Argumentation and primary science

Abstract
The importance of argumentation in science education is outlined and the relatively low level of argumentation typically observed in classrooms in the UK is noted, along with possible reasons for this. The research sets out to determine the extent to which primary school pupils engage in argumentation and to characterise their arguments in primary science lessons. A provisional framework is developed for analysing argumentation in this setting. Transcripts of pupils arguing are used to illustrate how pupils co-construct arguments without teacher intervention or guidance. A number of factors which appear to influence argumentation are noted.

Argumentation and science education

One of the goals of science is the generation of new knowledge. Claims to new scientific knowledge involve a discourse in which these claims are justified by suitable evidence. The process of evaluation and justification of claims to scientific knowledge is commonly known as argumentation, a process which is involved in both talking and doing science (Duschl, Ellenbogen and Erduran,1999). This process may be dialogic, in which two or more individuals assert conflicting claims to knowledge based on reason; it can also include the personal argument or "thinking things through", in which an individual takes evidence and reason into account in coming to conclusions about knowledge claims (Kuhn, 1992).

This close relationship between argumentation and science suggests that argumentation should be an important part of science education. Wellington and Osborne (2001) suggest that learning to reason in science involves learning how to construct arguments which link evidence with ideas and theories. Similarly Driver, Asoko, Leach, Mortimer and Scott (1994) claim that learning science is not just the acquisition of facts about the way the world is, but that "*learning science involves being initiated into scientific ways of knowing*" (p.6) and making sense of the practices of the scientific community. These practices include generating claims to knowledge and the use of argument to assert and defend such claims, to clarify and to persuade (Andrews et al, 1993). Science education can therefore be viewed, in part, as learning how to argue in science contexts (Kuhn, 1992). An emphasis on argumentation is not only consistent with general educational goals concerned with logic, reasoning and the use of evidence (Jimenez-Aleixandre, Rodriguez and Duschl, 2000) but also appears to have specific value in science education, particularly in relatively new areas of science where claims to knowledge may be contested (Millar and Osborne, 1998).

Research carried out in the UK (Newton, Driver and Osborne,1999) indicates that debate, discussion and argument are not common features of the science classroom. Mercer, Wegerif and Dawes (1999) comment on the value of language use for sharing and constructing knowledge and cite a number of research studies which suggest that the use of language in the classroom is often confused, unfocused and unproductive. Solomon (1998) puts forward some reasons why science teachers tend not to use discussion and argument as tools for teaching and learning, including lack of skill in managing the process and uncertainty as to its value. Similarly Yip (2001) describes how the pressure of the prescribed curriculum makes teachers reluctant to allow sufficient time for reflection or debate or to alter the flow of a carefully prepared lesson. Newton et al. (1999) identify teachers' resistance to changes in pedagogy as a further factor.

These descriptions of classroom practice are consistent with a view of science education as relatively unproblematic and comprising largely a set of facts and theories complemented by supporting empirical evidence. Nott and Smith (1995) aptly characterise the classroom practice of many science teachers as 'rigging' and 'conjuring', these being some of the ways used to resolve the frequent discrepancies between experimental observations and theoretical predictions. In these circumstances teachers may view scientific argumentation as a distraction rather than a goal for science education.

The model typically used for analysing argumentation in a school setting is that put forward by Toulmin (1958). Toulmin illustrates the structure of an argument in terms of a claim, data to support that claim, warrants which link the data and claims, backings to strengthen the warrants and rebuttals which point to circumstances in which the claim would not hold up. The presumption would be that developing the pupils' skills of argumentation requires them to assimilate and become more fluent in using the various aspects of an argument in a logical

fashion. Whilst this may be appropriate for older pupils and those with sophisticated language registers, there are questions about its suitability for primary school pupils, particularly those with restricted language registers.

The terminology used to describe argumentation is somewhat problematic, in that the word 'argument' itself may conjure up images of conflict and hostility which are uncomfortable for teachers of science. Scientific progress depends on new ideas conflicting with and ultimately taking the place of older theories (Kuhn, T., 1970). Similarly it can be argued that progress in individual understanding emerges from discrepancy between viewpoints rather than consensus (Kuhn, Shaw and Felton, 1997; Ogborn, Kress, Martins and McGillicuddy, 1996). However the existence of differing viewpoints does not automatically lead to conflict, just as having similar viewpoints does not necessarily lead to collaboration. Argumentation can be a collaborative process of peer interaction rather than a confrontational process. Solomon (1998) notes that strictly logical argument can be confrontational and destructive, preferring the word 'discussion' to characterise the collaborative process which is desirable in classrooms and linking this with Billig's (1987) 'rhetoric' which seeks to persuade through showing examples rather than through strict logic. There are strong similarities with Mercer et al's (1999) 'exploratory talk', which incorporates critical but constructive engagement with alternative ideas, relevant information being put forward, opinions being justified and explicit reasoning.

