Mapping children's discussions of evidence in science to assess collaboration and argumentation

Jane Maloney and Shirley Simon, Institute of Education, University of London, UK

Institute of Education, University of London
20 Bedford Way
London
WC1H 0AL

Tel: 020 7612 67744
Fax: 020 7612 6792

j.maloney@ioe.ac.uk

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Abstract

The research reported in this paper concerns the development of children's skills of interpreting and evaluating evidence in science. Previous studies have shown that school teaching often places limited emphasis on the development of these skills, which are necessary for children to engage in scientific debate and decision-making. The research, undertaken in the UK, involved four collaborative decision-making activities to stimulate group discussion, each was carried out with five groups of four children (10-11 years old). The research shows how the children evaluated evidence for possible choices and judged whether their evidence was sufficient to support a particular conclusion or the rejection of alternative conclusions. A mapping technique was developed to analyse the discussions and identify different 'levels' of argumentation. The authors conclude that suitable collaborative activities that focus on the discussion of evidence can be developed to exercise children's ability to argue effectively in making decisions.

Introduction

The extent to which children learn how to engage in debate and use evidence in science is important for future decision-making, particularly in the context of socio-scientific issues (Ratcliffe & Grace 2003). Science education has a crucial role to play in developing the skills children will need as future citizens, and a science curriculum should therefore reflect this need (Millar & Osborne 1998; Osborne 2000; Turner 2000). As long as school science places more emphasis on well-established laws and long-accepted theories, it will continue to reinforce the idea that science is absolute, and children will remain unfamiliar with how scientists use uncertain and contested knowledge to make decisions. It is perhaps not surprising that adults associate 'science' with 'certainty' and expect science to provide completely reliable knowledge. Yet scientific knowledge itself may only be a component in a complex process of decision-making, which can involve social, economic, ethical and political considerations (Driver, Leach, Millar & Scott 1996). Essentially, the curriculum should provide opportunities for children to become aware of the tentative status of some aspects of scientific knowledge so that they are better able to cope with uncertainty when having to make choices and decisions.

To develop decision-making skills, children need to learn to reason, to evaluate alternatives and to weigh up evidence competently, in other words, to develop the ability to engage in argumentation. Within this research, argumentation involves the communication and evaluation of knowledge claims, the justification of claims drawing on sources of evidence, and the use of strategies to resolve opposing positions. The argumentation process is essentially dialogic, arguments being either co-constructed by children working together, or produced individually, taking into account other children's statements. Argumentation plays a key role in the rational resolution of questions, issues and disputes (Siegel 1995) and can be practiced in schools through activities where students reason about problems and issues in different contexts (Jimenez-Aleixandre & Pereiro-Munoz 2002, 2005; Zeidler, Osborne, Erduran, Simon & Monk 2003). Yet, until recently the science taught in many UK schools has paid little attention to the development of the children's skills of argument (Driver, Newton & Osborne 2000), even scientific inquiry involving group work has tended to emphasize the written product rather than the process of discussion and argument (Watson, Swain & McRobbie 2004). Without knowing how children develop their arguments it is difficult to make recommendations for improving their argumentation skills. The main aim of this study was therefore to examine the ways in which groups of children argue and use evidence in decision-making in science.

In undertaking this study, techniques have been developed for analysing data arising from small group discussion. These techniques make a methodological contribution to the field of research into children's use of evidence and argumentation skills, as they provide a means for evaluating such skills. Schemata, referred to as 'discussion maps,' have been used to analyse children's discussions in detail to show how evidence is used in the process of argumentation and how children collaborate. As a result, levels of argumentation have been identified which teachers could use to assess children's development of these skills.

Changing the science curriculum to meet future needs

One reason why the acquisition of scientific knowledge alone is an unsatisfactory educational goal is that the knowledge base of science is expanding rapidly. Teachers of science are faced with more instances where the curriculum has to be modified in the light of new knowledge and new scientific procedures (Duschl 1990). For instance, projects have now been set up so that biotechnology practical work, such as bacterial transformation and DNA fingerprinting, can be carried out in schools. The gap between experts' knowledge and teachers' knowledge will constantly need to be addressed, and the challenge for curriculum developers will be to determine how pedagogy is able to cope with this dynamic aspect of the subject. Whatever policy decisions are made to address such issues, it is important to be clear how the curriculum might be made more relevant for future citizens. It is proposed here that a future science curriculum should enable students to develop:

- analytical skills to make judgements about the reliability of scientific evidence;
- an ability to make judgements about the validity and strength of conclusions;
- an appreciation of how scientific knowledge develops and that some scientific issues are unresolved.

If we accept that some of the scientific issues confronting society in the future will be too complex for non-scientists to understand, then science teachers will need to develop students' skills in such a way that they can participate in debate about controversial issues, even with limited scientific knowledge (Norris & Korpan 2000). Although there is increasingly some teaching about controversial issues arising from contemporary science, in the past students have been provided with little opportunity to develop the skills necessary to solve problems where they have to search for and evaluate evidence (Watson, Goldsworthy & Wood-Robinson 2000).

The ability to make judgements about the validity and strength of evidence requires the ability to think and reason scientifically. Wood (1998) suggests that in order for children to be empowered and participate in making choices they need to practice making decisions through the curriculum. She argues that children need to know they have a voice and will be listened to and taken seriously. Therefore, the way children will come to appreciate the importance of evidence is through being expected to use it to justify their own conclusions, even in a simple fashion. The implication is that science teachers need to use activities where children can explore different viewpoints so that children begin to understand how evidence is used to persuade someone to change a particular viewpoint.

The primary school years can provide opportunities within the curriculum for teachers to engage groups of children in collaborative decision-making activities that require interpretation and discussion of evidence. Yet there are conflicting research findings about the age at which children can develop these skills (Kuhn, Amsel & O'Loughlin 1988; Sodian, Zaitchik & Carey 1991; Samarapungavan 1992; Koslowski 1996; Leach 1999; Mercer, Dawes, Wergerif & Sams 2004), some authors suggesting that young children are not capable of reflecting on theories to interpret evidence (Kuhn et al 1988). The research reported here therefore set out to develop and use of decision-making activities for children that require them to think, reason and argue about evidence whilst working collaboratively in small groups. Should such activities be successful in promoting reasoning and decision making, they can be incorporated into the curriculum so as to address those analytical skills highlighted above, and in contexts of relevant content where reasoning and thinking can help children to develop their conceptual understanding of science.

Argumentation in science

One of the purposes of argument is to refine and clarify ideas in order to come to some form of decision. The situations that challenge people to use their skills of argumentation involve events that are difficult to explain or where there is an element of conflict, such as when the evidence is incomplete or contradictory. Reasoning, evaluating and justifying are the skills employed in resolving arguments and for children, can be developed through decision-making activities that use sources of evidence. Yet, the demands on teachers are such that children are rarely given the opportunity to argue unless it is a specific requirement of the subject. The teaching of argumentation in science is now a developing field of study in the UK (Osborne, Erduran & Simon 2004, Simon, Erduran & Osborne 2006; Watson et al. 2004) as argumentation activities help to meet national curriculum requirements that come under the umbrella of 'Ideas and Evidence'. The work of Osborne, Erduran and Simon has built on a wider base of international research concerning argumentative discourse in science education (Hogan & Maglienti 2001; Jimenex-Aleixandre, Rodriguez & Duschl 2000; Jimenez-Aleixandre & Pereiro-Munoz 2002, 2005; Kelly, Drucker & Chen 1998; Pontecorvo 1987; Zohar & Nemet 2002). A model used by some science educators (e.g. Kelly et al 1998; Jimenez- Aleixandre & Pereiro-Munoz 2002,2005; Osborne et al 2004; Simon et al. 2006) for identifying the structure of arguments and informing pedagogy on argumentation has been derived from the work of Toulmin (Toulmin 1958). Toulmin's argument pattern (TAP, figure 1) can be used to analyse argument structures to show the reasoning that has taken place to support and establish a claim. In its simplest form, Toulmin considers that an argument consists of a 'claim' with a reference to 'data', which are the facts that have led to the claim being made. The claim is an assertion that has to be supported by these facts if it is to be considered an argument. The explanation of how the facts or data support an argument includes the 'warrant' and 'backing'. Warrants provide the reasoning to justify how the data supports a claim; the backing provides the justification for the warrant. The 'good' argument is one that can be justified and can stand up to opposition where the evidence is strong and the warrants legitimate. If education is to facilitate the development of children's argumentation skills, situations will need to be engineered where children can utilise these skills and see how contentions only become arguments when supplied by reasoned warrants and legitimate backing.

