# ENHANCING THE QUALITY OF ARGUMENTATION IN SCHOOL SCIENCE

*Shirley Simon***

*Sibel Erduran**

*Jonathan Osborne**

** King's College London*
***Institute of Education, London*

Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, April 7-10, 2002 New Orleans, USA

Address for Correspondence: Jonathan.Osborne@kcl.ac.uk
Department of Education and Professional Studies, King's College London, Franklin-Wilkins Building, 150 Stamford Street, London SE1 9NN, United Kingdom.

## Introduction

Curriculum innovations in science like those sponsored by Nuffield in the UK and the National Science Foundation in the USA in the 60s and 70s, have had little impact on the practices of science teachers (Welch, 1979). Four decades after Joseph Schwab's introduction of the idea that science should be taught as an 'enquiry into enquiry' and almost a century since John Dewey advocated classroom learning be a student-centered process of enquiry, we find ourselves still struggling to bring student-centered enquiry practices to the classroom. Witness the publication of the AAAS edited volume on inquiry (Minstrell & Van Zee, 2000), the recent release of *Inquiry and the National Science Education Standards* (National Research Council, 2000) and the inclusion of 'scientific enquiry' as a separate strand in the English and Welsh science national curriculum (Department for Education and Employment, 1999). These three works serve as signposts to an ideological commitment that teaching science needs to accomplish much more than simply detailing what we know. Equally important is the need to educate our pupils and citizens about how we know and why we believe; e.g., science as a way of knowing (Driver, Leach, Millar, & Scott, 1996; Duschl, 1990; Millar & Osborne, 1998). The shift requires a focus on (1) how evidence is used in science for the construction of explanations and (2) the development of criteria used in science to evaluate the selection of evidence and the construction of explanations. An important insight that has developed over the last 50 years, and yet not fully unrealized at the level of the classroom, is the important role language plays in learning and in the design of effective learning environments.

The purpose of this paper is to report recent research on a particular type of language genre, namely argumentation. Whilst the consideration of the important role language, conversation and discussion have in science learning can be traced back 3 or 4 decades ( Scheffler, 1960; Bruner, 1964; Lansdown, Blackwood & Brandwein, 1971), it was not until the 1980s that serious discussion of the role of language in science learning began (c.f., (Aikenhead, 1991; Gee, 1996; Lemke, 1990; Sutton, 1992)). More recently, the field has turned its attention to that discourse which addresses argumentation (Driver, Newton, & Osborne, 2000; Newton, Driver, & Osborne, 1999). The case made here is that argumentation, i.e., the coordination of evidence and theory to support or refute an explanatory conclusion, model or prediction (Suppe, 1998) is a critically important epistemic task and discourse process in science. Situating argumentation as a central element in the design of enquiry learning environments has two functions: one is as a heuristic to engages learners in the coordination of conceptual and epistemic goals, and the other is to make student scientific thinking and reasoning visible to enable formative assessment by teachers. From this perspective, epistemic goals are not additional extraneous aspects of science that are marginalized to single lessons or the periphery of the curriculum. Rather, striving for epistemic goals like developing, evaluating and revising scientific arguments represent an essential element of any contemporary science education.

For contemporary science impinges directly upon many aspects of people's lives. Individuals and societies have to make personal and ethical decisions about a range of socio-scientific issues (e.g, genetic engineering, reproductive technologies, food safety) based on information available through the press and other media. Often accounts of new developments in science report equivocal findings or contested claims. Evaluating such reports is not straightforward requiring the ability to assess whether the evidence is valid and reliable, to distinguish correlations from causes, and to assess the degree of risk (Millar & Osborne, 1998; Monk & Osborne, 1997). Within the context of a society where scientific issues increasingly dominate the cultural landscape, where social practices are constantly examined and reformed in the light of scientific evidence, and where the public maintain an attitude of ambivalence (Giddens, 1990) or anxiety about science (Beck, 1992), there is an urgent need to improve the quality of young people's understanding of the nature of scientific 'argument'. An important task for science education, therefore, is to develop children's ability to understand and practice scientifically valid ways of arguing, and enable them to recognise not only the strengths of scientific argument, but also its *limitations* (Osborne & Young, 1998). Hence, the research discussed in this paper, seeks to study whether young people's quality of 'argument' about scientific issues and their critical capabilities can be enhanced in science lessons. In doing so, it builds on previous research into young people's epistemologies of science (Driver et al, 1996) and the conduct of group discussion in science lessons (Alexopoulou & Driver, 1997)

## Previous research on argument

Over the past few decades certain influential educational projects have all laid foundations for the work on argumentation in science lessons. These projects have promoted independent thinking, the importance of discourse in education and the significance of co-operative and collaborative group work (e.g, Rudduck, 1983; Barnes, 1977; Cowie and Rudduck, 1990; Solomon, 1990, Ratcliffe, 1996). In addition to these projects, a body of relatively unintegrated research concerning argumentative discourse in science education has begun to emerge (e.g, Russell, 1983; Geddis, 1991; Alverman et al., 1995; Boulter and Gilbert, 1995; Hammer, 1995; Means and Voss, 1996; Mitchell, 1996; Mason, 1996; Herrenkohl and Guerra, 1995; Herrenkohl et al., 1999). Perhaps the most significant contribution to this literature has come from Kuhn (e.g, (Kuhn, 1991)) who explored the basic capacity of individuals to use reasoned argument. Kuhn investigated the responses of children and adults to questions concerning problematic social issues. She concluded that many children and adults (especially the less well educated) are very poor at the co-ordination of evidence (data) and theory (claim) that is essential to a valid argument. More recent work by Hogan and Maglienti (2001) exploring the differences between the reasoning ability of scientists, students and non-scientists found, likewise, that the performance of the latter two groups were significantly inferior.

Koslowski (1996), who is critical of Kuhn's emphasis on covariation, was less doubtful of young people's ability to reason pointing to the fact that theory and data are both crucial to reasoning and interdependent and that lack of knowledge of any relevant theory often constrains young people's ability to reason effectively. Whilst this is an important point, what it suggests is that scientific rationality requires a knowledge of scientific theories, a familiarity with their supporting evidence and the opportunity to construct and/or evaluate their inter-relationship. Kuhn's research is important because it highlights the fact that, for the overwhelming majority, the use of valid argument does not come naturally. The implication that we draw from the work of Kuhn and others is that argument is a form of discourse that needs to be appropriated by children and explicitly taught through suitable instruction, task structuring and modelling. Just giving students scientific or controversial socio-scientific issues to discuss will not prove sufficient to ensure the practice of valid argument which needs to be fostered by teachers. Similar conclusions were reached by Hogan and Maglienti (2001:683) who argued that 'students need to participate over time in explicit discussions in the norms and criteria that underlie scientific work'

Hence our focus has been upon the pedagogical practices that support argumentation and foster students' epistemological development. And, whilst general advice concerning how to structure successful discussion and argumentation can be found in the literature (e.g, (Dillon, 1994)) – only a little has been situated within the specific context of the science classroom.

A significant problem confronting the development of argumentation in the science classroom is that it is fundamentally a dialogic event carried out among two or more individuals. Scott (1998)), in a significant review of the nature of classroom discourse shows how it can be portrayed to lie on a continuum from 'authoritative', which is associated with closed questioning and IRE dialogue, to 'dialogic' which is associated with extended student contributions and uncertainty. However, the combination of nature of the power relationship that exists between science teacher and student and the rhetorical project of the science teacher which seeks to establish the consensually agreed scientific world-view with the student, means that opportunities for dialogic discourse are minimised. Hence, introducing argumentation will require a shift in the normative nature of classroom discourse. Change will require teachers have to be convinced that argumentation is an essential component for the learning of science. In addition, they require a range of pedagogical strategies that will both initiate and support argumentation if they are to adopt and integrate argumentation into the classroom.