Solomon's (1992) and Kuhn et al's (1997) research indicates that peer interaction alone can be sufficient to enhance the quality of reasoning and discussion skills without any teacher intervention being necessary. This is not to deny the potential value of teacher intervention, but to recognise that reasoning, justification and use of evidence may be part of everyday discourse if a suitable context is provided. Wellington and Osborne (2001) provide some guidance for the types of strategies which might promote argumentation in the classroom. However in general

little guidance is currently available for teachers of science in relation to the nature or quality of argument in a science classroom setting, particularly primary science, and how argumentation might be promoted.

One possible strategy for promoting argumentation is the use of concept cartoons. Several researchers indicate that this strategy can generate dialogue amongst pupils, leading them to clarify their thinking, justify their answers, consider alternative explanations and explain their thinking (Feasey, 1998; Keogh & Naylor, 1999; Kinchin, 2000; Wellington and Osborne, 2001). In the concept cartoons the lack of agreement amongst the characters poses a problem, which is recognised as a condition for promoting argumentation (Jimenez-Aleixandre et al., 2000). The nature of the concept cartoons themselves, in which the characters appear to publicly disagree about their scientific understanding, could be seen to invite learners to join in with the debate and to add their individual point of view. The concept cartoons focus on science-specific questions which are mainly derived from key areas covered by the UK national curriculum for science. Since they tend to be used to promote science-specific outcomes, with argumentation being an incidental benefit, they may also begin to address some of the pedagogic issues raised for teachers wishing to promote argumentation in their classrooms.

Aims of the research

This study seeks to answer the following research questions:

1. To what extent do primary school pupils engage in purposeful argument in science, using concept cartoons as a stimulus?
2. To what extent is it possible to characterise argumentation in this setting?

Methodology

The research strategy was to use concept cartoons with primary age pupils as a stimulus for discussion and argument. The resulting argumentation was identified and analysed using an analytical framework. Analysis of the quality of argumentation then enabled provisional judgements to be made about some of the factors which appeared to influence argumentation.

The use of concept cartoons was initially as an elicitation strategy which helps pupils to clarify their thinking and generates the need to resolve the cognitive conflict which the arguments reveal. Elicitation "*is the first stage in a process of determining what they (the pupils) want to know and helping them to develop their ideas*" (Millar and Murdoch, 2002: 29). Pupils were invited to engage in further enquiry as a result of their argumentation, so that argumentation was integrated as a purposeful aspect of scientific enquiry in which pupils recognise the need for evidence to resolve the argument.

Initially observations were analysed using pre-existing analytical frameworks in order to make judgements about the nature and quality of argumentation. The data sources used for the research were the pupils and their teachers. Data were collected through systematic structured observation, systematic unstructured observation, participant observation and interviews with individual teachers and pupils. The pupils' conversations were captured on audiocassette for transcription. This range of data collection methods allowed a degree of both qualitative and quantitative analysis of the data in relation to argumentation.

A pilot study was carried out to establish a baseline against which future data could be compared. This involved a short series of classroom observations to establish the amount of argument and to gauge teachers' and pupils' perceptions of the role of argument in primary science lessons. Four visits were made to a classroom in each of two contrasting primary schools. In these visits pupils were observed during science lessons described as typical and

afterwards the lesson was discussed with small groups of pupils and with the teachers. During the lessons the observer recorded the predominant classroom activity at 30-second intervals. This approach paralleled that used by Newton et al (1999) to identify the frequency of various types of interaction amongst pupils.

The data from this small sample suggested that in these lessons little time was spent in discussion or debate and limited use was made of activities which involve argument. This is consistent with Newton et al's (1999) findings for secondary science teaching. The pilot study provided very limited information about why pupils interacted in the way that they did or the relative value of different types of interactions, making clear the need for a different approach to analysis of the argumentation process.

The main research study was carried out in the same two schools, using one class of thirty pupils from each school. Both classes were mixed Year 3 and Year 4 (age approximately 7-9 years). One school was entirely white while the other included diverse ethnic groups, with almost half the pupils having English as an additional language. As far as could be ascertained none of the pupils had encountered the concept cartoons previously.

In School A the pupils were observed in small mixed achievement groups. Groups were presented with several concept cartoons which they discussed. Detailed notes were made on the pupils' non-verbal communication and behaviour during the lessons. This enabled voices to be attributed to the correct pupils during transcription and to relate verbal responses to their non-verbal actions. In School B all the pupils used the concept cartoons simultaneously. Observations were made during whole class science lessons. Pupils were given copies of three concept cartoons. In their usual groups they discussed each of the concept cartoons and chose one for further investigation. The nature of their investigation was left up to them and suitable

resources were available. In both schools tape recorders were visible and their presence and purpose made explicit to the pupils. The recording took place over an entire lesson, not just the earlier stages where the concept cartoons were used. This extended recording period provided useful data on whether the nature of the argument changed as the focus for the pupils' work shifted from the initial theoretical and hypothetical consideration of alternatives to a more practically-oriented investigation. It also provided data on the eventual outcome of the initial argument.