[Insert figure 1 about here]

Though some researchers have found difficulties in using TAP as a method for determining the structure and components of an argument (Kelly et al. 1998), others have found it useful as an analytical device to apply to classroom discourse on argumentation (Erduran, Simon & Osborne 2004; Jimenez- Aleixandre & Pereiro-Munoz 2005). The research reported here has built on Erduran et al's interpretation of TAP by using the framework to evaluate argumentation that occurs as children engage in decision-making activities. The analysis will help to determine the effectiveness of the activities in generating reasoning and argumentation, and also provide an indication of how collaboration worked to achieve these goals.

Collaborative work to develop argumentation skills

The value of talk in the process of learning has become well-established, many authors drawing on Vygotskian theory in identifying the role of dialogue in the social construction of knowledge (Mercer, 1995, Wells 1999). The kinds of talk that take place in children's interactions in primary classrooms can be characterised in different ways. Mercer & Wergerif (1999), for example, define exploratory talk as "that in which partners engage critically but constructively with each other's ideas. Statements are sought and offered for joint consideration. These maybe challenged and counter-challenged, but challenges are justified and alternative hypotheses are offered." (Mercer & Wergerif., 1999, p.97). On the other hand, cumulative talk is characterised by interactions that generate an end point, but do not do so collaboratively (Mercer & Wergerif, 1999). Typically, several members of a group using cumulative talk will contribute ideas, but these do not necessarily build on each other. The final decision taken by the group is likely to be the original decision of the most dominant group member, or an accumulation of several ideas, uncritically drawn together.

The ways in which children work together in groups have been described in different ways, for example as co-operative (Gillies, 2003), though many such studies come under the umbrella of collaborative learning. A distinction between the two is made by McWhaw, Schnackenberg, Sclater & Abrami (2003) who suggests that co-operative learning is considered to be the most structured approach to learning in groups, whereas collaborative learning occurs where students are given more power over their learning. Differences in definition are not accepted by all (Bruffee, 1995) and whilst being aware of this distinction, our position lies somewhere between the two; much of what we refer to in our analysis of groupwork could be referred to as co-operative (Gillies, 2003), but the unstructured nature of the work and autonomy given to the children leads us to use the term ‘collaborative’ in describing what we set out to study.

Where collaboration exists, groupwork can shape understanding and allow construction of joint meaning, yet there is considerable evidence that very little collaborative learning actually takes place in schools (Lyle, 1993). Where collaborative activities are attempted, several observational studies have found that most talk in these activities was off task, uncooperative and not constructive to learning (Galton, Simon & Croll, 1980; Bennett & Cass, 1989; Rojas-Drummond & Mercer, 2003). Children often do not work well together when given collaborative activities because children’s talk is naturally uncooperative and disputational. Children are not taught how to talk effectively, and so are frustrated when they try to do so in collaborative tasks (Rojas-Drummond & Mercer, 2003). In addition to a lack of skills, various other factors, such as group make up and task characteristics, may adversely affect the success of attempted collaborative activities.

Working collaboratively in a group to make decisions requires the members of the group to reason collaboratively (Nussbaum, 1998), therefore it is important to ‘learn how to argue’. Mercer (1995) also points to the role of arguing in developing understanding through dialogue:

> an excellent method for evaluating and revising your understanding is arguing, in a reasonable manner, with someone whom you can treat as a social and intellectual equal. (Mercer 1995: 89)

Working together means we argue about different points of view, we resolve differences and we create a shared understanding (Mercer 2000). For Kuhn (1993) the advancement of scientific thought by scientists can be linked to the way children develop their scientific thinking. She conceives ‘science as argument’ as science being a social activity that advances through discussion between people. Therefore, if we are to encourage children to develop their scientific thinking we need to teach them how to argue about their ideas in order to clarify what they think and then how to argue for their ideas when they try to convince others of their merits.

With properly designed activities and with appropriate resources, collaborative working can facilitate the development of children's scientific reasoning skills as they seek to justify an idea and convince others of its merits. Children may argue from different positions and in presenting their reasons for a particular standpoint they will be challenged in their own thoughts and also challenge evidence that opposes their view. Richmond and Striley (1996), carrying out research with tenth grade students (13 - 14 years old) who were given opportunities to investigate real-life problems using principles and concepts from a variety of scientific disciplines, found that:

> One of the most significant changes we observed ... was in the students' ability to formulate appropriate scientific arguments. They became more adept at identifying the relevant problem, collecting useful information, stating a testable hypothesis, collecting and summarizing data, and discussing the meaning of data. (Richmond and Striley 1996: 847)

Richmond and Striley also found that the discourse during laboratory-based activities revealed how social dynamics helped shape the development of an individual's conceptual understanding of scientific problems. They concluded that the development of equal participation in classrooms should be a critical goal of science educators. Science activities that required students to make reasoned arguments to solve problems involved co-operation and working collaboratively with others.

Research Design

In order to encourage children to argue in a constructive manner they need to understand how evidence is used to support theories; they need to be able to evaluate evidence in terms of its adequacy, its relevance and its source. Just as support for scientific theories can draw on a range of evidence, in the form of numerical data, recordings of observations or other established scientific facts, so children need to explore different ways to justify their ideas and conclusions. The research set out to develop activities that would enable us to see whether 10 –11 year old children could engage in argumentation in small groups, using evidence to support their decision-making. The research aimed to clarify how children made use of evidence in decision-making activities and whether they used evidence to justify their decisions. Four such activities were devised (see below) that were suitable for children in this age-range. The activities were designed to reveal differences in opinion in order that children could explore their reasoning and expose their thinking.

The research took place in three different schools in the London area that were chosen by the researchers to represent a range of social, ethnic and cultural origins. The activities were given to five groups of children who were selected according to ability, as indicated by their predicted levels for national tests, each group having children within the same ability range (see Table 1), so that comparisons could be made in how different groups of children were able to exercise their skills in group discussion. Only children who could read were included, as the evidence cards that were used contained textual material. Following our guidelines for choosing groups according to ability, teachers identified two boys and two girls to make up each group. Having a group of four children ensured that the children had opportunities to argue and discuss from different points of view, and as Jarvis (1993) and Gillies (2003) found, a group of four is small enough so that all the members can contribute to the discussion. Groups of four also allowed girls and boys to be equally represented and mixed groups are important because all-girl groups may want to seek agreement rather than challenge each other's ideas (Jarvis 1993). Table 1 shows the details of the five groups of children and characteristics of each school.

[Insert table 1 about here]

The activities were carried out in a school setting that was familiar to the children, but away from general classroom noise so as to facilitate audio-recording. The researcher observed each group of children as they undertook each activity, however the children managed their discussions autonomously and there was no intervention directing them towards a conclusion or any set time limit. The aim of this approach was to allow the children to explore their evidence freely and enable argumentation to run a natural course as the children discussed evidence and made their decisions. These strategies were adopted so that the children could express their ideas openly and have the freedom to explore ideas that they might later reject.

