Methods

Six approaches were used in compiling this research summary:

1. Two electronic bibliographic databases (Google Scholar and eLibrary at the University of Birmingham) were searched for references to: 'argumentation'.
2. Locating papers by Osborne, Erduran and Shirley (for example, 2004a; 2004b) and investigating those they cite and those citing them.
3. The most recent paper on science teaching methods written by Jonathan Osborne (2011) was used as a source and also for references not located in other searches.
4. A recently published book on Argumentation (Khine, 2012) was checked for key sources that might have been missed.
5. Sources identified in the briefing paper (Palmer 2011) and key reference sources they used not identified by 1 to 4.
6. Some key websites (for example, University of York, research2practice, AstraZeneca, and Nuffield Foundation) were searched for documents that were only available in these locations.

The strategy used was to focus on the work of key authors and acknowledged leaders in the field.

Introduction

Model-based inquiry and the use of argument in developing understanding are key areas where research in science education has an important contribution to make to the ways in which students engage with practical work in schools. There is considerable overlap of research in the areas of argumentation and model-based inquiry, indeed some see argumentation as a component of model-based inquiry (Stewart, Cartier and Passmore, 2005; Windschitl, Thompson and Braaten, 2008).

The innovator with respect to argumentation is Toulmin (1958; 2003) who proposed the argumentation structure. This structure identifies a way in which ideas (claims) are discussed by considering the evidence (data) that supports or contradicts them, and the principles (warrants) and assumptions (backing) on which they are based. Thus the purpose of the argumentation process is to establish the relative merits of a claim: through considering the evidence that supports it and that which appears not to, and through considering whether alternative explanations provide a more comprehensive understanding.

In most science lessons it seems that teachers do the talking and structure the arguments (Cross & Price, 1996). In order to address this issue it is important that methods such as argumentation are used which involve students in discussion and thinking processes which Abrahams and Millar (2008) refer to as having 'minds on' the science. Recent research (Venville and Dawson, 2010) shows the value of argumentation in improving genetics subject knowledge which was significantly better in the argumentation group than a control group.

The key findings of the research

- The innovator with respect to argumentation is Toulmin (1958; 2003) and he proposed the argumentation structure.
- Argument and dialogue are the processes by which we learn (Andriessen, 2006).
- Knowledge construction for the learner requires the opportunity to engage in critique and the higher order thinking skills of synthesis and evaluation (Osborne, Erduan and Simon, 2004a).
- Argumentation is the means that scientists use to make their case for new ideas (Latour and Woolgar, 1986).
- Relatively little opportunity is provided for argument and discussion in school science lessons (Driver, Newton and Osborne, 2000).
- Teachers wishing to develop argumentation skills in pupils should themselves give reasons for the explanations they give (Simon and Maloney, 2007).
- ‘The task confronting the teacher is not solely one of convincing the student of why the scientific account is correct but also one of convincing them of why alternative theoretical accounts, including their own misconceptions, are wrong’ (Osborne, 2011 p 100).
- Teachers whose lessons included the highest quality of argumentation also encouraged higher order processes in their teaching (Simon, Erduran and Osborne, 2006).
- Teachers report that they value argumentation as a way of improving teaching and learning (Sampson, 2009).
- Explicit teaching about argumentation enhanced students’ biological knowledge (Zohar and Nemet, 2002).
- Argumentation improves subject knowledge which was significantly better in the argumentation group than the control group (Venville and Dawson, 2010).
- Passmore and Stewart (2002), Zohar and Nemet (2002) and Venville and Dawson (2010) provide part of a growing body of evidence suggesting that argumentation is better than other approaches at preparing students for assessment.

Research synopsis

Argument and discussion are felt by many, for example Andriessen (2006), to be the key processes by which we learn. Toulmin (1958; 2003) is recognised as the source of the argumentation structure and the main components of his model are:

- ***Claim****:* a conclusion, idea, proposition or assertion
- ***Data****:* the evidence and facts used to support the claim
- ***Warrants****:* these are the statements (rules, principles, etc.) which explain the connections between the data and the claim/conclusion/assertion
- ***Backing****:* these are assumptions, usually taken to be commonly agreed, that provide the justification for the warrants

- ***Qualifiers:*** conditions under which the claim is true
- ***Rebuttals:*** statements which contradict the data or warrant
- ***Counterclaims:*** opposing/alternative ideas or assertions

Sampson and Clark (2008) distinguish between an argument and argumentation by using 'argument' to mean the data that students use to articulate and justify claims or conclusions and 'argumentation' to describe the overall process.

