



Towards a more social pedagogy in science education: the role of argumentation

Rumo a uma pedagogia social na educação em ciências: o papel da argumentação

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Abstract

This presentation will argue that one of the major problems school science suffers from is a pedagogy which is dominated by the conduit metaphor of teaching. This is the idea that communication is a one way process where teachers conceive of themselves as didactic disseminators of knowledge. When teachers were the sole source of knowledge in a community, such a concept was difficult to challenge. However, in a contemporary context, where young people have access to a growing range of interactive technologies to engage in creative and autonomous self-expression, the predominance of such authoritative modes of interaction are open to question and are, in part, responsible for much of young people's disaffection with school science. Moreover, the range of alternatives begins to expose the inherent functional ineffectiveness. This presentation will argue, rather, that it is dialogic modes of interaction which are an essential element of learning and teaching in the 21st Century. These offer students the opportunity to engage in deliberative interaction about the ideas of science and to construct a deeper and more meaningful understanding of what science offers. Drawing on the work that I and colleagues have conducted in argumentation, I will show how the four essential elements to any science education – the development of conceptual understanding; the improvement of cognitive reasoning; improving students' understanding of the epistemic nature of science; and affording an affective experience which is both positive and engaging – can all be facilitated through a focus on argumentation.

Key words: argumentation, science teaching, social pedagogy, dialogism

Resumo

Este texto argumentará que um dos principais problemas do ensino de ciências advém de uma pedagogia que é totalmente dominada pela metáfora do conduite. Esta é a idéia de que a comunicação é um processo unidirecional onde professores concebem a si próprios como disseminadores de conhecimento. Quando professores eram a única fonte de conhecimento na comunidade, esse era um conceito difícil de ser contestado. Contudo, no contexto contemporâneo, onde os jovens têm acesso a um espectro crescente de tecnologias interativas que lhes permite o engajamento em formas de auto-expressão criativas e autônomas, a predominância por estes modos de interação carregados de autoridade passa a ser questionada e, em parte, responsabilizada pela falta de gosto dos jovens pela ciência. Além disso, este espectro de alternativas começa a expor ineficiências funcionais intrínsecas. Este texto argumentará que, ao contrário, modos dialógicos de interação são elementos essenciais da aprendizagem e do ensino no século XXI. Eles oferecem aos estudantes a oportunidade de se engajar em interações deliberativas sobre idéias científicas e de construir um conhecimento mais profundo e significativo sobre o que a ciência oferece. Com base no trabalho que eu e meus colegas conduzimos sobre argumentação, mostrarei como os quatro elementos essenciais para qualquer projeto de educação em ciências – o desenvolvimento de entendimento conceitual, a melhoria do raciocínio cognitivo, melhorar do entendimento da natureza epistêmica da ciência, e proporcionar uma experiência afetiva que é positiva e envolvente- pode ser facilitada por meio de um foco na argumentação.

Palavras chave: argumentação, ensino de ciências pedagogia social, dialogismo

Introduction: Beyond Transmission: The Role of Dialogic Teaching in school science?

Across the globe, it is possible to find the same kind of lesson in school science – one which is essentially deeply rooted in the view that the function of education is to transmit part of the cultural capital that constitutes the canon of science. In itself, there is nothing particularly wrong with this. The function of education is to ensure that young people do have access to the best that is worth knowing – in this case the best explanations we have of the material world and some understanding of what, at least in the UK, is commonly termed ‘how science works’ or ‘ideas-about-science’. As an aside, it is worth noting that this referent is not the same as the nature of science. This particular term is restricted to what philosophers have to say about science whereas ‘how science works’ is a broader set of concepts about science including some idea of the social practices of science and concepts of risk and their assessment.

It was Reddy (1979) who most elegantly argued that our ideas of education were dominated by the conduit metaphor. From his perspective, knowledge is conceived of as an object to be transferred from one person to another. As he pointed out, it is deeply embedded in our thinking where we talk of the need to ‘get it across’ or that our students ‘didn’t get it’. ‘It’ here is clearly some form of objectified and reified element of knowledge and the use of ‘across’ implies that communication is one way. Associated with such discourse is also the notion that most acts of communication are a success and failure is the exception, whereas the testimony from the performance of most communicative acts, and from our daily experience, is the opposite – failure is the norm and success is the exception.