The research was organised into two phases comprising a pilot study and a main study. The pilot study took place over one academic year and the main study involving the five groups of children in three schools was carried out in the following year. The exploratory nature of the pilot phase was necessitated by the lack of any substantial literature providing activities that facilitated children's use of evidence in decision-making activities. Activities had therefore to be developed afresh or by adaptation. Essentially, the purpose of the pilot study was to try out the activities and research approach and subsequently refine research methods and analytical techniques. The pilot study showed that the activities needed to relate to children's knowledge and interests in order to stimulate debate and discussion (Samarapungavan 1992). To explore differences in the ways children use evidence, activities were devised that presented data in different formats. Two activities that included evidence presented in the form of information and pictures were adapted from published materials found in the Science and Technology in Society for Key Stage 2 Science Project (SATIS 1993). The SATIS materials, produced by the Association for Science Education, UK, are aimed at putting science and technology into context and are designed to stimulate group work and co-operation. They form the basis of scientific debating activities in many UK classrooms. Activities where evidence was presented in the form of tables of figures had to be designed de novo as no published materials suitable for the primary age group were found.

To determine how children selected evidence and used it to justify choices, the activities needed to provide legitimate alternatives. If a decision became very obvious to the children, there would be no reason for them to explore all the evidence. The evidence also had to be presented in a form that was accessible to the children in terms of language, presentation and amount of evidence provided.

In summary, the activities suitable for this research would need to:

- relate to children's interests;
- present evidence in different formats (pictures, written information, artefacts, tables of data);
- provide alternative choices.

Brief details of these activities and the format of the evidence are provided below. More information is given for Activity 1 in Appendix 1, as this is used to exemplify the analytical framework.

Activity 1: Finding a home for gerbils

This activity was adapted from a task in Unit 1 A Home for Gerbils (SATIS 1993), where the children were asked to evaluate and select a home suitable for some gerbils. The children were given pictures and descriptions of three homes that they could use as evidence to guide their decisions (see Appendix 1). However, as gerbils would survive in all the homes, the decision concerned which home should be chosen rather than what could be chosen. For ethical reasons, the choice of home was discussed with the children at the end of the activity. Home 3 is recommended by the RSPCA (Dunphy, Holden & Ings 1993) as it is most like the natural environment of the gerbil, and this information was finally given to the children.

Activity 2: The best cup for a picnic

In this activity the children were provided with data from an investigation about the properties of materials called Which cup to take on a picnic? The investigation explored the properties of three different cups; one made of glass, one of thin plastic and one of thick plastic. The data provided information concerning the stability, the insulating properties, the mass (given as weight) and the strength of each cup. This information was presented in a tabular form familiar to the children, along with the three cups. Using this evidence the children were asked to decide which cup they would take on a picnic.

Activity 3: What can be done about the bats?

This activity was also taken from the SATIS materials. The task, taken from Book 3, Unit 5 Bats in Conflict (SATIS 1993) was adapted to engage children in a group decision. The children were presented with the problem 'What to do about bats in the library roof?' for which they first suggested individual solutions. The children recorded their ideas about what to do about the bats on paper, firstly as individuals to ensure that they all had something to contribute to the discussion. They were then presented with 'evidence' in a form of the Bat Fact? cards. As the children read the facts and ascertained whether the fact was true or false, issues were raised that required them to reconsider their plans. For example, if the plan involved killing the bats they would find out from the Bat Fact? cards that they would be fined £2000 should they harm any bats. The children produced a group plan after discussing the information on the Bat Fact? cards; this new plan revealed whether the children had been influenced by the evidence and the discussion showed which pieces of evidence were used in coming to the decision.

Activity 4: Whose conclusion is correct?

This activity engaged the children in the interpretation of data. They were given three different accounts of a scientific investigation carried out by four fictitious ten year-old children. The investigation was designed to find out the effect of friction on the speed of a rolling marble. The children were also given fabricated data on the time taken for a marble to roll down two tubes that had been covered in two different surfaces; one tube had ridges of glue down its length and the other was covered with bubble wrap. The accounts of two of the children provided some anomalous data as they had the same results as each other but their conclusions were different. Models of the tubes with the appropriate covering were also given to the children. The children were asked to read the accounts and decide what had happened during the investigation.

Data collection and analysis

The children were observed and video-recorded whilst they discussed their decisions and all conversations between the groups of children were audio-recorded and then fully transcribed. The discussions were video-recorded because not all points in a discussion were made through speech; some were made through gestures and pointing at objects (Driver et al. 2000). For example, the children pointed at pictures of the gerbil homes or held a particular cup and said ‘I like this one’. The use of video-recording also helped to overcome difficulties in identifying the speaker (Samra-Fredericks 1998). Some of the children’s voices sounded very alike and the video made it possible to distinguish which child was speaking. The video also provided records of the interactions between the children; it showed who distributed the pieces of paper in the activities, the actions unrelated to the activity that some of children displayed (e.g. jumping up in front of the camera, gazing around the room). Such records facilitate analysis of the data for making sense of the social aspects of collaborative learning (Barron 2003) and were important in defining the roles children played in the discussions. There were 20 transcripts of the groups’ discussions, one for each of the four activities from the five different groups of children.

The analytical scheme devised to determine the nature of collaboration and argumentation displayed by the five groups of children drew on Mitchell’s (2001) parameters of argumentation. Within Mitchell's list are some characteristics that were judged to be beyond the skills of ten to eleven year old children; for example, 'adapting the arguments of one context so that they operate effectively in another' (Mitchell 2001: 33). Thus the criteria selected from the list were those that the children in the study could be expected to demonstrate. That is, they could be expected to:

a. discuss most or all of the evidence made available
b. provide claims supported by evidence
c. test alternative choices and consider both positive and negative issues of the possible options and
d. engage in sustained dialogue by making claims, reviewing evidence and discussing arguments as an iterative process.

The findings reported in this paper focus specifically on parts b and d in order to show the ways in which frameworks were developed to 'map' children's argumentation. Parts a and c are reported elsewhere (Maloney 2005, Maloney in press). Part b is a precursor to part d, as it involves identifying arguments, which are then incorporated within maps created for part d.

Claims supported by evidence

During the discussions the children made claims and put forward ideas about their choices. When the claim was supported by a reference to evidence it was identified as an 'argument'. These arguments were analysed using Toulmin's argument pattern (TAP) (Toulmin1958) in its simplest form (figure 1), which included a **claim** supported by an appeal to **data** and a **warrant** that explained the link between the claim and the data. An example from Activity 1 illustrates the approach:

St Anne's Group 2: Gerbil Activity

Junior: The thing I don't like about it (Home 2) is that the holes (in the tubes) are too small, 'cos if it's a big gerbil...

Junior made the **claim** that he did not like Home 2 (for gerbils) and the **data** to which he appealed consists of 'the holes are too small'. A **warrant** for this argument might be an explanation for why Home 2 not a good choice. Alicia completed the **warrant** later on in the discussion:

Alicia: Yes, and if it's too big, it might get stuck

Further support could come from **backings** that lend authority to the warrant. However, few of the arguments put forward by the children contained all these elements and the children made many 'incomplete' arguments in terms of a TAP analysis.

In the initial stages of coding the transcripts reliability checks were undertaken as two people coded the same transcripts. In each case, discussion took place until there was inter-coder agreement (Silverman 2000) for the TAP codes. Further reliability checks took place when the transcripts were analysed for a second time and consistency in the allocation of TAP codes was established.

Figure 2 shows the number of claims, supported by evidence, made by the five groups of children.