At the core of such strategies is the requirement to consider not singular explanations of phenomena but *plural* accounts (Monk & Osborne, 1996, Driver, Newton & Osborne, 2000). Students must, at the very least spend time considering not only the scientific theory but an alternative such as the common lay misconception, i.e. that all objects fall with the same acceleration v the notion that heavier things fall faster. Such contexts can also be social considerations of the application of science such as the use of animals for drug testing, problem-based learning situations, or computer mediated situations such as the material developed by the WISE project (Bell & Linn, 2000), amongst others.

The evidence that exists suggests that argumentation is fostered by a context in which student-student interaction is permitted and fostered. For instance, Kuhn, Shaw, and Felton (Kuhn, Shaw, & Felton, 1997) in testing the hypothesis that engagement in thinking about a topic enhances the quality of reasoning about the topic, found that dyadic interaction significantly increased the quality of argumentative reasoning in both early adolescence and young adults. Likewise, the work of Eichinger et al. (1991) & Herrenkohl et al. (1999) found though that bringing scientific discourse to the classroom required the adoption of instructional designs that serve permit students to work collaboratively in problem solving groups. Some of the research on discourse points, too, to the importance of establishing procedural guidelines for the students (Herrenkohl, Palincsar, DeWater, & Kawasaki;1999). The point to make is that *both* epistemological *and* social structures in the classrooms are important factors for designing inquiry activities that foster argumentation. Thus, whilst one element is the need to provide students access to not a singular world-view but to plural accounts of phenomena and the evidence that could be used in an argument, of itself, that is not sufficient as the second element is a context which foster dialogic discourse. This we see as requiring the use of techniques such as student presentations, small-group discussions couple with guidelines and assistance that support the appropriation of argumentation skills and discourse. In the work reported with this paper we have worked initially with a group of 13 teachers to explore and develop their practice at initiating argumentation in the classroom, and then in the second year with a subset of 6 teachers to explore what effect such activities had on the classroom discourse and student use of argument. In developing materials and strategies for argumentation, we have used, therefore these elements as guiding principles which underlie the approach and design of all that we have sought to do.

## Research Objectives

We believe that promoting the practice of 'argument' in science lessons requires the development of appropriate pedagogical strategies that offer practical guidance for teachers. Furthermore, the benefit of such guidance needs to be assessed through empirical studies. Our research was seeking, therefore to:

(i) identify the pedagogical strategies necessary to promote 'argument' skills in young people in science lessons;

(ii) trial the pedagogical strategies and determine the extent to which their implementation enhances teachers' pedagogic practice with 'argument';
(iii) determine the extent to which lessons which follow these pedagogical strategies lead to enhanced quality in pupils' arguments.

Achieving these objectives, and helping pupils to comprehend the argumentative nature of science, would, we believe, contribute to enhancing the public understanding of, and engagement with, science. For they would enhance their understanding of the role of argument in constructing the link between data, claims and warrants, and students' ability to critically assess reports about science.

## Our analytic perspective upon argument

Assuming, as the research evidence suggests, that a context that fosters and develops students' use of argumentation can be established, then what can teachers learn by listening to these conversations and how can they foster and improve the quality of argument? Essentially, how can they respond formatively to assist their students and develop their reasoning? How, for instance, can they identify the essential features of an argument? How are they to judge that one argument is better than another? And how should they model arguments of quality to their students? Before we can ask teachers to engage their students in argumentation and use the information they acquire from the process to plan subsequent lessons or evaluate students learning, it is essential to provide some theoretical guidance to answer such questions. Thus, an important component of this research has been the need to adopt and develop a set of criteria to analyse both the content and the form of children's arguments.

In our analysis of argument in this research we have chosen to focus on the form of argument rather than its content. This is because we believe that engaging in the *process of argumentation* is an *a priori* necessity to any examination of its content. Thus, helping students to construct elaborated arguments, albeit fallacious, will provide vital insights into the form and type of reasoning that underlies science and the first stage to developing their thinking and reasoning skills. Developing their ability to evaluate and critique such arguments is, therefore, a secondary process that builds on students evolving ability to construct coherent links between claims, warrants and data.

In our work, despite examining other models of argumentation (Walton, 1996), we have chosen to use the analytic framework developed by Toulmin (1958). His model of argument was one of the first to challenge the 'truth' seeking role of argument and consider, instead, the rhetorical elements of argumentation and their function. For Toulmin, the essential elements of argument are claims, data, warrants and backings. Normatively, any argument relies on an evidential base which consists of supporting data whose relationship to the claim is elaborated through the warrant, which in turn, may be dependent on a set of underlying theoretical presumptions or backings. Arguments may be hedged with qualifications to show the limits of their validity and are commonly challenged by querying the data, warrants or backings. In practice, arguments are field dependent. As in practice, the warrants and backings used to make claims are shaped by the guiding conceptions and values of the field. Toulmin's model has been used as a basis for characterising argumentation in science lessons (Russell, 1983) and is implicit in a coding system (Kuhn et al., 1997; Pontecorvo, 1987) that we will draw on. In addition, following Pontecorvo, we have focussed on the epistemic operations adopted by students—that is their reasoning functions and strategies. These are the salient cognitive operations, produced by the speaker, which correspond to strategies which are more or less effective for constructing valid argument. Features which we have concentrated on, therefore, in the analysis of argumentation in both scientific and socio-scientific contexts, include: the extent to which students have made use of data, claims, warrants, backings and qualifiers; and the extent to which they have engaged in claiming, elaborating, reinforcing or opposing the arguments of each other.

## The Research Programme

*General features of the research*
A group of teachers interested in collaborating with us was initially established for some preliminary work in the area. From this group, 13 were selected - our principal criteria being the experience and confidence of the teachers, as the work would involve a degree of risk on their part, drawn from schools that had a broadly representative sample of pupils of average academic ability. The teachers involved in the study incorporated a series of nine argument-based lessons, approximately once a month, involving focussed discussions relevant to the National Curriculum science during the first year. The first and ninth lessons were devoted to discussion of a socio-scientific issue of whether zoos should be permitted whilst the remaining lessons have been devoted solely to discussion and argument of a *scientific* nature. Our initial work with teachers led to the choice of students in Grade 8 as the most suitable because of the freedom from examination constraints.

Teachers were initially provided with a set of materials drawn from a trawl of the literature, and our own ideas, for use with students. These aimed to develop their knowledge and capabilities with scientific reasoning by examining evidence for/against a theory, e.g. the particle hypothesis, the explanation of day and night. Other activities have focussed on sets of data, their interpretation and the conclusions that can be drawn from them. Resources for teaching all of these lessons have also been developed by teachers.

The research has been conducted in essentially two phases. In the first year (Sept 99 – Sept 2000), we have sought to focus on developing the skills of the teacher and the materials for use in argument-based lessons. To this end, we have video and audio-recorded the teacher at the beginning of year 1 and year 2 and systematically analysed these transcripts to evaluate the characteristics of their approach to argumentation, to see if there is an identifiable measure of their progress. We have also taped and transcribed two groups in each class to develop a schema for evaluating the quality of their argumentation. During that time, they have also attended 6 half day meetings, held at King's College London, to discuss and share pedagogical strategies for teaching such lessons, develop materials and to develop their understanding of our theoretical perspective on argument. In the second phase of the project (Sept 00 – Sept 01), we have worked with a reduced subset of 6 teachers and asking them to repeat the process. Support in this phase was reduced to three half day meetings across the year and in situ feedback provided whenever a visit was made for the purpose of data collection. In addition, another set of classes, taught by the same teacher, has been used as a control. The focus of our analysis in this stage has been on the recordings and transcripts of the discussions by pupils to see if there was any improvement in the quality or quantity of argument. The intention of this paper, is to summarise the salient findings that have emerged from the work of the project and explore their implications.

## Developing Teacher’s Practice

***Materials and Support for Argument***
One of the features of this work was to try and develop materials that could be used for supporting argumentation in the classroom. The essential precursor to initiating argument

is the generation of difference or plural theoretical interpretations. Hence, a common framework for all the materials we have developed has taken the form of presenting competing theories to students for examination and discussion. These have been presented to pupils to read in small groups and then discuss. However, initiating argument also requires a resource or evidence to enable the construction of argument. Hence, commonly, competing theories have been accompanied by evidence which students are asked to use to to decide whether the evidence presented supports theory 1, theory 2, both or neither – an example of which is shown beneath.