Analysis of the relationship between concept cartoons and argumentation required decisions about the criteria by which the quality of argumentation is judged. Analysis of transcripts of the lessons using concept cartoons was carried out using the framework provided by Toulmin (1958) since this appears to be commonly accepted by other researchers in this field as the definitive analytical framework. Since the Toulmin framework is not generally applied in a primary school setting, a framework put forward by Mercer et al. (1999), based on the use of key linguistic indicators, was also used to provide an alternative perspective on the data. The Mercer et al framework is not in common use in the science education community but it has been successfully used with primary school pupils.

Refining the methodology

In practice there were difficulties in applying the Toulmin (1958) model to the transcripts of pupils engaged in argumentation. A selection of the transcripts in which it was felt that productive argument had taken place were coded in accordance with Toulmin's model. Very few pupils related data to their claims through the use of warrants. The use of backings or theoretical justifications for warrants was almost entirely absent. There were no examples of a pupil or group presenting an argument that would fit well with all or most of Toulmin's model, even where the researcher and classteacher felt that the pupils' arguments were worthwhile.

Pupils also made statements which appeared to be intrinsic to the discussion but which were difficult to fit into Toulmin's categories. The point is made elsewhere that "*nearly all researchers have found the application of the Toulmin schema problematic*" (Simon, Erduran and Osborne, 2002: 16), suggesting that the language and behaviours inherent in the Toulmin model may not be consistent with the types of language and behaviours typically found in school pupils. In this research the lack of connection between the model and the research data appeared to exclude the Toulmin model as a valuable means of analysing the data.

Difficulties also arose in using the Mercer et al (1999) model. Mercer et al established four significant factors in "good argument" (namely *takes long turn at talk*; uses *because*; uses *I think*; uses *I agree*) and asserted that where pupils make greater use of these elements they attain more correct answers. If pupils are using more of these elements they are arguing better. However when discussing the concept cartoons not all of the groups attained a definite answer. Sometimes they agreed to disagree, chose to accept several answers as possibilities or chose to test out their theories. In several instances the children moved straight to the need for empirical testing, saying "*this is how we will test*", and then argued about the type of test that would be most suitable. Whilst this would not score highly on the Mercer et al model, from a science education standpoint it is an appropriate response.

Initial analysis also showed almost the exact opposite of what could be predicted from Mercer et al's model. Those discussions which led to the correct answer met fewer of the criteria for a good argument than those which came to an incorrect answer. Mercer et al (1999) start from the presumption that a good argument is one which leads to the right answer. This presupposes that there is a right answer and that the purpose of discussion is to try to attain it. This presumption works well for multiple choice exercises but less well for the concept cartoons, which are frequently context-dependent and do not necessarily result in a single right answer

being identified (Naylor and Keogh, 2000). For these reasons the Mercer et al (1999) model was also discarded as a means of analysing the research data.

A new model was therefore constructed, drawing on the work of Toulmin and Mercer et al as above and also on Andrews, Costello and Clarke (1993) and Costello (2000). This model (the Downing model) focuses on the nature of the interaction between the individuals, rather than the content of the argument (as in Toulmin) or the linguistic elements (as in Mercer et al). Fleer and Robbins (2001) suggest that the focus on the individual as the unit of analysis in research may be misguided, particularly in research with young children. They argue that the sociocultural context in which children operate is very powerful, that this has a profound influence on the way that children think and talk, and that this should therefore influence how research is conducted. The Downing model attempts to recognise the importance of the group in analysing argument. There is an inevitable tension between analysing the contribution of individuals and analysing the nature of the interaction amongst the group. A focus on the individual takes no account of the quality of the interaction, whilst a focus on the group may not do justice to the differing contributions of individuals.

The model was developed on a provisional basis in order to ascertain whether it proved more useful than either of the other two models as an analytical framework. Data was re-analysed using the new model, with a greater emphasis on the socio-cultural context in which the pupils were operating and on the interaction amongst the group. The model has seven levels which attempt to identify the different nature of the interaction. These levels can be summarised as follows.

Level 1: pupils are unable or unwilling to enter into discussion

Level 2: pupils make a claim to knowledge

Level 3: pupils begin to offer grounds to support their claims

Level 4: pupils offer further evidence to support their claims

Level 5: pupils respond to ideas from others in the group

Level 6: pupils are able to sustain an argument in a variety of ways

Level 7: pupils evaluate the evidence and make judgements

This model was viewed as a means to an end rather then an end in itself – that is, developing a new model was a necessary step towards analysing the data rather than being the main focus of the research. Further details of the model are given in Naylor, Downing and Keogh (2001).