[Insert figure 2 about here]

It can be seen from figure 2 that the Castle Hill Group and the Woodstreet Junior Group 2 both make 50 or more justified claims. However, 41 of the 50 claims made by the children in Woodstreet Junior Group 2 were made in the Cups activity, where more detailed study of the data reveals that many of the arguments were repeated several times. For example, the justification given for 17 of the 41 arguments made by the children referred to the unsuitability of the glass cup as it could smash and cut someone. In contrast, the Castle Hill Group explored a wider range of criteria, for example, if the cups stack, how heavy they are, the cost of each cup, the insulating properties of the material as well as aspects of safety. Therefore, the number of claims supported by evidence is not, by itself, necessarily an indicator of the quality of argumentation. Mitchell suggests that the exploration of different types of evidence is part of a good argument and that one of the practices that characterises good argumentation is the ‘moving from wider to narrower perspectives and vice versa’ (Mitchell 2001: 33). If the number of claims made in a discussion is small, it is likely that there will be a limited number of viewpoints to consider. The more evidence explored, the greater the possibility there is of having a range of different viewpoints. A discussion where the same evidence is used many times will result in the arguments being repeated. A more detailed study of sustained dialogue reveals these characteristics and subsequently provides more information about the quality of argumentative discussion and the use of evidence.

Engaging in sustained argumentation dialogue: construction of Discussion Maps

When children engage in sustained argumentation dialogue they bring together their ideas and explore the available evidence to make judgments about these ideas. It is an iterative process where claims are challenged and evidence reviewed throughout the discussion. However, in this study the nature of the dialogue was varied, and not all groups followed the same pattern of discussion. Some groups took one claim and discussed its merits before moving on to consider another claim; others expected each member of the group to make a preliminary choice before the merits of each claim were explored.

A coding system was devised to show these different approaches to engaging in discussion. The system, termed a ‘Discussion map’, was designed to identify the nature and extent to which children engaged in sustained argumentation dialogue. The construction of these maps was initially informed by the work of Chinn and Anderson (1998), who used ‘argument networks’ to analyse the structure of discourse of children in small groups as they discussed issues raised by stories (not scientific in nature). Figure 3 illustrates an argument network, based on Chinn and Anderson’s model, constructed from part of a transcript of the Cups Activity. Diagrams, representing the ideas expressed in the whole discussion, form an intricate web of arguments and sub-arguments indicating the different positions the children take in the argument and how they support their claims.

[Figure 3 about here]

One of the major problems encountered in the use of argument networks was of a practical nature; a transcript that was four pages in length produced an argument network that required 13 pages. However, the construction of argument networks identified the need for some diagrammatic representation of the discourse, as the diagrams demonstrated clearly the varying patterns of discussion for the different activities. For example, they showed whether the arguments put forward were discussed by the group or ignored, and whether arguments were followed by the presentation of a new claim. For opposing arguments, the diagrams indicated whether the evidence was examined to evaluate the opposing claims or whether claims were just accepted and not challenged. The diagrams also showed which children were taking part in the discussions. As a result of this pilot work and the developing clarity about the requirements to aid analysis, the 'Discussion Map' was devised to capture all these features in a more economic way (Examples are shown in Figures 4 -7). A Discussion map is constructed through identifying key episodes of 'talk' that include argumentative discussion using evidence. These episodes are termed <u>Argument</u>, <u>Review</u> and <u>Clarification</u>. A fourth category of talk is needed to complete the transcript analysis, so that the Discussion Map captures the intervals and frequency of the key episodes of talk, this fourth category includes all other types of discourse and is termed <u>Other Talk</u>. The characteristics of the four episodes of talk are explained below.

<u>Argument:</u> As the children explored possible decisions, the assertions or claims that were accompanied by justifications were defined as arguments for or against their choice (Kuhn 1991) and identified using Toulmin's argument pattern (TAP). For each argument children made a claim that was either justified with reference to the information they had been given or

with reasons of their own. Arguments could, but were not often, be supported with a warrant and backings

Review: Review episodes were identified when children read out sections from the information sheets or stated evidence without constructing an argument. For example, in the following extract the children were reading out facts from the cards containing information about bats (in quotation marks). As they read, they made no comments or arguments about what was in the text. The children read out the cards in pairs: Luke and Sheerah are one pair, Naveed and Osei are the other pair.

Extract:

Luke:	'Bat droppings can be a nuisance"'
Sheerah:	'They can make a mess on cars.'
Naveed:	Yes, 'Sometimes there are problems...'
Luke:	**'**Windows and things stored in lofts. But, the droppings are only made of insect skeletons and crumble into a powder.'
Naveed:	Oh look they can … 'Their urine can damage polished wooden surfaces. This is sometimes …'
Osei:	**'**Although bats only produced small amounts of urine, it can damage polished wooden surfaces. This is sometimes a problem in churches.'

Review episodes appeared in most discussions at the beginning of the activity as the children shared the information that they were given. In many instances, the children read out the information and did not refer to it again. However, in some of the more sustained discussions, the children went back to review the evidence again and checked the validity of their claims.

Clarification: In some discussions the children asked questions of each other or of the researcher to clarify the evidence. The type of questions included in this sequence are factual, for example, in the Castle Hill Group, Joanne asked the researcher if the home they needed to choose was for more than one gerbil. The evidence she had said that Home 1 (see Appendix 1) is only big enough for one hamster and she wanted to check that her interpretation was correct. If the questions were challenges to other members of the group (e.g. Why do you think that?) then these were included in the episodes referred to as Other Talk, as they are different forms of discourse not directly relating to the use of evidence.

Other Talk: In essence, Other Talk episodes were those that were not identified as Argument, Review or Clarification and consequently included a variety of types of talking (Mercer, 1996). In some sequences the children confirmed, elaborated ideas, made comments, oppositions and counter-oppositions, in other sequences they made incomplete arguments: such as making a claim but without any justification or reason to support the claim.

The first stage of constructing a Discussion Map from a transcript required the identification of the arguments put forward using the TAP scheme. The episodes of Clarification and Review were then included, followed by summaries of all the Other Talk, which filled out the structure of the Map. Examples to illustrate the Maps (Figures 4 to 7) are taken from the activity 'Finding a home for gerbils' (Appendix 1).

The Maps have four columns. The first includes the line numbers in the transcript, showing the length of each episode, the second identifies the type of episode and the number of arguments included in the discussion. The third column provides detail about each episode, for example the nature of the talk or of the claim, whether the talk is repetitive, or when new ideas are introduced. The final column includes the names of the children talking, and is used to see whether all the children in the group contribute to the conversation.

Extracts from the Discussion Maps illustrate different approaches to argumentation. Figure 4 shows a series of episodes where the children reviewed the information they had been given (see Appendix 1) and discussed the qualities of the Homes but did not form any arguments. Figure 5, on the other hand, shows that the children used the information to form many arguments. However these children did not discuss each other's arguments, either to argue for their ideas or to convince each other of the merits of their claims. In other words there was no 'exploratory talk' (Mercer & Wergerif 1999). Examples from other activities show similar patterns; a review episode followed by a series of arguments and a final decision with no consensus. This pattern of discussion suggests that although a group may work co-operatively the children are not reasoning collaboratively (Nussbaum, 1998) and there is no perceived need for negotiation to reach a consensus.

Figure 6 reveals how Woodstreet Junior Group 1 created a shared understanding of the merits of Home 2 as they presented arguments appealing to data about the space for the gerbil in the home. The arguments were interspersed with Other Talk when the children discussed the space in each home. However, the lack of review episodes shows that the children did not draw on a range of evidence, instead they concentrated on the space provided in each home and the need for a gerbil to have an exciting and stimulating environment where it could run up and down. As they did not check the relevance of other evidence (and they were given the opportunity to do so) they did not appreciate that wheels are not suitable in a gerbil home, as gerbils have long tails that can get caught in the spokes of the wheel.

Figure 7 illustrates argumentation that was sustained and where the children spent time reviewing evidence and seeking clarification to check the relevance of the information they had been given. The whole Map has been included to show how this group followed an iterative process where arguments were fully explored. For example, Joanne's argument 1 (against home 3 as it has 'little mountains that the gerbil won't like') was challenged by Alex and Simon as they believed the gerbils would like this home and 'would be happy in it' (argument 2) and they were supported by Cicely who suggested it is like the natural environment of the gerbils (argument 5). In the Other Talk episode (lines 222-253) Joanne was persuaded to change her mind and the group agreed to choose Home 3, which is the most suitable home for gerbils. Thus this group had engaged critically and constructively with each other's ideas (Mercer & Wergerif 1999).