Despite the evidence that this is so, as Nystrand et al. (1997) have pointed out – across the globe teachers talk and students listen. Nystrand et al.’s comments were based on a exhaustive study of the teaching of English in 58, 8th grade classes in high schools across two years. Even in English, a subject which might be expected to be less authoritative and more discursive, their major finding was that:

‘the question-answer ‘recitation script’ remained dominant and classroom discourse is overwhelmingly monologic. When teachers were not lecturing, students were either answering questions or completing seatwork. The teacher asked nearly all the questions, few questions were authentic, and few teachers followed up student responses.’ (NYSTRAND et al., 1977)

In the case of science, the tendency of teachers to use such authoritative discourse, what Mortimer and Scott (2003) have termed ‘interactive-authoritative’, is even more pronounced. For their subject is, above all others, dominated by a body of consensually agreed knowledge about which there is no controversy. All possibility of any element of interpretation or tentativeness in the ideas that school science has to offer have been carefully excised by a process in which scientific knowledge changes from Type 1 to Type 5 (Latour & Woolgar, 1986) (Table 1).

Type 1 statements are speculations or conjectures, usually found at the end of an article or in private discussions.

Type 2 statements are claims that called attention to the circumstances affecting their status, usually found in research papers.

Type 3 statements are statements with attribution or modality that linked the basic claim to the source of the claim, often found in review articles.

Type 4 statements are claims about things in the universal present tense, usually found in textbooks.

Type 5 statements are the taken-for-granted facts that rarely got mentioned except by outsiders.

Table 1: Categories of Scientific Statements

Through such a process knowledge in science is transformed from a set of contestable claims about the world to a set of uncontested and unquestioned ‘facts’. In this process, the first thing to happen is the excision of any of the historical nature of such knowledge. How this knowledge came to be and the struggle by which it was attained is simply forgotten. In one sense, unlike the humanities, this is because the project of science is closure. Once the community has agreed on a given idea – for instance, the structure of DNA, the origin of the elements or the existence of the electron, it simply moves on. The consensual agreement of the scientific community that it represents the best available understanding we have lends such knowledge an authority that few can challenge – least of all the neophyte student.

The outcome is twofold. First, school science appears as monolithic – a body of knowledge which is unquestioned, uncontested and unequivocal. The result is that school science remains the last authoritative socio-intellectual subject on the curriculum (Ravetz, 2002). Mathematics, for instance, is more about developing an understanding of a limited set of

mathematical concepts and their application to the process of enquiry in mathematical contexts. And much of school history, at least in the UK, has moved away from treating historical knowledge as a canon of well-established facts to one where it seeks to show that it is a process of interpretation and weighing historical evidence to construct an interpretation of past events.

No such paradigmatic revolution has occurred in school science. Rather, what we have observed over the past three decades is the gradual accretion of even more knowledge to the catalogue of 'facts' that constitutes school science. Chemistry for instance, has transformed itself from a subject which was about the manipulation of materials and developing a knowledge of standard tests and reactions to one which now routinely deals in model-based explanations (HABRAKEN et al., 2001). School physics has now accreted, at least in the more advanced courses, such topics as Feynman diagrams, special relativity and the quark model of matter. Neither is school biology immune with an increasing emphasis on biomolecular explanations (particularly genetic) with an emphasis on development rather than the study of physiology. The result is a curriculum where students are frog-marched across the scientific landscape; where there is no time to stand and stare; and where the emphasis is on the acquisition of an extensive body of information. That this is so is perhaps most elegantly expressed by pupils themselves from a study we conducted seven years ago to look at students' views about their experience of school science (OSBORNE & COLLINS, 2001). The curriculum, they said, is:

"all crammed in, and you either take it all in or it goes in one ear and out the other. You catch bits of it, then it gets confusing, then you put the wrong bits together and, if you don't understand it, the teachers can't really understand why you haven't grasped it."