A pictorial way of looking at the overall process is presented in Figure 1. This shows that while the argument may be illustrated in a linear way as data supporting a claim, argumentation is not a linear process.

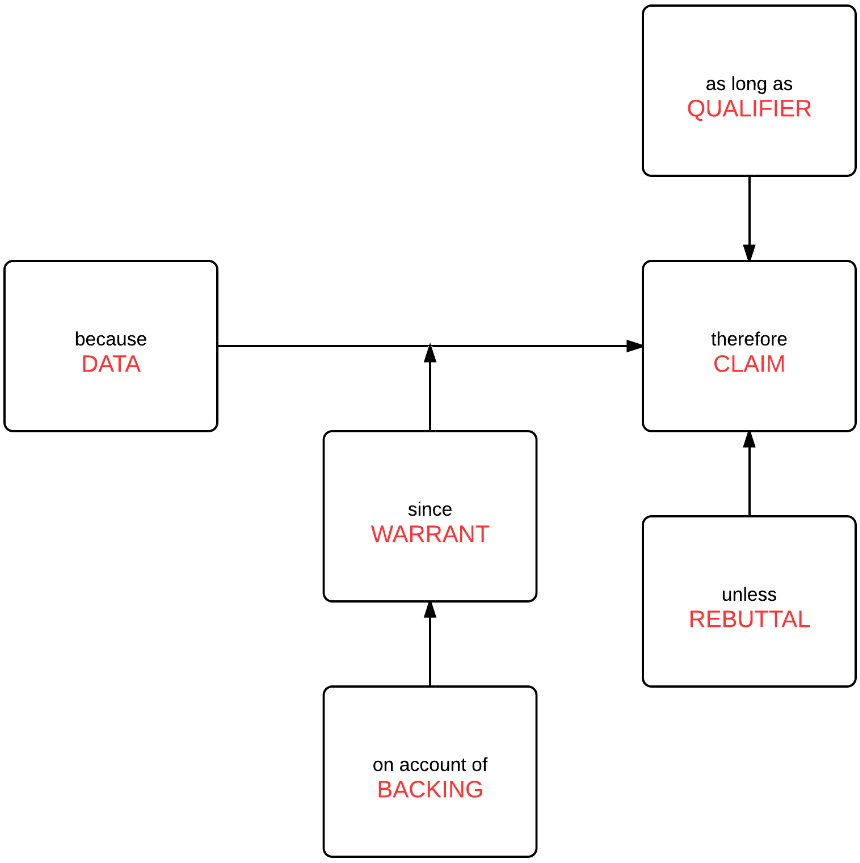

Figure 1 Toulmin's argumentation model (modified from Kelly et al. 1998)

A 'counterclaim' could replace the 'claim' in *Figure 1* as it could be a possible alternative conclusion based on the same or different data.

The importance of Toulmin's work for school science was first reported by Driver, Newton and Osborne (2000). They identified that while argument and discussion were key practices in which research scientists engaged, relatively little opportunity was provided for these activities in school science lessons. They saw this as an important example of the way in which knowledge is socially constructed through claim and counterclaim being judged by the extent to which they were supported by evidence.

They identified one of the key barriers as the '*lack of teachers' pedagogical skills in organising argumentative discourse within the classroom'* (p 287) and that the consequent lack of opportunity afforded to students to practice argumentation failed to support them to

> '*critically examine the scientific claims generated by the plethora of socioscientific issues that confront them in their everyday lives'* (p 287).

Driver et al (2000) also pointed out that if we want young people to develop the skills of scientific argument for themselves, and not just provide an audience for the teachers' reasoning, then science lessons will need to offer opportunities to practice such reasoning for themselves. Students should be encouraged to identify the reasons for supporting a particular claim:

> *'to attempt to persuade or convince their peers; to express doubts; to ask questions; to relate alternate views; and to point out what is not known'* (p 291).

Driver and her co-workers suggested that teachers offered few opportunities for students to practice these skills in their lessons.

Venville and Dawson (2010) identify two foci in the research literature about argumentation, firstly about the nature of skills involved and, secondly, evidence of the impact of argumentation on students' knowledge and understanding about science. They are among a small number of researchers who provide evidence of its efficacy (Osborne, MacPherson, Patterson and Szu, 2012). Venville and Dawson (2010) tested students' understanding of science conceptual knowledge before and after an argumentation activity using control and experimental groups. They reported that the argumentation group improved significantly in the complexity and quality of their arguments and they, but not the control group, gave more explanations showing rational informal reasoning. Genetics knowledge improved in both groups, but with the argumentation group improvement was significantly better than the control group. These learning enhancements were achieved in 3 lessons with most of the first lesson devoted to teaching about argumentation using resources from the IDEAS materials (Osborne, Erduan, & Simon, 2004b). However, Venville and Dawson (op cit) carried out their assessments using individually completed paper and pencil exercises, including a writing frame in which students, from both the control and experimental groups, were supported in structuring their argument and ideas.