Results

The Discussion Maps indicate that groups can have different levels of sophistication in their approach to using evidence and the process of argumentation. At the simplest level a group may discuss the available evidence but not necessarily use this evidence to make arguments. At the most sophisticated level children may review and discuss the available evidence, which then leads to an argument that in turn engenders further discussion. The evidence can then be further examined to see how it can support different arguments and the discussion eventually leads to the reinforcement or refinement of the original argument or the development of a new argument.

Four different approaches have been identified from the Maps each with increasing levels of sophistication. The level descriptors draw on Mitchell's (2001) parameters of argumentation as discussed above. The levels identified are as follows:

Level 1. Discussion with few or no arguments (e.g. Figure 4)
Evidence is discussed but not used to make arguments.

Level 2. Series of arguments (e.g. Figure 5)
The children state their arguments one after the other. They take it in turns to say something. There is no discussion beforehand.

Level 3. Arguments with discussion
Type 3A:
The arguments are dispersed within the discussion. The discussions concern the argument but may also include story-telling related to the argument.

Type 3B: Repetitive arguments (e.g. Figure 6)
The arguments are repeating the same points. The discussion is confirming points made, not challenging the arguments put forward.

Level 4. Discussion leading to arguments
Type 4A:
Discussion leads to an argument but the following discussion is not related. There is no challenge to the argument it is just followed by a different argument.

Type 4B: Discussion leading to refined arguments
Discussion leads to an argument that engenders relevant discussion. The discussion relates to the previous argument and this leads to the reinforcement or refinement of the original argument or the development of a new argument.

Type 4C: Sustained Argumentation (e.g. Figure 7)

> Discussion leads to an argument that engenders discussion and review of evidence. This leads to the reinforcement or refinement of the argument or the development of a new argument. The process of evaluating new arguments is sustained throughout the conversation.

These levels were used to identify the quality of argumentation for each group of children by examining the Maps in each of the four activities. The levelling task was repeated on three occasions, with some months apart, to test the reliability of the system. Where any differences occurred in the allocation of the levels, the process was repeated until agreement was met. The different levels identified in each map are presented in table 2, each level represented with a tick. As can be seen from the table, some maps indicated only one level of argumentation in a discussion as the conversation maintains the same character throughout. However, most groups start their discussions at level 1 and then go on to higher levels.

[Insert table 2 about here]

Table 2 shows that the Castle Hill group reached the highest level of argumentation in all four activities as they immediately discussed the information they had been given to make tentative arguments. They evaluated and refined these arguments by returning to review the evidence. Other groups were more variable in their approach but all four groups reached some aspect of level 4, showing that reasoned arguments could be constructed through discussion, even though the dialogue was not always be sustained. Moreover, level four was reached for all four activities by each of the five groups of children, showing that each of the activities had potential for argumentative discussion.

Discussion and implications

The main aim of this study was to examine the ways children argued and made use of evidence when working on group decision-making activities in science. As all the groups were working autonomously, without teacher intervention, we have shown that children aged ten to eleven years old can use information to justify and support their claims by themselves. However, the results show that the number of claims supported by evidence varies from group to group (Figure 2). As discussed earlier, the number of arguments is not necessarily an indicator of a high level of argumentation, as many claims may be repeated. A more detailed analysis was developed to look more closely at the quality of argumentation through the construction of Discussion Maps, as these captured the nature of argumentative discourse involving the use of evidence. The Maps have enabled us to develop a hierarchy of levels that reflect the argumentation skills of children working in small groups. Such an analysis may be suitable for use by teachers when assessing the ways in which children use evidence in small group discussion. The Castle Hill Group demonstrated the highest level of argumentation, as the children:

- discussed most or all of the evidence made available;
- gave evidence in support of a claim and requested others to give evidence to support their claims;
- considered and evaluated alternative viewpoints;
- would review evidence and so were prepared to be convinced by a stronger argument.

In contrast, children from Woodstreet Junior School (both groups) demonstrated lower levels of argumentation skills. The talk characteristic of these groups shows that they:

- did not discuss most of the evidence;
- did not give evidence to support a claim nor asked others to give evidence to support their claims;
- did not challenge opposing views or demand evidence for claims counter to their own;
- did not review the evidence and when faced with evidence that supports a counter claim and they were not prepared to change their mind.

Children with less sophisticated reasoning skills appeared to make up their minds before any discussion took place and were not influenced by the arguments of other members of the group.

The findings of this research also suggest that the science curriculum could include opportunities for developing reasoning through the use of well-designed small group activities. The chosen activities required children to make decisions in groups, through having to explain their ideas and justify their claims to each other. Teachers can use such activities to foster argumentation skills and respond formatively to children as they develop reasoning. The activities also show that children's skills in interpreting and evaluating evidence can be developed in different contexts. For example, children could interpret the data they have recorded from an investigation, they could also be given activities where they interpret and evaluate evidence from secondary sources.

We found that although all our groups of children worked cooperatively they did not necessarily work collaboratively, as some children made independent decisions and their group did not reach any consensus. It seems, therefore, that children do not develop the skills of argumentation just by being given the opportunity to use them, suggesting that they need to be trained to work together in a purposeful and systematic way (Gillies, 2003). Herrenkohl et al. (1999) came to similar conclusions when they found that some children aged eight to ten years old, despite being given the opportunity to question and challenge their peers, did not do so; to engage in sophisticated conversation, children required explicit guidance on which roles to take to monitor their own and their peers' thinking. Our Discussion Maps also identify the ways in which different group members contribute to the activity. Further analysis, arising from the maps, of the roles children take in discussion, has enabled the critical nature of their relative contributions to be more fully explored (Maloney, in press).

The research has implications for the ways in which teachers could help children to know how to work in a group, and how to review and evaluate evidence. If teachers become aware of the need to make these skills part of their teaching objectives, then perhaps we can begin to develop all children's argumentation skills in the future. Through explaining the meaning and purpose of classroom activities, and using their interactions with children as opportunities for encouraging children to make explicit their own thought processes (Mercer, 2000), teachers could support the development of reasoned argument.

Teachers would also need to develop children's cooperative skills beyond the level of 'taking it in turns' to speak. Listening to each other is not merely a matter of being quiet when another person speaks; listening requires a response to what is being said. The Castle Hill Group were able to listen to each other, disagree with each other and ask one another to justify their claims. The consistency in performance of the Castle Hill Group suggests that they may have developed some ground rules the argumentation process, and how to work together collaboratively. The inconsistent performance shown by other groups suggests that although they were capable of high levels of argumentation, they had no such ground rules and their performance was erratic. There was no evidence of 'collective thinking' (Mercer 2000) as there were few instances of children asking questions of each other to find out how a claim could be justified.

Although teachers may find it difficult to embed this practice in their teaching (Gillies, 2003), they may be convinced of the need to do so if they can see the advantages to pupils' learning in science. Gillies (2003) describes how cooperative learning can lead to metacognitive thinking, and Kuhn (1993) is convinced that argumentation can lead to the development of scientific thinking.

This research has shown that where children prompted each other by asking for reasons for decisions, evidence was used more systematically and the level of argumentation was more sophisticated. It is therefore possible that some children can drive the process of scaffolding small group discussions themselves and can work more independently of the teacher. If children do take on this role then group work could become more effective, as teacher input could be directed towards children who are not yet capable of taking on this role for themselves.

Our conclusion is that children should be taught about the effects of the roles they adopt on the success of a group and about the skills of collaborative work (Johnson and Johnson 1987, Herrenkhol et al. 1999, Jarvis 1993), moreover this understanding does not come naturally and the necessary skills need to be taught to young children (Kuhn 1991). It is important that these skills are taught early on as intervention to enhance group discussions for older age groups has limited impact (Ratcliffe and Grace 2003).