Data and data analysis

One aspect of the first research question (to what extent do pupils engage in purposeful argument using concept cartoons as a stimulus?) was relatively straightforward to answer. It was immediately apparent that the pupils did argue in response to the concept cartoons. For example, in the first four lessons surveyed, the mean proportion of time devoted to small group discussion in a typical science lesson taught by the class teacher was less than 2%. By contrast, when concept cartoons were used as the stimulus for a lesson with the same classes, the mean proportion of time devoted to small group discussion increased to 26.5%.

Keogh and Naylor's (1999) research already indicates that concept cartoons can be an effective stimulus to discussion and argument and there was no intention to replicate their research. The question of whether pupils argued purposefully required more detailed analysis. As suggested above, the seven-level Downing model of argumentation was used as an analytical framework. This was used to analyse 38 lesson transcripts. Of these, 37 of the transcripts were analysed as level 4 or above and 32 of them as level 5 and above, suggesting that the great majority of the arguments were purposeful and productive when analysed using the Downing model. The higher-level transcripts (level 5 and above) were analysed further in an attempt to identify

common characteristics of productive argument or factors which appeared to influence argumentation.

The majority of these higher-level transcripts appeared to indicate that pupils were talking collaboratively and co-constructing arguments. This appeared to be the case even though they had not received any training in argumentation and the teacher was not present to direct their conversations. In a typical transcript pupils appeared to have a common goal of reaching a shared understanding. They would begin their discussion by considering the alternatives offered in the concept cartoon, then contribute their ideas about how suitable these alternative possibilities were. Opening statements in the discussion tended to represent different points of view about the science involved. From that point onwards they tended to build on each other's contributions in order to reach a shared understanding. Conversations were typically dialogical and interactive, often overlapping, rather than following a monological chain of reasoning.

Interruptions generally reflected this collaborative mode of working. Although in principle interruptions might be disruptive, there were many examples of supportive interruptions and of children indicating a desire to speak without interrupting the speaker. Interruptions frequently took the form of agreement with the speaker, clarification of meaning, supportive evidence being put forward, the next step in a chain of reasoning being offered, and so on.

The transcript below (transcript 1) illustrates a group of children co-constructing an argument. The class are nearing the end of a sequence of work about forces and motion. They have covered work on gravity as a force giving objects weight, friction as a force slowing moving objects, air resistance and balanced/unbalanced forces. Claire, Donna, Joe, Mairi, Rosie and Simon make up a higher achieving group of nine year-olds who are used to working together. They are discussing a concept cartoon showing what forces will be acting as a person moves

on a skateboard. The transcript is laid out in columns so that con-construction and interruptions can be identified more clearly.

Simon	(Reading) *There must be a force that keeps her moving*			1
		(Reading) *The only force acting is friction*	Rosie	2
Donna	(Reading) *If there isn't any friction she will keep moving*			3
		(Reading) *She isn't pushing so there can't be any force*	Claire	4
Simon	He is not right, that one (*pointing*). Friction is not the only force.			5
		No, 'cos gravity	Rosie	6
Donna	Yeah, gravity. Well I mean that is always there.			7
		Yeah but that like, well it is a force but well, you know it kinda isn't, well like it doesn't make you move	Joe	8
Donna	What is friction?			9
		Oh that, well don't you remember right, when we did right, the cars on the slope thing, with the sandpaper, you know	Simon	10
Rosie	She (Donna) was away			11
		Yes but, I know. We did it before it I think.	Donna	12
Joe	Good right well then I think that one is right then (*pointing*)			13
		Which?	Claire	14
Joe	(Reading) *If there isn't any friction she will keep on moving*			15
		She won't though. Not forever!	Rosie	16
Mairi	No but well that is because there is friction, isn't there and well right so she will stop right, she will but right (reading) *if there **isn't** any friction*			17
	she will keep on moving	She will keep on moving! Exactly. That is what I just	Joe	18
Rosie	Yeah so he is right definitely	said.		19
		And he is wrong, definitely	Simon	20
Claire	So that leaves those two. Him and him (*pointing*).			21