Further evidence of the efficacy of argumentation in developing students' knowledge comes from Zohar and Nemet (2002). They found that explicit teaching about argumentation, in the context of dilemmas in human genetics, enhanced student performance in both biological knowledge and argumentation. They reported an increase in the frequency of students in the experimental group who referred to correct, specific biological knowledge in constructing arguments and who scored significantly higher than students in the comparison group in a test of genetics knowledge.

In a study focussed on evolution, Passmore and Stewart (2002) found that students developed a deep understanding of natural selection and used that understanding to reason about other ideas linked to evolution. The researchers provided opportunities for students to create and justify knowledge claims through introducing them to important explanatory ideas about evolution and providing opportunities for students to use and revise these ideas in small group discussion. Passmore and Stewart (op cit) together with Zohar and Nemet

(2002) and Venville and Dawson (2010) form part of a growing body of evidence suggesting that argumentation is better than other approaches at preparing students for assessment involving both multiple choice and short answer questions.

An interview study of science teachers by Sampson, (2009, cited in Osborne, MacPherson, Patterson and Szu, 2012) reported that they valued argumentation as a way of improving teaching and learning but they had a number of concerns. The most frequently teacher-reported concerns were about their lack of ability to teach argumentation and that average and low ability students are not motivated or able to argue effectively. This latter finding has also been reported by Zohar and Nemet (2002).

Part of the problem that low ability students have with Toulmin's framework is to distinguish between data and warrants (Sampson and Clarke, 2008). Zohar and Nemet (2002) have suggested addressing such issues by collapsing data, warrants and backings into a single category called justifications.

Simon, Erduran and Osborne (2006) have also reported that teachers have difficulty with using argumentation; only half of the 12 teachers they worked with used the approach competently. Findings like these indicate that implementing argumentation requires teachers who understand the argumentation process and feel confident about its use in science lessons.

Osborne (2011) states that:

> 'the task confronting the teacher is not just one of convincing the student of why the scientific account is correct but also one of convincing them of why alternative theoretical accounts, including their own misconceptions, are wrong' (p 100).

He goes on to explain that developing an understanding of science means not just knowing that the idea is right and why it is right but also knowing why competing explanations are wrong. In moving towards such an understanding students need opportunities to build arguments based on evidence and expose them to the critical evaluation of their peers in small group class discussion.

Simon and Maloney (2007) found that teachers wishing to develop argumentation skills in pupils should themselves give reasons for their explanations and expect students, likewise, to give reasons for their choices. In a study exploring students' responses to anomalous data (Chinn and Brewer, 1998), it was found that only 8 of the 168 students modified their views as a consequence of evidence contradictory to their previously held beliefs. Driver, Newton and Osborne (2000), when commenting on this study, concluded that there was a general lack of pedagogical expertise among science teachers in organising activities in which students are given an opportunity to discuss. This was not seen as a consequence of teachers' reluctance to change, more a lack of pedagogical skills.

An important element for engaging learners with argumentation in science lessons is to establish an appropriate environment and context for such activity to take place (Duschl and Osborne, 2002). Appropriate contexts require students to consider multiple explanations of phenomena; both the accepted scientific explanation and alternatives including common misconceptions (p 56).

Research that takes argumentation beyond the questions of why it is taught, how students develop informal reasoning and decision-making, how teaching argumentation can be scaffolded, and whether it makes a difference, is uncommon. Simon et al (2010) have shown that teachers face difficulties when adopting new pedagogical approaches which conflict with existing beliefs about teaching and what it means to learn science. Their short, but intensive, programme of professional development has enabled lead teachers to embed activities within their existing school curricula, model pedagogical approaches for their colleagues and begin to change their own practice in becoming more dialogic. Hence, a research and development programme which targets specific approaches to enhancing argument and discussion in science lessons, such as that embodied in this project, could make an important contribution to promoting students' understanding of science.

The implications for teaching approaches (including practical work)

Issues linked to design of resources

There are some published resources involving argumentation. The IDEAS (Ideas, Evidence & Argument in Science) pack published by King's College London (Osborne, Erduan and Simon, 2004b) contains 15 lesson activities and associated supporting resources for teachers.