***Example 1: Competing Theories A***

Theory 1: Light rays travel from our eyes onto the objects and enable us to see them.

Theory 2: Light rays are produced by a source of light and reflect off objects into our eyes so we can see them.

*Which of the following pieces of evidence supports Theory 1, Theory 2, both or neither. Discuss.*

a. Light travels in straight lines
b. We can still see at night when there is no sun
c. Sunglasses are worn to protect our eyes
d. If there is no light we cannot see a thing
e. We 'stare at' people, 'look daggers' and 'catch people's eye'
f. You have to look at something to see it.

In addition, sessions with the teachers in the first year of work aimed to develop their theoretical understanding of argument and explored how argument could be supported in the classroom through the use of argument prompts. Fuller details can be found in Osborne, Erduran, Simon & Monk (2001).

***Data Sources***

The data sources were verbal conversations of teachers and students audio-taped in classes of year 8 (age 12-13) students. In year 1, we worked with 13 teachers videoing two lessons – one at the beginning of the year and one a year later. At this stage of our work the focus was on argumentation in socio-scientific context. Hence, the main task within these lessons was an exploration of arguments for, and against, the funding of a new zoo. Each lesson had 3 sections. At the onset, the teacher distributed a letter outlining the task and there was a whole class discussion on the pros and cons of zoos. Then the students were put into groups and asked to come to some consensus about whether or not the zoo should be built. Finally, in the last phase of the lesson, the groups made presentations and shared their opinions with the rest of the class. As homework, students were typically asked write a letter or compose a poster that would communicate their arguments. Needless to say, there was considerable variation between teachers in the detail of each individual teacher's implementation

The schools chosen for this work were located in the Greater London area and ranged from urban to suburban settings with mixed ethnic groups. Three schools were all-girls schools, one school was private, and 12 schools were public. Audiotape recorders were wired on the teachers so as to capture their verbal contribution to the lesson as well as their interactions with students during the group format. In addition, two groups of four pupils were selected and their conversations recorded.

In the second year of our work, a smaller subset of teachers were selected on the basis that they were individuals who were, for a variety of reasons, considered to have made more progress in their ability to facilitate and incorporate argumentation in their pedagogical practice. As well as recording their second attempt at teaching the zoo lesson, this phase sought to examine their ability to incorporate and use argumentation in a scientific context and to compare the development of the experimental group with a control. Thus in addition to the data collected from the 6 lessons exploring arguments for and against the establishment of a new zoo at the beginning of year 2, data were collected from the same teachers teaching the same lesson to a control group; and from the same teachers implementing argument in a scientific context. In each of the lessons, a tape was collected from the two teachers and two selected groups of four pupils.

In the intervening period, teachers taught a minimum of 8 lessons using argument in a scientific context. Because of the contingent nature of individual schemes of work and school curricula, it was impossible to expect that all teachers taught the same lessons. Thus using a general set of frameworks that had been developed to support argumentation, teachers wrote their own lesson material to facilitate the use of argumentation in that was appropriate to the content of their curricula.

At the end of the year, another set of data was collected from the same group of 6 teachers teaching argumentation to the intervention class in a scientific context and in a socio-scientific context. Again, data were collected by audiotaping the teachers and videoing the same set of four pupils, wherever possible (12 teacher tapes, 24 pupil videos). In addition, a set of exactly similar data was collected from the control group for comparison purposes (6 teacher audiotape, 12 pupil videos). In addition, field notes were collected of salient features of the lesson and the materials used by the teachers.

Finally, a semi-structured interview was also conducted with the teachers at the beginning of each year to ascertain their views on argumentation and to explore their reflections on the zoo lesson. These data sought to identify teachers' perceptions of the salience of teaching argumentation to pupils and their understanding of its significance. Such interviews were also used as a means of identifying any changes that had occurred over the year. Each interview was recorded and transcribed. The interviews included questions on how teachers felt about their zoo lesson and what they viewed as important for student participation and learning of argumentation. No final interview was conducted but a group discussion was held at the end of the project which was recorded and transcribed.

***Analyses***

All of the audiotapes were transcribed and analysed to determine the nature of argumentation in the whole class and the small group student discussion formats. The analysis of the teacher transcripts sought to answer our second question – that is what development had taken place in the teachers' use of argumentation in the classroom, whilst the analysis of the student group discussions sought to answer our third question – that is what development had occurred in the quality of the pupils' ability to argue and reason in a scientific and socio-scientific context.

*Identification of arguments*

The approach taken to the analysis of the teachers' discourse was to use the Toulmin (1958) model of argument as an analytical framework to identify the salient features of argument in the speech. This required an extended process of defining and elaborating how this framework should be interpreted and used. The following section illustrates our method of coding the transcripts using TAP as a guiding framework. In the case of the following example:

*‘Zoos are horrible, I am totally against zoos’*

our focus would be on the substantive claim. In this case, the difficulty lies in the fact that both can be considered to be claims i.e.

*‘Zoos are horrible’ and ‘I am totally against zoos’*

The question for the analysis then becomes which of these is the substantive claim and which is a subsidiary claim. Our general view is that there is inevitably a process of interpretation to be made and that some of that process is reliant on listening to the tape and hearing the force of the various statements here. Part of this might be substantiated by Austins’ (1976) distinction between locutionary statements – ones which have an explicit meaning and perlocutionary statements – ones which have implicit meaning. And the perlocutionary force with which these statements are distinguished is an aid to resolving which is intended as the substantive claim.

Here our reading is that the emphasis lies on the second part of the statement because the task context demands a reference to a particular position (for or against zoos) and that this is therefore the substantive claim. In choosing to use TAP in this manner, we have developed a good reliability (more than 80 %) between the coders.

As an example, we’ll consider the following case between the student and the teacher.

S I’ve got a con. If the animals are always walking about in the same places they might get angry and be dangerous.

T Right, this is an anti, is it? So, being caged may alter their behaviour.

The position represented by the student is ‘against zoos’ expressed as a claim in the phrase: “I’ve got a con.” The student further adds to this claim by saying that “if the animals are always walking about in the same places, they might get angry and be dangerous.” This elaboration, we consider as data to support his claim. The teacher’s subsequently interprets and justifies the choice for data by saying that “being caged may alter their behaviour.” We regard the teacher’s contribution as the warrant to the argument being constructed. Such a co-construction of arguments between students and teachers was typical in all the transcripts we have studied in our project. Thus, our approach to the work was always to seek to identify, through either a careful reading of the transcript, or alternatively, listening to the tape, what constituted the claim. Once, the claim was established, the next step was the resolution of data, warrants and backings. Our view here is that a necessary requirement of all arguments that transcend mere claims are substantiated by data. Therefore, the next task is the identification of what constitutes the data for the argument which is often preceded by words such as ‘because’, ‘since’ or ‘as’. The warrant, if present, is then the phrase or substance of the discourse which relates the data to the claim. For instance, in the following argument which is co-constructed by teacher and student:

T Yeah. Can you think of any others for?
S The zoo has like endangered species.
T Yes, if they are becoming extinct or endangered then it becomes a way of protecting endangered species doesn't it?

A claim is advanced that they are for zoos using the data that that 'the zoo has endangered species which is substantiated by the warrant that 'if they [animals] are becoming extinct or endangered, then it [the zoo] becomes a way of protecting endangered species.' Using this approach to the analysis of argument, we were able to achieve inter rater reliability in excess of 80%.

*Lesson structure and features of teacher talk*
Lesson structures were determined by viewing video material of each Zoo lesson and noting the main lesson phases and time spent in whole class and small group formats. Viewing was accompanied by a study of the transcript of the audiotape. Extracts of teacher talk focusing on aims and organisation of argument activity or facilitation of the processes of argument were identified and summarised for each phase of the lesson. For example talk focusing on a lesson aim, such as the extract beneath was coded as 'introduces aim of task, to produce good arguments'.