Dominated by copying with no time to question:

"Yeah, you're writing things down from the overhead projector, you haven't had time to read it while you're copying it down, it's only when you come back to revision that you think 'I didn't understand that and I wished I'd asked him'. But then you remember that you didn't have a chance to ask because you were that busy trying to copy it down you weren't reading it."

And where there is certainly no opportunity for discussion of any of the implications:

But still like this morning we were talking about genetic engineering... She didn't want to know our opinions and I don't reckon that the curriculum let's them, lets us discuss it further. I mean science, okay you can accept the facts, but is it right, are we allowed to do this to human beings?

Moreover, these findings are not unique to the experience of school science in the UK. Lyons, drawing on his own work, a study in Sweden and ours found that though the countries may be different, the student experience in the classes was the same (LYONS, 2006).

More problematic is that when education is seen as process of information transmission, ideas are second hand, reliant on other people's interpretation of experiences and on extrinsic motivation for their acquisition. With such an emphasis, the result is that learning becomes a

performance orientated. Such students believe that people are either intrinsically smart or dumb – that is that individuals hold a ‘fixed IQ’ of intelligence and those that hold this view tend to avoid any challenging task, either believing that the task is bound to be beyond them or that there is a risk of failure which will damage their belief about their IQ. In contrast, are students who are task or learning oriented. These students believe that they can improve by their own efforts and that they can learn from failures, and are more willing to take on challenging tasks. Students in this second category out-perform those in the first and cope better with such changes as the transition from school to university (DWECK, 2000). Such students are engaged in a process of knowledge creation, albeit for themselves – one which requires all the higher order thinking skills of reasoning, conjecturing, evaluating evidence, counter arguing and intrinsic motivation.

More importantly, as Gilbert (2005) has argued, the metaphor of knowledge as an object is no longer helpful in educational thinking. It persists because it fits with individuals everyday thinking but is:

“now a serious problem as we attempt to reorient our education system to the needs of the knowledge society. As long as we continue to squeeze our educational thinking to fit with this metaphor, it will be impossible for us to accommodate forms of knowledge that cannot be seen as objects i.e. knowledge work, knowledge creation, the knowledge society - ideas which are incompatible with the knowledge-as-object-metaphor.” (GILBERT 2005)

Contemporary cognitive science sees ability rather differently. For them, ability is the *capacity* to think and learn. This capacity is highly malleable. It is developed by bringing out or developing a person’s basic ways of knowing – that is, through education. Education's purpose, therefore, is not to act a sieve – sorting people according to the talents and capabilities they already have but to develop and enhance their abilities. The failure of school science to make a contribution to such a goal must make its place at the curriculum table questionable.

One of the outcomes of this state of affairs, I would argue, is the global flight of youth from science (OSBORNE, SIMON & COLLINS, 2003; SJØBERG & SCHREINER, 2005). Indeed my contention is that the lack of interest in school science is a product of the mismatch between the values communicated by school science, the manner in which it is taught, and the aspirations, ideals and developing identity of young adolescents. There is now a large body of work which would indicate that students’ sense of self-identity is a major factor in how they respond to school subjects (HEAD, 1979, 1985; SCHREINER & SJØBERG, 2007). Ever since the work of Goffman (1959), social life has been seen as a performance with agreed rules in which every facet of individuals’ public choices and behaviour, such as language, actions, values and beliefs, are tacit symbols or codes of social identities. Identity is both an embodied and a performed (HOLLAND, LACHOITTE, SKINNER & CAIN, 1998) construction, that is both produced agentically by individuals and shaped by their specific structural locations (e.g. see ARCHER, L. & YAMASHITA, 2003). Identities are understood, therefore, as discursively and contextually produced (i.e. produced through relationships and interactions within specific sites and spaces) – and as profoundly relational. That is, a sense of self is constructed as much through a sense of what/who one *is not*, as much as through the sense of who/what one *is* (Said 1978).