		So either the force. There must be a force that keeps her moving or there isn't	Mairi	22
Joe	Because she isn't pushing			23
		Well when I'm on, I have a skateboard at home and well. . Okay so, when right you're on a skateboard and you well you push off right and if right you don't push off again right well then you just stop	Simon	24
Joe	You don't just stop, you slow down. Don't you. Like a car with the brakes			25
	on	Yeah, yeah you slow down because of friction	Simon	26
Joe	Yeah friction, yeah so right that is			27
	force that	Friction slows her down and so does wind	Claire	28
Joe	Wind yes if she was going in, like if the wind was, if the wind was from the front, I mean that could be pushing her from behind			29
		The wind could be pushing her yeah great, so she could like be pushed by the wind	Mairi	30
Donna	A strong wind could. .			31
		So right she pushes off, right with her feet. And then the wind will Okay so right she pushes off with her feet to start off then right the wind keeps her going but right friction makes her slow down and stop.	Simon	32
Joe	Yes she has to like start it			33
Rosie	top And stop			34
		Unless the wind was too hard. Then she wouldn't stop	Donna	35
Joe	Well the friction will stop her eventually. She can't keep going forever.			36
		No so right the friction right, the wind will keep her going right and the friction will slow her down so right when they balance	Claire	37
Simon	When they balance she will stop.			38
		Equi lidi. . that thingy	Joe	39
Simon	Equi-lid-ihibru			40
		Well whatever, that. The forces will balance and everything is stop	Joe	41
Rosie	Cool. So right. We've done			42

	those two, right and then these two so right now well he is right then.			
		No wrong. Because she stops remember	Joe	43
Rosie	Yes, friction yes that's the friction one init, so right, but right that's that one and right			44
		The wind. The wind is like the force that keeps her moving	Claire	45
Rosie	Exactly so he is right and he is wrong.			46
		Two right and two wrong. Good.	Claire	47
Mairi	We've finished			48
		So no wait, we've not 'cos now we design an experiment to prove we're right.	Rosie	49
Simon	Evidence!			50

Transcript 1: skateboard

In this transcript the group appears to be co-constructing an argument with the goal of reaching a common understanding rather than proving that an individual is right. Lines 18, 26, 28 and 31-34 show examples of interruptions which did not disrupt the flow of the conversation and which were supportive of the speaker, contributing to the co-construction process. This type of dialogue was typical of groups of children co-constructing arguments through interactive dialogue, though co-construction was not always as consistent as in this transcript. It is apparent from the transcript that attempting to evaluate the argument through analysis of each individual's contribution can be extremely difficult. Data and claims are frequently inseparable and the forms of speech used do not readily lend themselves to linguistic analysis.

It is notable that there is no teacher intervention or teacher direction of the children's conversation. They engage in a focused argument, drawing on experience and evidence to justify their views, without any formal training in argumentation. The engaging stimulus for their

conversation and their common goal of reaching a shared understanding are likely to be significant influences in keeping their conversation focused in this way.

The second transcript shows another example of co-construction. Simon, Aiden, Stuart and Michael are a group of 9 year-old boys. They are discussing a concept cartoon which poses the question of whether two overlapping shadows will be darker than a single shadow.

Simon	So what have we got to do?			1
		Decide which is the right answer, which that one is (*pointing*)	Aiden	2
Stuart	No way is it. Man you are so wrong. Look that . .			3
		The shadow is twice as dark where the shadows overlap (reading). Two shadows, two lots of dark. Makes sense.	Michael	4
Aiden	Nah mate. *The shadow is twice as dark*. See look, ***the*** *shadow* (reading). The equals one. Once not twice. Get it?			5
		What?	Michael	6
Stuart	Man, what are you on about? Look at the picture. Look at the shadow there (*pointing*).			7
		Stu, that's just a drawing. Not a photo or nothing. You can make a drawing anything. Them kids have no arms, see. Just a picture.	Aiden	8
Simon	Right, wait. So what are you saying man?			9
		Right, okay, so what makes a shadow?	Michael	10
Aiden	The sun			11
		. . or a torch	Stuart	12
Michael	Nah, listen, it's the tree			13
		It ain't	Aiden	14
Michael	Yeah, yeah, the tree makes the shadow			15
		So the tree standing in the night makes a shadow?	Aiden	16
Stuart	What? No way does it. It's the sun makes the shadow, mate			17
		That's not the answer. The sun makes the shadow. We got to pick	Simon	18

		one of these (*pointing*)		
Michael	Yeah, but right. See there's the sun and there's the shadow			19
		Yeah, like I said. The sun. The shadow. Just one all the same.	Aiden	20

Transcript 2: shadows

In this transcript the conversation is fairly symmetrical, with no individual taking on a dominant role. The dialogue tends to be rather fragmented, with short or incomplete sentences which were frequently overlapping or simultaneous. The transcript gives the impression of a collaborative group that is 'thinking out loud' in an attempt to work out the problem together. In this transcript there is a strong sense of all the pupils being involved in exploring the ideas, but each statement appears to assume much of the information contained in previous statements, so that each new statement is relatively short (lines 10-20). The boys' form of speech appears to emphasise short stylised comments rather than lengthy, well-constructed paragraphs.