> 'And we are trying to think this morning about what sorts of things will make a good argument. How are you going to persuade this agency that yes, the zoos should be opened? You need to put forward strong arguments, or if you don't want it, strong arguments against the zoo.'

Such talk is an indicator of the ways in which the teachers view the nature and teaching of argument, and how they view the learning process. In essence it provides insights into teachers' beliefs, practices (Fullan, 2001), value congruence and knowledge and skills (Harland & Kinder, 1997) and how these may have changed in one year.

*Interviews*
Using a grounded approach, an initial coding schema was developed to capture the major themes, with reliability checks undertaken by two members of the research team. Following our analyses of TAP and teacher talk, these coded themes were examined and cross-referenced to the data from the lessons. A particular focus of analysis were comments relevant to teachers' actions and talk about argumentation including the ways in which they conceptualised the teaching of argument, the decisions they made about teaching strategies, and their reflections on students' progress and performance with argumentation.

## Results

*Changes in the Teachers*
Each teacher implemented the same activity one year apart with comparable students. The lessons were similar in structure in that there was an introduction, group discussions, group presentations and finally assignment of homework in either case for both years. Typical transcript data on two teachers for the two years are summarized in Figures 1 and 2. The x-axis indicates the features of Toulmin's argument pattern (TAP) that were used in different combinations. For example, CD indicates those instances where a claim (C) was coupled with data (D). CDWB indicates that there was a claim, data, warrant and backing as part of one argument presented. The y-axis illustrates the frequency of instances that such permutations of TAP occurred within the transcript. In other words, we counted the number of times each sort of TAP occurred in the data across both years for each teacher.

The figures seem to suggest several trends. First, there was argumentation discourse in the classroom across both years. In the figures we see specific examples of to what extent each teacher's class is involved in the construction of which aspect of TAP. In other words, we can trace the nature of different permutations of TAP in either teacher's implementation of the lesson. Second, each teacher carries out/uses argument in the same way across the two years. In other words, the trends across the use of different permutations of TAP are similar across two years. This would suggest that there is no common pattern and that the use of argumentation is teacher dependent – there are no universals.

**Figure 1: Sarah Year 1 vs 2**

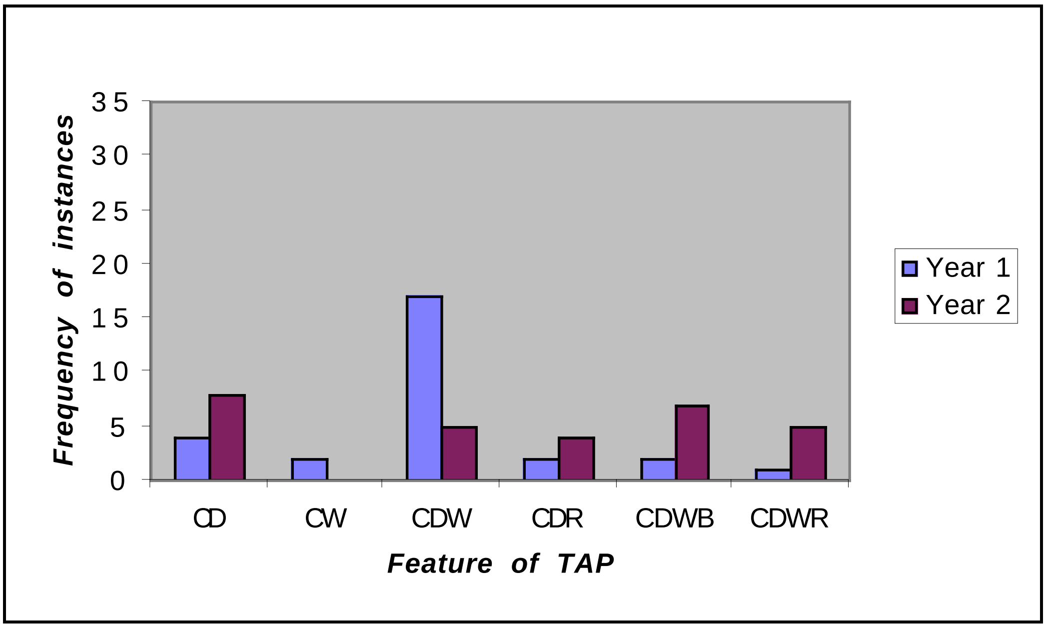
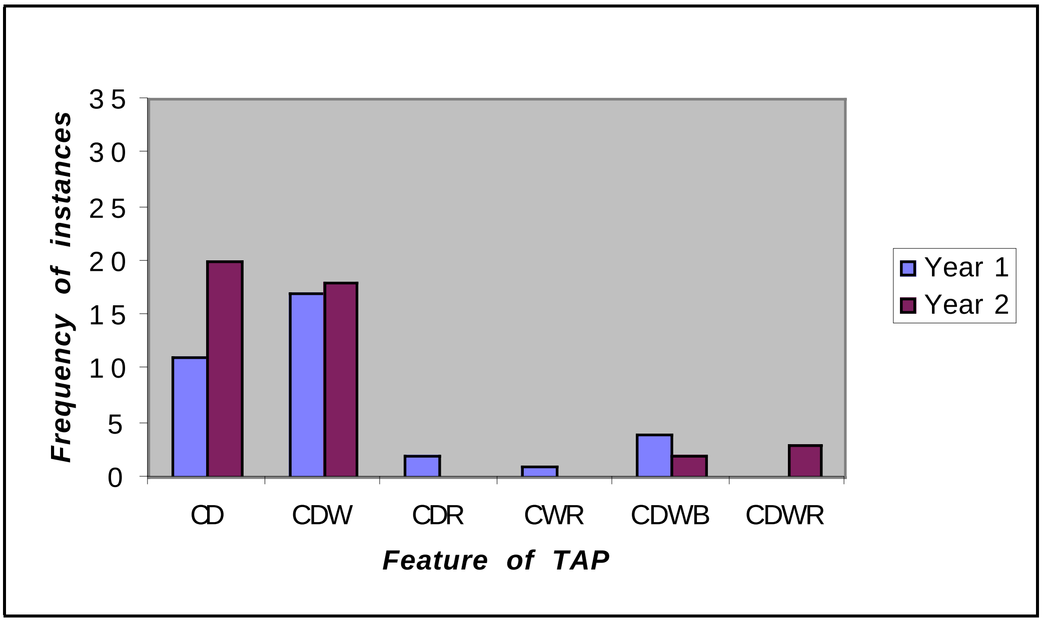



**Figure 2: Matthew Year 1 vs 2**



Overall, the figures illustrate the nature of progression of teachers across two years. Going from left to right on the x-axis, there is an increasing complexity in the way that TAP is constructed, i.e.inclusion of warrants, backings, rebuttals. Hence, the right side of the graphs indicate an improvement in the nature of arguments. Likewise if there is a shift, for example, from CD (claim-data) to CDW (claim-data-warrant) then this shift across two years is taken as an improvement in the arguments constructed in the class format. Using this approach to analysis for all the teachers, we have produced a profile of the discourse of argumentation for all the teachers across the two years (Table 1).