An important message from the findings of this research is that if teachers were to provide children with activities where scientific evidence is discussed and if children were taught to adopt the roles that maximise the use of evidence and argumentation skills, children's scientific reasoning skills and their understanding of scientific concepts could be enhanced. The science curriculum needs to address this issue so that appropriate activities and opportunities can be incorporated and pedagogical approaches be supported.

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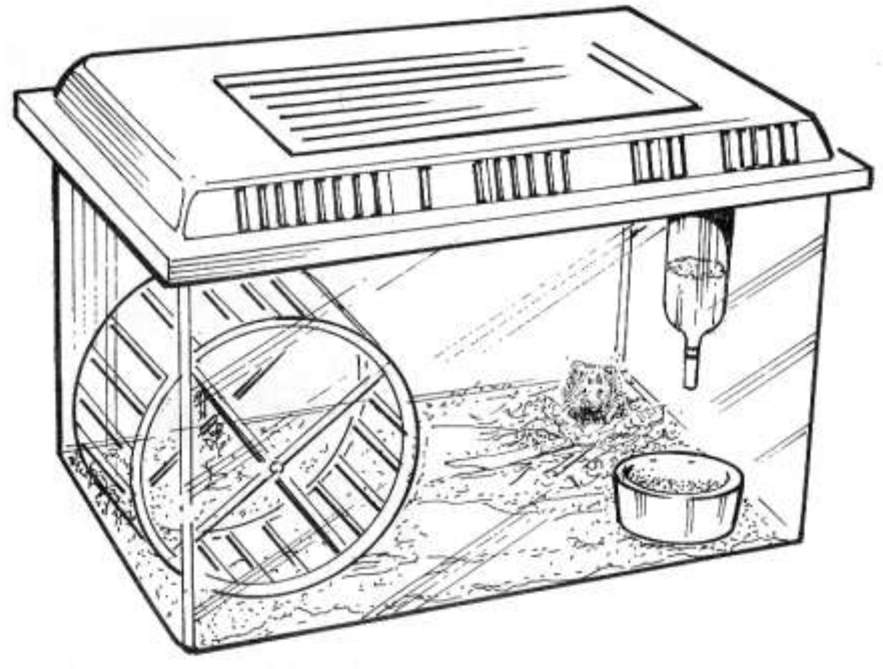
Appendix 1 Gerbil Homes

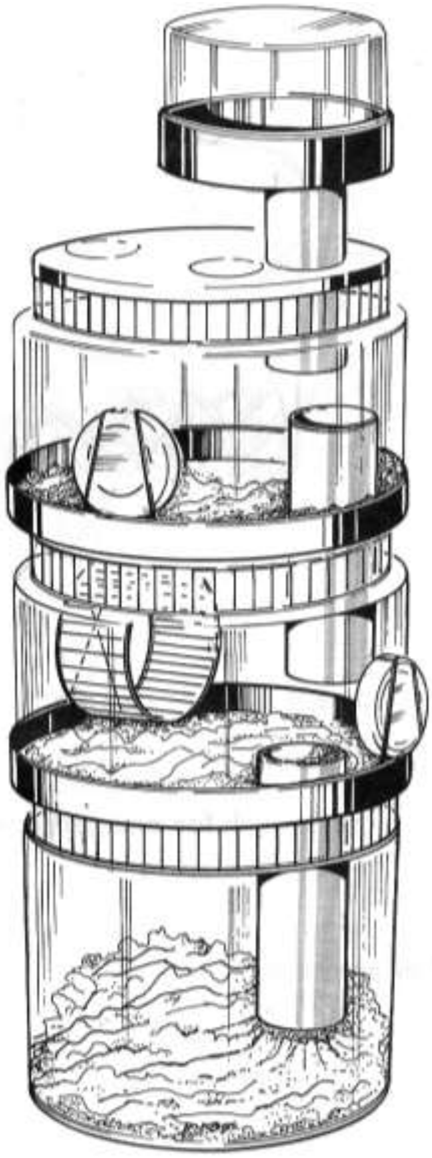
Home 1

This home is made for hamsters
It is made of plastic with a plastic roof
It is big enough for one gerbil
There is an exercise wheel and a plastic food bowl
It is quite expensive



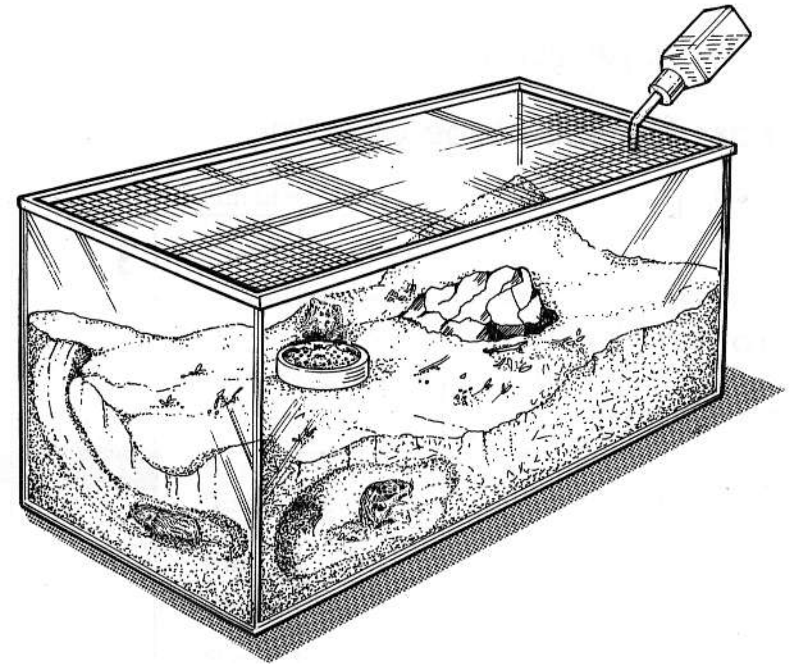
Home 2

This home is made of plastic.
It has lots of tubes connecting the cylinders.
You can make it bigger by adding more cylinders.
There is plenty of room for an exercise wheel.
It is very expensive.



Home 3

This home is made from an old aquarium.
It is a cheap home.
It has a layer of garden peat, sand and gravel.
There are two rocks and a top layer of wood shavings.
There is room for twigs and hay.