The first two transcripts illustrate how pupils can engage in and sustain an argument without any direction or intervention from the teacher. In neither case had the teacher set out any explicit rules for how the pupils interacted. Any ground rules for conversation were left to evolve within each group. Where teachers do choose to intervene it might be expected that the dynamic within the group would change. Normally in these classrooms power and control are distributed asymmetrically. It is the teacher that decides who should speak and when. In these specific lessons the teacher has provided the stimulus, organised the groups and given pupils the freedom to speak as they wish. If the teacher now intervenes in the group discussion the ground rules which have evolved are likely to be disturbed. This is illustrated in the following transcript. Joshua, Charlie, Elizabeth, Megan and Martin are group of low achieving nine year-old pupils. They have been discussing a concept cartoon which features black and white cards

casting shadows on a table. They have been engaged in discussion for approximately 10 minutes.

Joshua	(Reading) *The black card will make the darkest shadow*	1
Charlie	The black card will make the darkest shadow because, well, it is already shadow	2
Joshua	The black card is darker	3
Charlie	The card is dark and a shadow is dark so it adds up and the shadow is darker	4
Elizabeth	No you won't be able to see the shadow if it is already dark	5
Megan	I think it is either that one – darkest card makes the darkest shadow or that one, both shadows are the same	6
Elizabeth	It can't really make a difference can it?	7
Megan	No, I think that too. I don't think it will make any difference what colour something is	8
Elizabeth	Say like you wear dark clothes and have fair hair. Your shadow is like normally like all the same colour. It is like all black. Think. I haven't seen a purple shadow	9
Charlie	I think it will make some difference but not much. Black is stronger. If you wear white on a black floor you wouldn't see the white, only the black	10
Martin	What? You wouldn't see a shadow at all	11
Joshua	You would, you would	12
Elizabeth	It would hardly be there but you would see it	13
Megan	Yeah because like now I can see a shadow of my foot, but not very much	14
Martin	So does it make a difference the colour of the card or how thick it is?	15
Megan	I think both shadows are the same	16
Martin	Yeah I do. No difference	17
	The teacher approaches the group. The children stop talking and look towards the teacher.	18
Teacher	How is it going?	19
	Pause	20
Teacher	Are you nearly ready with your answer yet?	21
	Pause	22
Teacher	Josh?	23
Joshua	Well, erm, we kinda nearly are	24
Elizabeth	Me and Megan, erm well, we think it will not make a difference	25
Charlie	But I don't agree with them, exactly	26
Elizabeth	No, Charlie does not agree with us	27
Joshua	And well, yes, and I agree with Charlie. Because he says the black card will make the darkest shadow, and well because it wouldn't let as much light come through it	28
Megan	But, we don't. We… we think both will be the same, because, well, it is like, you know when, you have white card with black writing on it you know you well you can't see the writing on the shadow can you?	29

Transcript 3: shadows

After the arrival of the teacher the balance of power within the group is altered. The pupils' initial response to the teacher is to wait for permission to speak. In a whole class setting a question from the teacher usually results in the pupils putting up their hands to answer before the teacher invites a response. This kind of behaviour is less appropriate in a small group, and the pupils appear uncertain as to how to respond in this situation. When the teacher directs the question to Joshua (line 23) the rules of engagement are clarified and Joshua is able to respond. What is evident is that the pupils' ability to discuss freely is suspended on the arrival of the teacher. They are used to a situation where they can talk as they like without the teacher present, but in the teacher's presence they revert to their 'whole class' behaviour of waiting for permission to speak.

A similar effect can be seen in the next transcript which shows a short interchange amongst a group of six nine year-olds. They are discussing a concept cartoon which shows various possibilities for what might happen when you kick a football.

Sophie	Is it *It comes down because it runs out for force* or is it *It comes down because there is no upwards force after you have kicked it*?	1
William	They are the same really	2
	general murmerings of agreement	3
Sophie	Yeah, yeah that's true they mean the same	4
Caleb	Actually they all do, those three	5
Andrew	Only this one is different because it blames gravity	6
William	Well yes, but really when you think about it that is the others are the same.	7
Andrew	So they are all right. . .	8
Caleb	. . . or all wrong. I guess we decide.	9
	Further conversation. The teacher comes over	10
Teacher	Okay red group. What's the problem?	11
Lauren	Well Miss, you see those three answers, well they are all the same.	12
Teacher	How do you mean, the same?	13
Lauren	Well you see they are all like the same thing	14
Teacher	Okay. Well I don't think they are the same. Andrew do you?	15
Andrew	No Miss. But I mean, well they are kinda a bit the same.	16
Teacher	A bit the same? Caleb?	17
Caleb	Well. I mean . . . well we said . . . erm well right so take *If I kick the ball high enough it will never come down* right well that means right that the ball right,	18

	it well right that one is not true, is it? So right well it's . . .	
Teacher	Okay, so you don't like that one. But are the others the same? Sophie?	19
Sophie	No Miss Jackson	20
Teacher	So what is the problem? Isaac?	21