**Table 1: Profile of argumentation discourse for the classrooms of all the teachers from year 1 to year 2.**

| *Teacher* | *Year* | *CD, CR* | *CDW, CDR* | *CDWR, CDWB* | *CDWBR* | *Sig* |
|---|---|---|---|---|---|---|
| **Bunn+** | Year 1 | 48 | 47 | 5 | 0 | |
| | Year 2 | 59 | 27 | 14 | 0 | * |
| **Drayton** | Year 1 | 41 | 47 | 10 | 2 | |
| | Year 2 | 23 | 31 | 38 | 8 | ** |
| **Evans** | Year 1 | 36 | 43 | 21 | 0 | |
| | Year 2 | 43 | 43 | 14 | 0 | |
| **Frearson+** | Year 1 | 33 | 9 | 49 | 9 | |
| | Year 2 | 52 | 3 | 42 | 3 | * |
| **Henderson** | Year 1 | 0 | 82 | 18 | 0 | |
| | Year 2 | 8 | 44 | 44 | 4 | ** |
| **Kaufman** | Year 1 | 48 | 38 | 14 | 0 | |
| | Year 2 | 25 | 57 | 16 | 2 | ** |
| **Lecky+** | Year 1 | 20 | 70 | 10 | 0 | |
| | Year 2 | 0 | 50 | 50 | 0 | ** |
| **Manning+** | Year 1 | 48 | 32 | 16 | 4 | |
| | Year 2 | 5 | 85 | 10 | 0 | ** |
| **Parkyn+** | Year 1 | 21 | 68 | 11 | 0 | |
| | Year 2 | 28 | 31 | 41 | 0 | ** |
| **Pearn** | Year 1 | 32 | 47 | 16 | 5 | |
| | Year 2 | 38 | 43 | 19 | 0 | |
| **Spokes** | Year 1 | 36 | 48 | 16 | 0 | |
| | Year 2 | 41 | 41 | 14 | 4 | |
| **Terry+** | Year 1 | 31 | 57 | 12 | 0 | |
| | Year 2 | 46 | 42 | 12 | 0 | |
| | | | | | | |
| **Totals** | | | | | | |
| **Year 1** | | 394 | 588 | 198 | 20 | |
| **Year 2** | | 368 | 497 | 314 | 21 | ** |

+Teachers with whom we continued working in year 2 of the project.

The data show how the discourse of the classroom is dominated by arguments that contain fewer elements of TAP and are less elaborated. The important detail, nevertheless, is that there is a significant ($p<0.01$) improvement between year 1 and year 2 with more elaborated arguments being used by some or all of the teachers. Closer analysis shows that this change is a result of the changes made by 8 of the twelve teachers and that for 4 teachers there was no significant change. At the end of year 1 of this project, it was necessary to select 6 teachers to continue for the second year- a decision which was made on the basis of our knowledge and experience of working with these teachers as this analysis had not been undertaken yet. Two teachers who we wished to continue working with were unable because they had taken up new posts either within or at another school, whilst one working with the other teacher who had shown significant change had proven to be problematic. Hence, one of the teachers selected for the second year of the project, was a teacher who, from this analysis, had exhibited no significant change in their practice over the course year.

Analysis of teachers' classroom talk and interview data suggests some possible explanations for the differences between their TAP profiles, and the variation in shift to the right from one year to the next. The two profiles shown above are not only quite different in terms of TAP, but also in terms of change, Sarah's profile shows a marked shift to the right whereas Matthew's shows very little change from one year to the next.

A critical difference in the classroom talk of these two teachers emerging from the analysis of their transcripts and videos of the lessons lay in the emphasis placed on counter-argument. Sarah introduced this aspect of argumentation and encouraged it strongly. Matthew, however, entirely omitted reference to opposition and counter-argument from his teaching. He did not encourage students to rebut claims or produce further evidence in the face of opposition. The absence of this feature of practice suggests a possible explanation for the difference between the two TAP profiles. One would expect more backings and rebuttals in arguments that are constructed to defend opposing positions, and these can be seen to be more frequent in the argumentation of Sarah's lessons.

Sarah's classroom talk demonstrated more shifts in emphasis across the two years than Matthew's, which remained similar from one year to the next. Sarah communicated the aim of the task in year 1 as 'thinking of ideas', whereas in year 2 she immediately focused on the process of producing a good 'strong' argument with evidence. A second change occurred in the way she encouraged students to focus on good argument, opposition and counter-argument, with much more emphasis in year 2. A third change in Sarah's practice occurred in the way she set up the group task in year 2. She introduced role-play, where students were to be different members of the community, and tried to encourage them to anticipate opposing arguments:

> First thing you need to do in your pair is decide whether that person will agree with the opening of the zoo or be against the zoo. Then what you need to do is to think of what that person's main argument will be and what the evidence they will have to support their idea, you then need to give another argument they might have and the justification they might have for that. And finally, and this is quite important, you need to think what someone opposing the argument might say. What their argument would be - the person that's going to disagree with you. What might their argument be? And how would you persuade them you were right? That's very important, that last bit.

Analysis of Sarah's interview provides further insights into her changing practice. Though she was aware at the beginning of the project of the value of what she termed 'saying the opposite', she developed this idea much more during the course of the year. In terms of her own professional development, Sarah thought that teaching argumentation had made her 'a lot more conscious' about what she was saying and what she was trying to achieve in her teaching. She also valued argumentation for the way it provided challenge for the students. Her attempt at role-play in year 2 shows she was willing to take risks and try new approaches that she thought would provide challenge, a development recognised as indicative of teacher change (Loucks-Horsely et al, 1998).

The changes in Matthew's talk were less dramatic, demonstrating a shift from telling students about evidence to evoking more extended answers from the students themselves. Matthew's changes did not extend the processes of arguing, rather, they resulted in a more refined pedagogy emphasising the same processes. Throughout both years Matthew had a strong focus on the use of evidence to justify arguments, and in the second interview, the extract beneath shows that he judged his own progress in terms of how he valued the use evidence:

> I now look much more critically at, both in teaching and setting homework, for questions which require more reasoning and evidence….whereas in the past I might have thought - well, that's going to be too difficult for them… I think I appreciate the importance of trying to ensure that students see a difference between a statement and a reason for that.

## Argumentation in the Classroom

In evaluating the group discussions for argumentation of good or better quality, our essential position is a commitment to the development of rational and analytic thought and discourse. In that we share with Toulmin a belief that:

> A [person] demonstrates his rationality, not by a commitment to fixed ideas, stereotyped procedures, or immutable concepts, but by the manner in which, and the occasions on which, he changes those ideas, procedures, and concepts. (Toulmin, 1972, p. v)

Changing one's thinking is not possible unless there are opportunities to externalise your thinking and hold up one beliefs and their justification for inspection by others. In that sense, we feel that one of the major achievements of our work has been to permit and encourage deliberative and dialogical interactions between pupils. Such opportunities are rarely a feature of school classrooms which, rather, are dominated by monological interactions and triadic dialogue (Ogborn, 1996, Lemke, 1990). Hence, in our preliminary analysis of the data obtained from the small groups of pupils in the second year, we sought to see whether had been opportunities for pupils to engage in deliberative discussion of a dialogic nature. This was done by examining the transcripts and categorising the talk into one of four categories: teacher talk; student talk which advanced claims only; student talk which consisted of claims *and* grounds; and student talk which was non-argumentative which was of a procedural or off-task nature. A sample of such talk with its coding is given beneath

| | | |
|---|---|---|
| Teacher | OK. So you are saying that if the moon is light the light is fire and fire needs oxygen. All right. That's kind of added to the stuff......... you have actually talked about...... but what Mark was saying about the shadow and light, the moon passes through a shape, it is in the shadow from the earth, and you can't see it. So we know it doesn't give out light. B, the moon shrinks . Let's discuss this one. Michael..... why is the moon.. | *Teacher talk* |
| Pupil | The moon is solid and it can't expand. | *Student Claim* |
| Teacher | It can't expand. What were you saying about water? | *Teacher talk* |
| Pupil | It can't expand because it hasn't got water on it. | *Student Claim with Grounds* |

Counts of the number of words uttered were then made and a sample of results for one for all the tapes analysed so far is shown in Table 2..

**Table 2: Table showing percentages of group discourse of an argumentative nature**

| | *LESSON* | *Zoo Exp* % | *Zoo Control* % | *Science 1* % | *Science 2* % | *Leisure Centre Exp* % | *Leisure Centre Control* % |
|---|---|---|---|---|---|---|---|
| Type of Discourse | Claims | 3 | 3 | 3 | 4 | 5 | 2 |
| | Grounds | 25 | 21 | 14 | 11 | 16 | 20 |
| | Non-Argument | 8 | 8 | 18 | 9 | 12 | 6 |
| | Teacher | 64 | 68 | 65 | 75 | 67 | 72 |

The data presented in this table illustrate several features. First, previous research has occupying 5% or less of all discourse. These data, however, show that in these lessons argumentative discourse (claims, claims + grounds) now occupies 14% - 28% of the total discourse which is a major shift in the normative form of authoritarian dialogue that permeates science classrooms. The second notable feature of these data is that argumentative discourse is significantly less for argumentation in science lessons than it is for socio-scientific lessons suggesting that initiating argument in a scientific context is harder and more demanding for both pupils and teachers. The data also suggest that there is little difference in the amount of discourse between the experimental groups and the control groups indicating that the amount of argumentative discourse is a feature of the teachers structuring and organisation of the lesson rather than any feature of the groups.

