can see this exchange as an example of what Gibbons calls 'stretches of discourse'. This high-quality talk is what teachers hope will happen when groups work together.

Next, the science. The children draw on their everyday experience of sorts of paper to make their predictions. Each has something to offer in terms of information and reasoning:

Alana:	Black paper is 'solid'. Five or six sheets of tissue might be opaque.
Dijek:	Tissue paper is thin and transparent; light 'shines in it'.
Ross:	Things can be seen through tissue paper if lit from behind.

They do not use scientific vocabulary (opaque, transparent), finding their own ways of expressing their concepts. They might benefit from experiencing and understanding uses of these terms. As in Transcript 1, the work is conducted in a spirit of enquiry. Within the limits of the activity, they are discussing science.

Transcript 3, 'Blocking out sound', involves three children working on the same programme as the children in Transcript 1. This group's teacher did not approach the talk lessons programme with any enthusiasm. The transcript has been selected as typical of the exchanges of groups with little or no talk training. There are no indicator words.

Transcript 3. Control group, blocking out sound

Hannah: [Reads] 'Keep it Quiet. Which material is the best insulation? Click "measure" to take a sound reading. Does the pitch make a difference?'
Darryl: No we don't want clothes. See what one it is then. [Points to screen]
Hannah: No it's cloth.
Darryl: Oh it's cloth.
Hannah: Go down. This is better when Stephanie's in our group.
Darryl: Metal?
Hannah: Right try it.
Deborah: Try what? That?
Hannah: Try 'glass'
Darryl: Yeah.
Deborah: No one.
Hannah: Now–
Darryl: Measure.
Hannah: Now measure. Hold. [Turns volume control dial below screen]
Darryl: Results, notes.
Hannah: Results. We need to go on a different one now. Results.
Darryl: Yeah, you need to go there so you can write everything down.
Hannah: I'm not writing.
Deborah: Results. [Leans across to operate the mouse]
Hannah: OK, alright. That's fine – that's fine. Now take it off. Take it off.
Deborah: Oh no Darryl
Hannah: Back – back. Right.
Darryl: My turn
Hannah: Ohh – I haven't had a turn.
Darryl: Deb – oh, your turn then.
Deborah: Hannah's. [Hannah takes the mouse. Deborah picks up a pencil]
Hannah: I choose which materials we go on – measure.
Results 0.7. Right write – write 'glass'. [Points to screen]
Darryl: Write 'glass' [Points to screen. Deborah writes]
Hannah: 0.7. Cork 0.6 C.O.R.K. 0.6. Right let's try–
Deborah: It's someone else's turn.
Darryl: It's my turn [Darryl takes the mouse]
Hannah: We've done glass haven't we?
Deborah & Darryl: Yes
Darryl: It's my turn. We done that.
Deborah: Yeah.
Hannah: We've just done the cork.

Comment. The talk continues in this staccato manner for a further 28 exchanges, after which the group have guessed and tried all the options; they are working through the program as if it were a computer game. The results are inconsequential.

The talk is to do with guesswork; that is, prediction with no explicit reason to back it up. Its main subject matter is repeating the text on the screen and organizing turn taking. There is no talk awareness; questions are brief and not thought provoking; the children become distracted from speaking and listening by having to write things down, and by their concentration on the equipment; there is no indication of sharing information, exploring ideas, or joint decision-making. There is tension within the group as they compete for turns. The talk proceeds in an unstructured, aimless way. The group are 'on task' and produce a written list of results, but they have discussed no science, and have not developed their collaborative skills.

Further findings and some implications

In addition to this observational evidence we have some quantitative evidence that exploratory talk exchanges generated measurable learning in the science curriculum. Both experimental and control classes undertook a test of scientific understanding in the topics covered in Year 5 of the UK National Curriculum, at the beginning and at the end of the school year. Most of the questions were taken from optional Standard Assessment Task tests published by the UK government, with supplementary questions that we designed to probe more conceptual understanding. An analysis of co-variance revealed that the experimental classes improved their scores more than the control classes. This result was highly significant (p = 0.000). When we considered the Standard Assessment Task questions alone the statistical difference between the experimental and the control classes remained very significant (p = 0.013). The statistical evidence therefore suggests that the kind of exchange generated by the children in our focus groups, exemplified in Transcripts 1 and 2, led to measurable learning gains in science.

Implications of the Nuffield Thinking Together research for teaching and learning are:

- Attainment in science is not entirely a function of understanding given concepts. There is also an aspect of thinking concepts through and knowing how to question personal ideas, opinions and assertions and those of others.
- Science understanding and knowledge can usefully be rehearsed, questioned and even generated within groups of children who understand what they are doing with talk.

Discussion and conclusions

Children approach school science with an everyday understanding of how things work, which is sometimes based on little evidence and on much imagination. Without wishing to undervalue this – imagination should definitely be fostered, after all – school science must address the child's entitlement to learn. Teaching and learning involves organizing an approach based on science as enquiry; that is, science as a way of thinking in which what is 'known' is always open to question. Science as enquiry involves encouraging children to find ways to verify or establish a joint understanding, based on creating the conditions where what happens can be observed, or can be clearly visualized, noticed or recorded. School science positions children as newcomers in the community of practice of those enquiring about the world around us. As newcomers, children can be invited to describe their spontaneous conceptions about various phenomena; for example, how the seasons occur, or why things float or sink. Their subsequent development of scientific concepts is undertaken through structured activity and mediated through oral language. Children must move forward simultaneously in their use of specialized vocabulary and way of thinking, and in their understanding of current scientific explanations, models and ideas. New language and new ways of using language are learned by doing, which means for children, primarily speaking and listening, with science as a context.

Teachers use IRF strategies with many intentions, but with a principle aim of promoting whole class discussion. Learning is a social process. Teachers organize classrooms to try to bring large groups of children to the same conceptual starting place and use IRF to agree with them a common understanding, even if that turns out to be ephemeral. Generating common thought may sound an impossible task. But talk (and other psychological tools like music) can have minds not thinking the same thing, but similarly oriented, as magnets attune iron filings. Scaffolding usually addresses more individual needs. Teachers provide opportunities for children to talk to one another about their science. This allows crucial practice in the use of new vocabulary in context. Even more importantly, group talk can help learners to exchange ideas, to have access to different perspectives and to make meaning together. However, this may not happen if groups of children remain unaware of talk as a tool for thinking together.

Talk skills – the language tools essential to initiate and sustain Exploratory Talk – are both identifiable and teachable. Children can have pointed out to them strategies that will help them to find out what their peers think, and why. They may then come to understand that this has great value for the achievement of the group, which can do better in collaboration than each child might do alone: and for themselves, as they engage in stretches of discourse in which their peers provide focused supportive assistance. Talk-trained children can scaffold one another's learning, not by chance, but by intent. The exemplar transcripts provided in this paper demonstrate this happening.

The benefits of Exploratory Talk for group members in science is that they are enabled to grapple with concepts and generate new 'why?' questions when they reach the limits of their understanding. But, if we consider talk as 'natural' to children, learned from others by assimilation, we might feel some anxiety that Exploratory Talk is somehow 'manufactured' and that teaching children how to do it is too prescriptive. We may believe that children should generate their own talk strategies. However, talk skills are simply conceptions, there to be learned in any way possible, like anything else. Learning effective talk is a critical aspect of becoming educated. Perhaps we might consider natural talk as metal ore, and taught Exploratory Talk as refined metal, available once discovered to make things with and do things with. Each individual child should not have to make the discovery for themselves. We can move our children towards achieving their potential in science by teaching them what they can do with words.

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