Transcript 4: football

The impact of the teacher's presence is clear. The children no longer talk to each other but now engage in dialogue only with the teacher (lines 12, 14, 16, 18, 20). The teacher controls the direction of the conversation, asks direct questions of individuals, adjudicates when they respond and becomes the most dominant voice in the conversation. This was a common occurrence in the transcripts: when transcripts recorded the presence of a teacher the shift in the group dynamics appeared to disempower the children and reduce the length and intensity of their involvement in argumentation with each other.

In a small number of cases one pupil took on the role of the teacher, organising the discussion and adjudicating between the ideas of other pupils. Occasionally one pupil would look to another to take on the role of the teacher, possibly because they did not have ideas of their own. This is illustrated in the following short transcript, where a group of four nine year-olds are discussing the same concept cartoon as in Transcript 2.

Vicky	Can I see what you've put?	1
Craig	Well what have you . . . you haven't written anything	2
Vicky	No, I, well. . . have you?	3
Craig	You're hopeless. All you need to do is write down which one you think	4
Vicky	But I don't	5
Craig	(*sighs*) Well I have put that one: *The shadows are just the same where they overlap*. Because that is what I think. But you can't put that now	6
Vicky	Why not?	7
Craig	Because it's not what you think. Unless you agree with me. Which you can if you want. But it doesn't matter because we are supposed to discuss it now and then you can make your mind up. Joe, have you finished? Maxine?	8

Transcript 5: shadows

In this short section of dialogue Craig appears to be reticent about taking on the role of the teacher and dismisses Vicky's attempt to cast him in that role. He appears to be wanting to work from a position of equality within the group, rather than working in the role of an expert for Vicky. This type of dialogue was unusual, in that the pupils' response to the concept cartoons was generally that they all wanted to contribute their ideas to the discussion, as is shown in the previous transcripts.

Transcripts 3, 4 and 5 illustrate the significance of the dynamics within the group for generating and sustaining argument. On reflection it seems surprising that so many of the groups worked so well together. In many cases the groups were randomly assigned at the start of the lesson rather than using the groups in which pupils typically worked. The typical group size used was between four and six. Occasionally smaller groups were used. Although no numerical data were collected it was evident that pairs did not engage in extended discussions like the bigger groups. Even though the concept cartoon presented alternative ideas to the pupils, it seems likely that the lack of variety in the pupils' views resulted in consensus being reached quickly and the opportunities for argument correspondingly reduced. The added intimacy of a very small group might also make disagreement with the views of other group members more difficult.

Whole class 'discussion' also appeared to be relatively unsuccessful at generating sustained argument by pupils. Discussion managed by the class teachers tended to follow the fairly standard model in which the teacher asks a question, one pupil is chosen to respond and then the teacher evaluates that pupil's answer. Lines 10-21 in transcript 4 illustrate the type of

interaction which was typical during whole class discussion, with the teacher clearly in control of the conversation. There was a marked contrast between discussion where the teacher was involved and small group discussion without the teacher present. On their own groups of 4, 5 or 6 pupils generally seemed to establish some kind of group identity and interact freely, but then reverted back to their more usual type of behaviour when the teacher was managing the discussion. One possible interpretation of this change in behaviour is that the pupils were so fully attuned to the power relationships within the class, where the teacher is the unquestioned authority for every decision, that they were able to argue with their peers as equals but unable to argue in a similar way with the teacher.

Tape recording the pupils' conversations and then analysing the transcripts proved to be a very effective means of characterising argumentation in this setting. However some potentially significant behaviours were observed which were difficult to capture in the transcripts. One was the value of silence. Silence sometimes appeared to indicate that pupils were thinking carefully and fully engaged in the argumentation process. Although this could be observed it was not really evident in the transcripts. Similarly the use of non-verbal behaviour, such as gesture, appeared to be integral to the argument but was not represented in the transcripts. For example, pupils would frequently point to a particular character in the concept cartoon to indicate agreement with that viewpoint, with more vigorous gestures indicating stronger agreement. Sometimes their body language appeared to change as they changed their ideas and began to argue from a different viewpoint. In order to do justice to these types of behaviours it would be necessary to use some other means of data collection, such as video recording.