## Assessing the quality of argumentation

In seeking to answer our third research objective we have focussed on the discussions between pupils. In each class, two groups of 3 to 4 pupils were identified by the teacher and their discussions were taped and transcribed. The transcripts were then searched to identify genuine episodes of oppositional analysis and dialogical argument. Opposition took many different forms and many arguments where co-constructed where students provided data or warrants for others' claims. Transcripts of group discussions (2 groups per teacher) were examined to determine the number of episodes of explicit opposition in student discourse. In other words, the instances where students were clearly against each other were traced. Typically these instances were identified through the use of words such as "but", " I disagree with you", "I don't think so" and so on. Once these episodes were characterized in the group format, they were re-examined for the interactions among the students in terms of who was opposing whom, who was elaborating on what idea or reinforcing or repeating an idea. In this fashion, the pattern of interaction for each opposition episode was recorded for two groups from each teacher's classroom. The main processes identified in such episodes were opposing claims by other (O), elaboration (E) or reinforcement (R) of a claim with additional data, warrants, advancing claims (C) or adding qualifications (Q). Such analysis helps to identify the features of the interaction and the nature of the engagement between the students.

*The Nature of Opposition*

Each oppositional episode was analysed using TAP to identify the principal components of an argument being deployed by the individuals in the group. In these episodes, claims were not always clearly stated but implied or extracted through questioning and the dialogue takes several iterative readings to identify its principal features. All episodes were read independently by two coders who then met to compare their analysis and resolve differences in interpretation. These oppositional episodes are characterised by a diverse range of arguments and some examples are provided later to illustrate the nature of our analysis and the results. The essential issue raised by these episodes is how to define their quality. What, for instance, makes one better than another? To answer this question, we have developed a framework for the analysis of quality which outline beneath.

One of the features of previous research is that nearly all researchers have found the application of the Toulmin schema problematic, as his criteria do not assist the ready resolution of data from warrants from backings resulting in poor reliability. Yet, in our work, we found little problem in the identification of claims or rebuttals but the distinction between data and warrants was often hard to make as it depended on contextual information which was either absent from the transcript or impossible to determine unambiguously from the video. Our schema for argumentation therefore transcends this problem by looking at argument from a framework which avoids the necessity to resolve the problems which arise from the use of a generalised analytical framework in a context where meaning may be indeterminate.

In establishing this framework, we have drawn two major distinctions. The first is does an argument contain any reasons i.e. data, warrants or backing to substantiate its claim, as transcending mere opinion and developing rational thought is reliant on the ability to justify and defend one's beliefs. Hence, we see the simplest arguments are those consisting of a claim, and the next level are arguments accompanied by data or warrants followed by arguments consisting of claims, data, warrants and rebuttals.

Episodes with rebuttals are, however, of better quality than those without. For individuals engaged in episodes without rebuttals remain epistemically unchallenged. The reasons for their belief are never questioned and are simply opposed by a counter claim that may be more or less persuasive but is not a substantive challenge to the original claim. At its worst such arguments are reducible simply to the enunciation of contrasting belief systems. For instance, the confrontation between a creationist and a Darwinist without any attempt to rebut the data or the warrants of the other would have no potential *to change the ideas and thinking* of either. For the basis of their belief rests on the data and warrants they use as justification. Only arguments which rebut these components of argument can ever undermine the belief of another. Oppositional episodes without rebuttals, therefore, have the potential to continue forever with no change of mind or evaluation of the quality of the substance of an argument. Thus, arguments with rebuttals are an essential element of better quality arguments and demonstrate a higher level capability with argumentation. This analysis has led us to define quality in terms of a set of 5 levels of argumentation as follows:

**Table 3: Analytical Framework used in for assessing the quality of argumentation**

| | |
|---|---|
| Level 1: | Level 1 argumentation consists of arguments that are a simple claim v a counter claim or a claim v claim |
| Level 2: | Level 2 argumentation has arguments consisting of claims with either data, warrants or backings but do not contain any rebuttals. |
| Level 3: | Level 3 argumentation has arguments with a series of claims or counter claims with either data, warrants or backings with the occasional weak rebuttal. |
| Level4: | Level 4 argumentations shows arguments with a claim with a clearly identifiable rebuttal. Such an argument may have several claims and counter claims as well but this is not necessary. |
| Level 5: | Level 5 argumentation displays an extended argument with more than one rebuttal. |

The following set of examples are provided, then, to illustrate how our analysis has been applied to the data.

**Episodes without rebuttals**

The first example is a short simple disagreement, the second is much more complex as it involves one student providing a relatively sophisticated argument which does not appear to be understood by his opposers, who argue at a different level.

*Example 1*

O R R

S1: Right For
S2: We are not for it
T: First, write in then, then write things around it
S2: I am not for it.

This episode is simply a claim for zoos - 'right for' followed by a counter claim ' we are not for it' repeated by 'I am not for it', making it an example of weak argumentation as the claim is unsupported and there are no rebuttals. Instead, there is simply a counter claim and as such, there is no potential for the justification of belief to be examined and, hence, no possibility or resolution. This episode can be summarised simply as a claim v counter claim. As such it is an example of a level 1 argumentation.

*Example 2*

**O**

S1: I don't think they would hurt them in a professional zoo.

S2: But they might scare the other animals by seeing some sedated animal being dragged off.

**O**

S1: Maybe stress.

S3: Not stress. Distress.

Here, what we have is a claim that professional zoos would not hurt animals which is countered by claim that animals in zoos might be scared (claim) as they would see other sedated animals being dragged off (data). Thus, our summary of this example is that it consists of:

claim v counter claim + data

Moreover, despite some embedded complexity, as a example of arguing we would contend that it is essentially weak as there is no attempt at a rebuttal (by either party) permitting the justification of belief by both parties to remain unexamined. Therefore, we would consider this to be a level 2 argumentation.

## Episodes with rebuttals

*Example 3*

The episode beneath begins with the implicit claim that zoos are beneficial. The data for this argument is that 'some animals wouldn't be able to breed in the wild' and there is a warrant supplied that this is because 'they may not have enough food'. This claim is further supported or elaborated by the claim that 'the animals need a safe place to live' and the data to support this claim is that otherwise 'they will be at risk from predators'. This second claim is weakly rebutted with a negation which is thinly supported by the data that the risk from predators is just 'nature'. However, as the rebuttal of the proponent's data does not make a clear, self-evident connection to the data supporting the original claim, we consider this to be an example of a weak rebuttal and a level 3 argumentation. A summary of this argument would be that it consists of

claim (+ data + warrant ) + claim (+data) v rebuttal (+ data )

| | | |
|---|---|---|
| O | 1. | Some animals wouldn't be able to breed in the wild, because they may not have enough food. |
| | 2. | No, no, no, because an animal......... |
| E | 3. | Extinction. |
| | 4. | The animal needs a place to live because they would be at risk from other predators. |
| E | 5. | What are you putting? |
| | 6. | A place to live, or they would be at risk from other predators. |
| O | 7. | They might not have enough food to eat. |
| O | 8. | But I mean, that's nature, one has to.... |
| | 9. | But we are for it |
| | 10. | OK. |

***Example 4***
Our fourth example is an argument taken from a scientific context where pupils have been given alternative theories to explain the phases of the moons which are on numbered card, A, B, C, D, which are referred to in the dialogue.

| | | |
|---|---|---|
| E E O E | M | ............. A, the moon spins around, so the part of the moon that gives out light is not always facing us. Jamal, A? |
| | J | The moon doesn't give out light. |
| | M | Right, so that's why A is wrong. That's true. How do you know that? |
| | J | Because the light that comes from the moon is actually from the sun. |
| | M | He is saying the light that we see from the moon is actually a reflection from the sun. How do we know that? Mark? |
| | M | Because the moon is blocked by the |

Here, the first pupil advances the claim that it is explanation A appealing to a datum that 'the moon does not give out light'. There is then a rebuttal supplied with supporting data that the 'light that comes from the moon is actually from the sun' and a warrant which is unfinished.