There are further examples of lessons involving argumentation available on the Internet. 'Talking Science' was published in 2009 by the AstraZeneca Science Teaching Trust http://azteachscience.co.uk/resources/materials/talking-science.aspx. These materials contain introductory activities and lesson examples, some using concept cartoons, directed at year 6 and 7 and drawing, for elements linked to pupil prompts and progression in arguments, on the IDEAS pack (Osborne, Erduan and Simon, 2004b).

The literature identifies three main approaches to lessons involving argumentation; structure, immersion and socioscientific (Bevan, 2012). In the first a separate lesson is taught on the process of argumentation while in immersion, argumentation is integrated into the process of scientific inquiry. For the third approach argumentation is taught in the context of debating a science and society issue. The distinction between the last two approaches seems one of context only. Ford (2008) reports that immersion provides the best support for developing scientific literacy.

Science in Society (Nuffield Foundation, 2012) is an advanced level course offering a useful guide to the structure of an argument. The course guide to Argument acknowledges the use of a range of terminologies and offers the following which they say conforms to the terminology in other courses that involve argument. Such terminology might be considered for a place in this project as it seems likely to be clear to both teachers and pupils.

- At the very minimum an argument must consist of a conclusion and at least one reason for accepting the conclusion. The nature of the reason will depend on the type of conclusion. It may be data used as evidence for a factual conclusion or it may be an ethical principle to justify a decision. A good argument will usually include several reasons.

- The link between reason and conclusion will often involve underlying assumptions, not made explicit but essential to the reasoning.

- In many cases a counter-argument reaching a different conclusion is possible. This might use the same data but come to a different conclusion, it may use different data, or it may involve different values.
- Counter-argument is an important part of a debate between two or more people but the existence of counter-argument should also be acknowledged in any fully developed written argument, where it would then be criticised.
- A detailed argument on a complex issue may involve several simple arguments where the intermediate conclusions build up to an overall conclusion. The strength of the overall argument will depend on the strength of the component parts.
- Any of the component parts of an argument can be criticised, including the link between reason and conclusion. (http://www.nuffieldfoundation.org/science-society/argument)

If multiple choice questions are to form part of the resources developed for the project, then questions with stems such as the following could be useful (Millar, 2009):

- Which one of the following is the best statement of the flaw in this argument?
- Which one of the following is the most sensible inference to draw from the above observations?
- Which one of the following conclusions can you draw from this information?

Such questions may test student abilities to construct an argument and to understand and evaluate other arguments. Different, more open questions in the form of 'is there evidence to support this claim or is it flawed?' or 'what are the limits of the evidence and is the interpretation offered justified?' could also be appropriate.

Issues linked to teacher continuing professional development (CPD)

King's College London have published a support pack for teachers (Osborne, Erduan and Simon, 2004b) which contains OHTs and handouts that support the following aspects of teacher CPD with respect to argumentation:

- Introducing Argument
- Managing Small Group Discussion
- Teaching Argumentation
- Resources for Argumentation
- Evaluating Argument
- Modelling Argument.

Strategies for organising small group work, tips on group composition and an introduction to Toulmin's model are particularly useful and address some of the concerns reported by Sampson (2009). An accompanying DVD illustrates teaching about argument and lessons involving argumentation.

The AstraZeneca Talking Science materials, mentioned in the previous section, contain resources that support teacher understanding of argumentation. They draw on the IDEAS materials (Osborne, Erduan and Simon, 2004b). The AstraZeneca approach is directed at teachers of year 6 and 7 students and they helpfully contrast the differences between the teacher's role in an argument-based and an investigation-based science lesson. This material may be of interest to the curriculum developers working on this project. Eley and Price (2009) write:

> '*In these argument-based lessons, the teacher is very much telling the pupils what they need to do so that they are faced with evidence to generate argument.* <u>*The pupils are not engaging in planning investigations or actively developing their investigative skills*</u>*. Once the teacher has explained the activity or carried out the demonstration, the groups should largely be left to talk, in the time they are given, about what they think. The teacher's role at this stage is to listen to the discussion and where appropriate, e.g. if the discussion has moved away from the main point, to ask questions to enable the pupils to continue. Questions should be open-ended, and they should facilitate pupils' thinking and expression of their ideas*' (p18).

Some elements of these materials may be seen as contentious, as, for example, in the underlined element above. These contrast in precision and to some degree in content with suggestions that teachers should:

- give brief instructions;
- have clear time limits for activities and discussion;
- listen to discussion;
- ask open questions if discussion is losing direction;
- help review ideas through plenary activities;
- present an opposite point of view to help children organise their ideas;
- keep them focussed on the process of argument.

These are taken from the teacher role identified by Osborne, Erduan and Simon. (2004b).

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