Discussion

The research set out to determine whether primary school pupils would engage in purposeful argument in science, given a suitable stimulus, and to characterise any argumentation which occurred. Transcripts of the pupils' conversations show unequivocally that they can and do engage in argumentation and that this is a purposeful process for them. The model which was developed as an alternative analytical framework has been tested out in practice and appears to have supported the analysis of argumentation. It is too early to make any comment on whether the model might have more general applicability. It would be necessary for the model to be implemented and evaluated in a greater variety of research settings to be convinced of its validity. In this research its greatest significance might have been to shift the focus from the logical content or linguistic elements of the argument and to focus instead on the process of argumentation, the interaction amongst the individuals and the socio-cultural factors which might influence their interaction. The decision by another research team to focus on the process of argumentation rather than the content (Simon et al, 2002) suggests that this may have been a useful shift to make.

One significant aspect of the data has been the extent to which primary school pupils co-construct an argument rather than viewing argumentation as confrontational. This is not to deny the value of different viewpoints. Quite the opposite in fact, when the purpose of using a concept cartoon as a stimulus is to explicitly represent different viewpoints and to legitimise a range of alternative perspectives on the situation. Kuhn (1970) observed that science is progressed more through controversy and argument than by harmony and consensus, and the value of argument can be seen in the pupils' conversations. The important point to emerge from the data seems to be the purpose of the argumentation process. Pupils typically interacted as though the purpose of argumentation was to explore alternative viewpoints in an attempt to build consensus as part of a scientific learning experience, rather than to maintain their own individual viewpoint as they might in a different setting. Argumentation appeared to be less about

defending a particular point of view and more about reaching the best view through a collaborative process. It may be that the nature of their interaction was influenced by the way that the educational experience was configured, with the stimulus for argumentation being an incidental part of the learning experience rather than the main focus. This may have enabled pupils to view argumentation as a means to an end, where their learning goals were defined in terms of learning science rather than learning the skills of argument.

Group size appeared to be a significant factor which influenced the discussions. Alexopoulou and Driver (1996) note the influence of group size in determining the effectiveness of discussion in groups. If pupils are to scaffold each others' learning then the group must be large enough to enable this to happen. Equally if all group members are to have the opportunity to engage in worthwhile argumentation then the group must be small enough to provide suitable opportunities. In this research group sizes of 4-6 appeared to be an optimum, with neither very small groups nor the whole class providing a suitable context for effective argumentation to occur.

By contrast gender appeared to be less significant than was anticipated in determining the nature of the pupils' interaction. Previous research (such as Swann, 1992) points to important differences in the way that girls and boys tend to interact verbally. Boys are more likely to take on a dominant role in discussion while girls are more likely to take on a supportive and exploratory role. Re-analysis of the research data from a gender perspective showed some relatively minor differences in terms of the number of contributions and words used but no apparent difference in the quality of the argumentation process. Examples of boys taking on a dominant role in the argument were balanced by examples of girls confidently taking on that role. It may be that the nature of the concept cartoon stimulus, which contextualised the

science in everyday settings and legitimised alternative viewpoints, helped to minimise gender differences, but the data is insufficient to reach any conclusions.

Argumentation appeared to be more productive in the absence of the teacher, with teacher presence (not necessarily intervention) having an inhibiting effect. This may be due to the power dynamics of the classroom, where power is asymmetrically distributed. Cazden (1998) notes how the teacher controls classroom talk, deciding whether anybody should speak as well as who and for how long. Pupils have to ask for permission to speak and the teacher can choose whether or not to grant permission. It is therefore not surprising that the presence of the teacher had an impact on pupils' conversations, for teachers cannot simultaneously retain power and expect to participate in group discussions as equals.

When pupils work in small groups in the absence of the teacher they are working more as equals and can create their own rules to govern the conversation. Generally they seemed able to cope with this transfer of power, presumably by drawing on their everyday experience of interacting in groups where they need to create their own rules. Although Mercer et al (1999) note the value of ground rules for conversation in shaping group conversations, in this research pupils appeared to function effectively in groups without any ground rules being explicit. The concept cartoon stimulus may have contributed to the quality of the interaction by putting forward a number of alternative viewpoints for discussion, so that pupils are cast in the role of adjudicating between the alternatives rather than having to put forward and defend their individual ideas. This could help to minimise existing power differentials within the groups by legitimising each of the alternatives, so enabling pupils to focus on the outcomes of their argument rather than adopting a more confrontational mode. The research appears to be consistent with Kuhn et al's (1997) findings that pupils could develop skills of argumentation without any teacher guidance or intervention.

The research appears to provide firm evidence that worthwhile argumentation can be generated in relatively young pupils by a combination of an engaging stimulus, clear curriculum relevance and learning goals which are framed in terms of science conceptual development. It does not address the issue of what positive roles the teacher can take on in relation to argument with primary school pupils. Presumably pupils' engagement in argumentation might be even more effective if teachers provide more frequent opportunities for argument, model the skills involved in argument and help pupils to evaluate the quality of arguments. This appears to be a worthwhile focus for future exploration.

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