Our summary of this argument would be that it consists of Claim (+ data) v Rebuttal (+ data + warrant).

This schema of analysis enables us to make various comparisons of the performance of the different groups at argumentation. Whilst, our data set is not yet complete, what follows is offered to illustrate the methods that we intend to use in our analysis. Firstly Fig 3 shows the distribution of arguments by level for all of the oppositional episodes currently analysed. In total, we have identified 162 oppositional episodes from 50 groups in 25 lessons. Thus in summary there were, on average, a little more than 3 oppositional episodes per group per lesson.

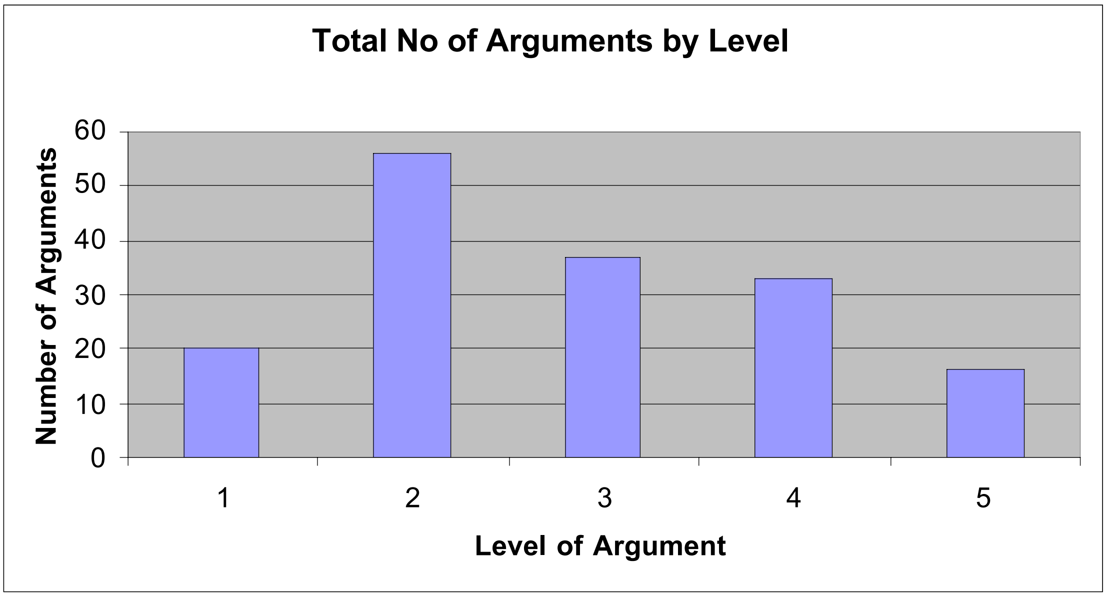



**Fig 3: Chart showing numbers of each level of argumentation achieved**

This chart shows that the largest number of arguments emerging from the data were level 2 (35%). Encouragingly though, 51% of arguments were at level 3 or above and, moreover, only 12% were at level 1. The latter is particularly encouraging as it suggests that only a small minority of arguments developed by pupils did not attempt to offer a rationale for their claims. Level 1 arguments are also problematic in that it is these types of argument that are have the most potential for argumentation which is confrontational reinforcing the lay perception that of 'argument as war' (Cohen, 1995 ) rather than argument as a process of collaborative brainstorming towards the establishment of 'truth' or better understanding.

This method of analysis permits a number of comparisons of the performance of the groups. Firstly, it is possible to compare the distribution of levels achieved across the by the experimental group in the zoo lesson and the first science lesson with those achieved in the last science lesson and the final leisure centre lesson. Table 3 shows such a comparison for the data we currently have.

**Table 3: Levels of argumentation achieved by intervention groups, pre and post-intervention**

| *Lesson* | *Argument Level Achieved* 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| **Zoo & First Science Lesson (Exp Group)** | 8 | 23 | 13 | 10 | 8 |
| **Leisure Centre & Second Science Lesson (Exp Group)** | 6 | 16 | 14 | 16 | 5 |

This analysis (for approximately two thirds of the data shows that there has been a shift towards the end of the intervention to more arguments of higher quality. However, this is not a significant shift.

Likewise, table 4 shows a comparison of the levels of argument achieved in by the groups in the discussion about the merits of zoos and with that 10 months later about whether a leisure centre should be placed in an area of well-established wildlife.

**Table 4: Levels of argumentation (socio-scientific context) achieved by 8 experimental groups in 4 lessons (4 different teachers) at the beginning (Zoo lesson) and end of the year (Leisure Centre lesson)**

| *Lesson* | *Argument Level Achieved* 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| **Zoo Exp** | 4 | 11 | 5 | 4 | 2 |
| **LC Exp** | 1 | 9 | 5 | 12 | 4 |

The difference between these two distributions is not significant although the pattern would again suggest that there were more high quality arguments at the end of the intervention than the beginning.

A similar comparison of the levels of argumentation achieved in the initial zoo based topic and the first argumentation lesson in scientific context shows no significant difference although there is some indication that higher quality arguments are achieved in the zoo lessons.

**Table 5: Comparison of Levels of argumentation (socio-scientific context) achieved by 8 experimental groups in 4 classes with the levels of argument achieved in a scientific context )**

| *Lesson* | *Argument Level Achieved* 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| **Zoo Exp** | 4 | 5 | 4 | 5 | 4 |
| **Science Lesson** | 2 | 9 | 3 | 3 | 0 |

Likewise, a similar comparison of the data we currently have comparing the levels of argument achieved in the end of intervention lessons on the leisure centre and the argument in a scientific context also show no significant difference in the levels of argument. Taken together, these data in this preliminary analysis would suggest that performance at argument may be context independent and that what matters is the opportunity to engage in argument rather than the specific context of its use. Moreover, given that our initial analysis (Table 2) suggests that there is significantly less argumentative discourse in scientific lessons, these data would indicate that the quality of argumentation may be independent of the quantity of argumentative discourse.

## Discussion & Conclusions

In this paper, we have presented our preliminary findings emerging from our work on developing argumentation in school science classrooms, its analysis and the assessment of its quality. Methodologically, we feel our work has made progress on several fronts. First the work has sought to develop with teachers sets of materials that can be used in a structured and focussed manner to facilitate argumentation in the classroom. As a result of this experience, we feel that we have gained some insights into the means of establishing a context which facilitates argumentation in the classroom and we will be attempting to develop and disseminate such materials in the next phase of our project. Second, our work with teachers has led to a change in the practice of the majority of this group leading us to believe that, despite the many obstacles and barriers posed by the demands to implement different and innovative practice, it is possible for science teachers to adapt, change and develop their practice to one where there is a fundamental change in the nature of classroom discourse.

Third, one of the many problems that bedevils work in this field is a reliable systematic methodology for a) identifying argument and b) assessing quality. Our adoption and use of Toulmin has also provided us with a method for recognizing the salient features of argumentation and the components of what are commonly termed the ideas of science and their supporting evidence. ‘Ideas’, on the one hand, consist of hypotheses, theories and predictions that are essentially claims, whilst the data, warrants, backings, rebuttals and qualifiers are the components and conditions of ‘evidence’. The use of these features offers teacher a richer meta-language for talking about science. More importantly, our work using TAP, and our focus on the *argumentation* rather than the content of arguments themselves has enabled the evolution of a workable framework for the analysis of its quality in the classroom. To date most of those working in the field have focussed on the *content* of an argument and its logical coherence. Our preference, in contrast, has been to examine the *process* of argumentation as this is the foundation of rational thought and to examine whether that process can be facilitated and its quality assessed.