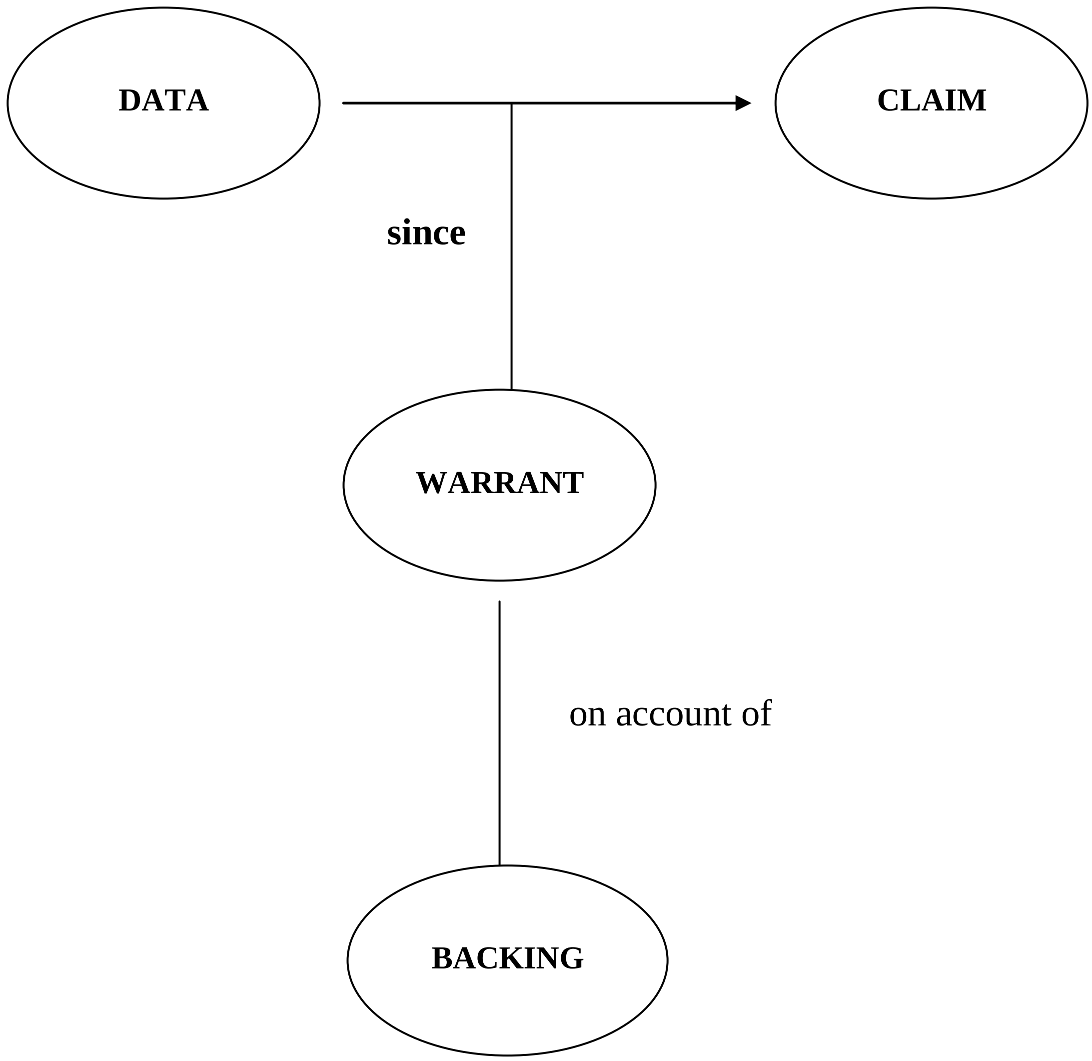


Figure 1. A simplified version of Toulmin's (1958) Argument Pattern (TAP)

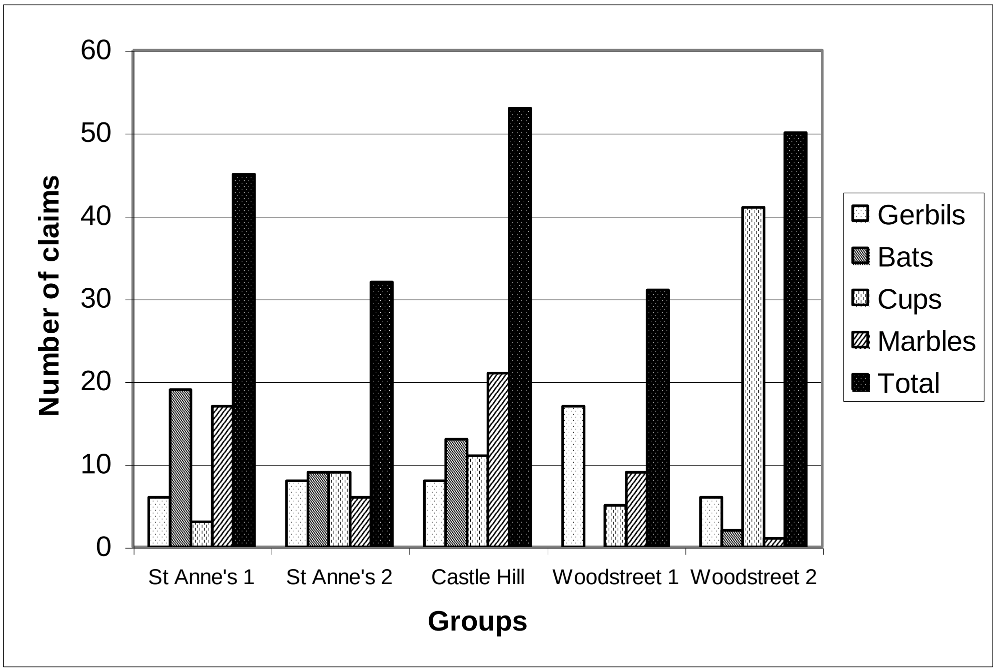


Figure 2. The number of claims supported by evidence in each activity

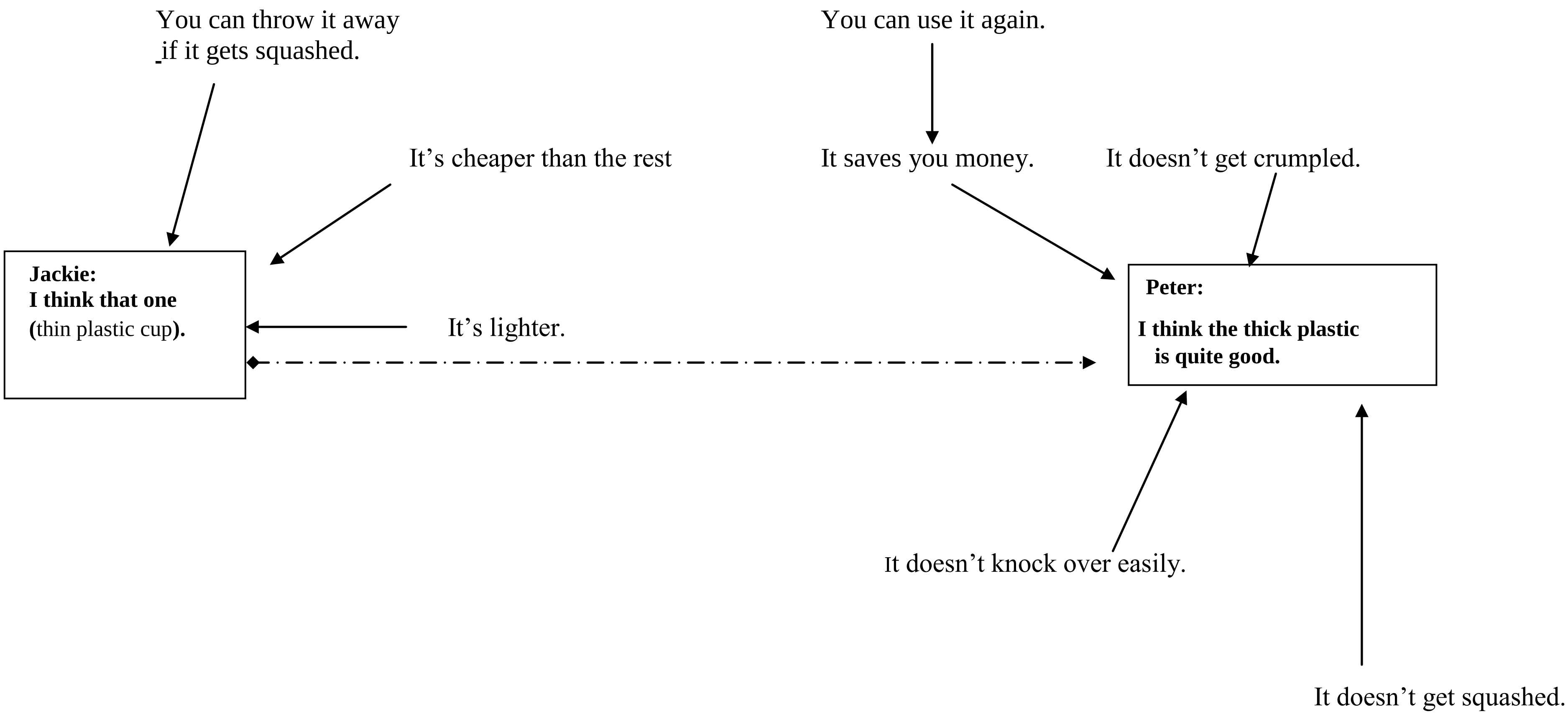


Figure 3. Argument network for excerpt from the pilot study data (the Cups Activity)

Gerbil Activity: St Anne's Group 2 **Children: A= Alicia; D= Daniel; H= Heidi; J= Junior**			
1 **Lines**	**2** **Episode**	**3** **Notes and source of evidence used** **C= claim; D= data appealed to**	**4** **Children**
40-41	**Review**	Reading out information on Home 2	D, & A
42-46	**Other Talk**	Home 2 looks good but no justification given	D,H & A
47-48	**Review**	Home 2 again	D
49-58	**Other Talk**	Home 2 is not safe but no justification given	H,J & A
59	**Review**	Home 2 again	A
60-66	**Other Talk**	Could choose H 3 but H 1 is good	All 4
40-41	**Review**	Reading out information on Home 2	D, & A
42-46	**Other Talk**	Home 2 looks good but no justification given	D,H & A
47-48	**Review**	Home 2 again	D

Figure 4. Extract of a Discussion Map

Gerbil Activity: St Anne's Group 2 Children: A= Alicia; D= Daniel; H= Heidi; J=Junior,			
1 Lines	**2 Episode**	**3 Notes and source of evidence used C= claim; D= data appealed to**	**4 Children**
27-28	**Argument 1**	C= I'd choose a home with room (not specific home) D=so it doesn't keep lounging about	A
29	**Argument 2**	C= it's best for them to lounge about D= because they don't come out in the day	H
30-34	**Argument 3**	C= you need a sound proof cage D=because you don't want them in another room	H
35-36	**Argument 4**	C= I don't like H2 D= the holes are too small	J
37-39	**Argument 5**	C= Home 2 & 3 might be good D= because H1 hasn't got a lot of facilities	H

Figure 5. Extract of a Discussion Map

Gerbil Activity: Woodstreet Junior Group 1 Children: A= Amy; C= Che; J= Jillese; P= Patrick			
1 Lines	**2 Episode**	**3 Notes and source of evidence used C= claim; D= data appealed to**	**4 Children**
	Review	Children read sheets	All 4
14	**Argument 1**	C= I think this one H2 D= 'cos it's got a good lot of space	P
15-38	**Other Talk**	The space in each home	All 4
39-40	**Argument 2**	D=no room in H3 to run C= then it would get fat	C P
41-45	**Argument 3**	C= this one is good D= it's got space to run around	A
45-63	**Other Talk**	Advantages of the levels in H2	A,C & P
64-66	**Argument 4**	D= you can make H2 bigger C= I'd go for this one	C P
67-80	**Other Talk**	H2 is good despite being expensive but no justification given	All 4
81-82	**Argument 5**	C= our school is lucky D= because we can bring tapes cassettes outside	C
83-85	**Argument 6**	C= I agree (H2 is good) D= this is so nice and big	C
86-95	**Other Talk**	Use of the 'rooms' in H2	All 4
96-98	**Argument 7**	C= (H2) is better D=because it can run up and down the tubes	C
99	**Argument 8**	C= if there were 2 (gerbils) that would be better D= because they could play together	C
100-162	**Other Talk**	What the gerbils would do in H2 H1 is boring but no justification given Toys for hamsters Space in H2	All 4

Figure 6. Extract of a Discussion Map

Gerbil Activity: Castle Hill Group **Children: A= Alex; C= Cicely; J= Joanne; S= Simon**			
1 **Lines**	**2** **Episode**	**3** **Notes and source of evidence used** **C= claim; D= data appealed to**	**4** **Children**
29-30	**Argument 1**	C= I don't think H3 is good D= it's got mountains that gerbil won't like	J
31-34	**Review**	Details of H3	C,A & J
35-39	**Other Talk**	Gerbils would like H3 but no justification given	A,S & J
40-46	**Review**	More details H3	C,S & J
47-49	**Other Talk**	H 2 is complicated but no justification given	J & A
50	**Argument 2**	C=I think the cheapest home is the best D= because it would also be happy in it	S
51-57	**Other Talk**	Why H3 is cheap Why H2 is not suitable	A & J
58-60	**Clarification**	How the gerbils get out of the cylinders in	J,A
61-73	**Other Talk**	How the gerbils move up and down H2	All 4
74	**Argument 3**	C= I think we should have H3 D= the gerbil would be happy in it	S
75-99	**Other Talk**	How the gerbils move about in H3 You can make H 2 bigger	All 4
100-101	**Clarification**	Can you fit a wheel in H 3	C
102-103	**Argument 4**	C= H3 is quite good then D= because it has more air etc	C
104-136	**Other Talk**	Not choose H2 but no justification given Comparing H1 and H3	All 4
137-139	**Argument 5**	C= I think that one H3 D= because it will be more like their natural habitat etc	C
140-150	**Other Talk**	If the air is filtered in H1	S,A & C
151-152	**Clarification**	What is peat?	J
153-168	**Other Talk**	An old fish tank would be smelly	All 4
169-170	**Clarification**	Is the home for more than one gerbil?	J
171-174	**Other Talk**	Is H1 big enough?	J & C
175-176	**Clarification**	Is there a food bowl in H1	C
177-186	**Other Talk**	H 3 is good but no justification given	All 4
187-189	**Argument 6**	C= H1 will get stuffy D= not as many air vents as H3	S
190-192	**Argument 7**	C= it will be better in H3 D= because there is only enough for one gerbil in H1	J
193-204	**Other Talk**	Gerbils being in an old aquarium	All 4
205-213	**Argument 8**	C= plastic is not a good idea D= because it may get scratched	C & J
214--221	**Clarification**	Where will the gerbils be kept?	S,J
222-253	**Other Talk**	Should the gerbils live in H3?	All 4
254-261	**Finalising the activity**	OK who votes for this one (H3)?	S

Figure 7. Extract of a Discussion Map

Table 1. The schools, classes and groups in the research

School		Children (selected by the teacher)	Level of ability (defined by predicted SAT scores)
St Anne's State Primary School (5-11 years)	Group 1	Luke, Naveed, Osei and Sheerah	4
Suburban school	Group 2	Alicia, Daniel, Heidi and Junior	3-4
Castle Hill Independent School (7-13 years) Semi-rural school		Alex, Cicely, Joanne and Simon	5-6
Woodstreet Junior State Junior School (7-11 years)	Group 1	Amy, Che, Jillese and Patrick	4
Inner city school	Group 2	Chantal, Elijah, Jason and Sharon	3-4

Table 2. Levels of argumentation for sequences of the discussions

St Anne's Group 1	**1**	**2**	**3A**	**3B**	**4A**	**4B**	**4C**
Gerbils				√		√	
Cups							√
Bats		√			√	√√	
Marbles		√				√√√	√
St Anne's Group 2	**1**	**2**	**3A**	**3B**	**4A**	**4B**	**4C**
Gerbils	√	√			√		
Cups					√	√	
Bats	√	√			√	√	
Marbles				√	√		
Castle Hill Group	**1**	**2**	**3A**	**3B**	**4A**	**4B**	**4C**
Gerbils							√
Cups							√
Bats							√
Marbles							√
Woodstreet Junior Group 1	**1**	**2**	**3A**	**3B**	**4A**	**4B**	**4C**
Gerbils			√	√		√	
Cups		√					
Bats	√						
Marbles		√		√			
Woodstreet Junior Group 2	**1**	**2**	**3A**	**3B**	**4A**	**4B**	**4C**
Gerbils		√				√	
Cups		√√√	√√√√√	√		√	
Bats	√		√	√			
Marbles	√			√			