Finally, we have illustrated how we can apply this schema to sets of data obtained from teachers implementing argumentation in the classroom. As yet, whilst these data sets do show evidence of positive improvement in the quality of student argument, this change has not been significant. Once the full data set is available, we will have a fuller picture of whether the change has been significant or not. If not, it would suggest that developing the skill and ability to argue effectively is a long-term process – something which only comes with recurrent opportunities to engage in argumentation throughout the curriculum rather than the limited period of 9 months of our intervention.

More significantly, we see our work not in isolation but as part of a growing body of work in this area (Herrenkohl & Guerra, 1995; Herrenkohl & Guerra, 1998; Kelly & Crawford, 1997; Kelly, Drucker, & Chen, 1998) that has begun to explore the difficulties and dilemmas of introducing argument to science classrooms – work which attempts to offer some insights into how practice can be developed. For if science is the epitome of rationality and the commitment to evidence now permeates the discourse of contemporary life, then exposing the nature of the arguments and epistemic thinking that lies at the heart of science is a growing imperative of any contemporary science education that seeks to establish its broader cultural value and significance.

## Acknowledgements

This study was supported by the UK Economic and Social Science Research Council grant number R000237915. In addition, we would like to acknowledge the many teachers who have worked with us on this project and their efforts with this research.

## References


Aikenhead, G. S. (1991). *Logical reasoning in science and technology*. Toronto, Ontario: John Wiley of Canada.

Alexopoulou, E., & Driver, R. (1997). Small group discussions in physics: peer interaction modes in pairs and fours. *Journal of Research in Science Teaching, 33*(10), 1099-1114.

Alverman, D E, Qian, G and Hynd, C E (1995). Effects of interactive discussion and text type on learning counterintuitive science concepts. *Journal of Educational Research*, 88, 146-154.

Beck, U. (1992). *Risk Society: Towards a new Modernity*. London: Sage.

Bell, P., & Linn, M. (2000). Scientific arguments as learning artefacts: designing for learning from the web with KIE. *International Journal of Science Education*, *22*(8), 797-817.

Boulter, C J and Gilbert, J K (1995). Argument and Science Education. In P J M Costello and S Mitchell (eds). *Competing and consensual voices: the theory and practice of argumentation*. Clevedon. Multilingual Matters.

Cowie, H and Rudduck, J (1990). *Co-operative learning traditions and transitions. Volume three of Learning Together - Working Together*. London. BP Educational Service.

Cohen, D. (1995). Argument is War....and War is Hell: Philosophy, Education, and Metaphors for Argumentation. *Informal Logic*, *17*(2), 177-188.

Davies, F., & Greene, T. (1984). *Reading for Learning in the Sciences*. Edinburgh: Oliver & Boyd.

Department for Education and Employment. (1999). *Science in the National Curriculum*. London: HMSO.

Dillon, J. T. (1994). *Using Discussion in Classrooms*. Buckingham: Open University Press.

Driver, R., Leach, J., Millar, R., & Scott, P. (1996). *Young People's Images of Science*. Buckingham: Open University Press.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education, 84*(3), 287-312.

Duschl, R. A. (1990). *Restructuring Science Education*. New York: Teachers College Press.

Eichinger, D. C., Anderson, C. W., Palinscar, A., & David, Y. M. (1991, April, 1991). *An Illustration of the Roles of Content Knowledge, Scientific Argument, and Social Norms in Collaborative Problem Solving*. Paper presented at the American Educational Research Association, Chicago.

Gee, J. (1996). *Social Linguistics and Literacies* (2nd ed.). London: Taylor and Francis.

Giddens, A. (1990). *The Consequences of Modernity*. Cambridge: Polity Press.

Herrenkohl, L. R., & Guerra, M. R. (1995). *Where did you find your theory in your findings? Participant Structures, Scientific Discourse, and Student Engagement in Fourth Grade*. Paper presented at the AERA Annual Meeting.

Herrenkohl, L. R., & Guerra, M. R. (1998). Participant Structures, Scientific Discourse, and Student Engagement in Fourth Grade. *Cognition and Instruction, 16*(4), 431-473.

Hogan, K., & Maglienti, M. (2001). Comparing the Epistemological Underpinnings of Students' and Scientists' Reasoning about Conclusions. *Journal of Research in Science Teaching, 38*(6), 663-687.

Kelly, G. J., & Crawford, T. (1997). An ethnographic investigation of the discourse processes of school science. *Science Education, 81*(5), 533-560.

Kelly, G. J., Drucker, S., & Chen, K. (1998). Students' reasoning about electricity: combining performance assessment with argumentation analysis. *International Journal of Science Education, 20*(7), 849-871.

Koslowski, B. (1996). *Theory and Evidence: The Development of Scientific Reasoning*. Cambridge, MA: MIT Press.

Kuhn, D. (1991). *The Skills of Argument*. Cambridge: Cambridge University Press.

Kuhn, D., Shaw, V., & Felton, M. (1997). Effects of dyadic interaction on argumentative reasoning. *Cognition and Instruction*, *15*(3), 287-315.

Lemke, J. L. (1990). *Talking Science: Language, Learning and Values*. Norwood, New Jersey: Ablex Publishing.

Loucks-Horsley, S., Hewson, P., Love, N., & Stiles, K. E. (1998). *Designing Professional Development for Teachers of Science and Mathematics*. Thousand Oaks, California: Corwin Press Inc.

Millar, R., & Osborne, J. F. (Eds.). (1998). *Beyond 2000: Science Education for the Future*. London: King's College London.

Minstrell, J., & Van Zee, E. (Eds.). (2000). *Teaching in the Inquiry-based science classroom*. Washington, DC: American Association for the Advancement of Science.

Monk, M., & Osborne, J. (1997). Placing the History and Philosophy of Science on the Curriculum: a model for the development of pedagogy. *Science Education., 81*(4), 405-424.

National Research Council. (2000). *Inquiry and the National Science Education Standards* . Washington D.C.: National Academy Press.

Newton, P., Driver, R., & Osborne, J. (1999). The Place of Argumentation in the Pedagogy of School Science. *International Journal of Science Education, 21*(5), 553-576.

Osborne, J. F., Erduran, S., Simon, S., & Monk, M. (2001). Enhancing the Quality of Argument in School Science. *School Science Review, 82*(301), 63-70.

Osborne, J. F., & Young, A. R. (1998). The biological effects of ultra-violet radiation: a model for contemporary science education. *Journal of Biological Education, 33*(1), 10-15.

Pontecorvo, C. (1987). Discussing and Reasoning: The Role of Argument in Knowledge Construction. In E. De Corte, H. Lodewïjks, R. Parmentier, & P. Span (Eds.), *Learning and Instruction: European Research in an International Context* (pp. 239-250). Oxford: Pergamon Press.

Ratcliffe, M. (1997). Pupil decision-making about socio-scientific issues within the science curriculum. *International Journal of Science Education, 19*(2).

Rudduck, J (1983). *The humanities project: an introduction*. (Revised edition.) University of East Anglia. School of Education Publications

Scott, P. (1998). Teacher Talk and Meaning Making in Science Classrooms: a Vygotskian Analysis and Review. *Studies in Science Education, 32*, 45-80.

Solomon, J (1990). The discussion of social issues in the science classroom. *Studies in Science Education*, 18, 105-126.

Suppe, F. (1998). The structure of a scientific paper. *Philosophy of Science, 65*(3), 381-405.

Sutton, C. (1992). *Words, Science and Learning*. Milton Keynes: Open University Press.

Toulmin, S. (1958). *The Uses of Argument*. Cambridge: Cambridge University Press.

Walton, D. N. (1996). *Argumentation schemes for presumptive reasoning*. Mahwah, NJ: Lawrence Erlbaum Associates.

Welch, W. (Ed.). (1979). *Twenty-five years of science curriculum development*. (Vol. 7). Washington, DC: American Educational Research Association.