In this context, an important feature of contemporary life is the ever growing range of choice coupled with the growth of communicative technologies i.e. the mobile phone and the internet with access to a much wider range of sources of information (BUCKINGHAM, 2000; SEFTON-GREEN, 2007). Such technologies emphasise connectedness over autonomy, processes over products, and systems over details and enable self-expression and the construction of identity. Myspace and Facebook, the social networking websites are archetypal examples. Knowledge for today's youth becomes an object to be acquired as and when it is needed through social and dialogic interaction rather than passive reception. Hence, the changing cultural context makes schools questionable institutions whose value has to be demonstrated and earned and where the teacher and texts are no longer the sole source of knowledge but one of many. What we are seeing is a slow cultural transformation in the nature of learning where subjects whose educational values are rooted in 19th Century paradigms of education as a process of knowledge transmission are increasingly questioned most evidently in the reluctance of students to listen.

Rather what lies at the heart of contemporary society – the process of knowledge generation – places an emphasis on the higher order thinking skills of constructing arguments, asking research questions, making comparisons, solving non-algorithmic complex problems, dealing with controversies, identifying hidden assumptions, classifying, and establishing causal relationships (ZOHAR, 2006). Any educational experience which does not afford some of these cognitive characteristics, such as the traditional school science curriculum, is perhaps, unsurprisingly, of diminishing interest to many of contemporary youth.

The Role of Dialogic Teaching

Dialogic interaction is the normative interaction in society. Its basic form is an interaction between individuals, who whilst they may differ significantly in their knowledge, skills and capabilities, recognise and respect each other. At its best such interaction is characterised by its social, reciprocal, supportive and purposive nature (ALEXANDER, 2005). More fundamentally, it is authentic – all participants can see the immediate purpose and potential value of such discussion which contrasts strongly with the question-answer recitation script which dominates the typical classroom – a discourse pattern which remains the sole preserve of formal educational contexts and is both alien and alienating.

Dialogic enquiry is central to learning as it demands the use of the epistemic processes – describing, explaining, predicting, arguing, critiquing, explicating and defining (OHLSSON, 1996) – all of which are also core to science and all of which are features of dialogic interaction. The dialogic approach to pedagogy in school science therefore seeks to develop a classroom environment which is *collective* in that teachers and children address learning task together; *reciprocal* in that teachers and children listen to each other and consider alternative viewpoints; *supportive* in that children articulate their ideas freely helping each other to reach common understandings; *cumulative* in that teachers and children build on their own and each others' ideas; and *purposeful* in that teachers plan and facilitate dialogic teaching with well-defined educational goals in view (ALEXANDER, 2005).

Over the past two decades, there has accumulated a body of literature which has begun to demonstrate the efficacy of approaches based on a more dialogic approach to teaching for

learning in science. For instance, the work of Alverman and Hynd (ALVERMAN, QIAN & HYND, 1995; HYND & ALVERMANN, 1986) has demonstrated conclusively that students who engage in discussion about scientific texts, and explore why the wrong answer is wrong as much as why the right answer is right, develop an enhanced conceptual understanding compared to those students who have not had such opportunities.

Likewise, Anat Zohar in her work with high school students on fostering students' argumentation skills in the context of learning genetics found:

“that students in the experimental group scored significantly higher than students in the comparison group in a tests of genetic knowledge. An assessment based on both written tasks and discourse analysis also revealed several major findings about argumentation skills. the analysis of written tasks showed an increase in the number of justifications and in the complexity of arguments. Students were also able to transfer reasoning abilities taught in the context of bioethical dilemmas to the context of everyday life.”

And, in a study of primary classrooms, Mercer et al. (2004) have shown that students who were offered the opportunity to engage in collaborative talk about the scientific tasks they were undertaking significantly outperformed a control group who were not offered such an opportunity.

Similar findings emerge from the work of Barron (2003) who found that students in twelve, 6th grade triads significantly outperformed those who had not engaged in discussion; the work of Herrenkohl et al. (1999) who found that the active use discussion allowed students to develop the ‘intellectual tools to ask questions of others that ultimately allowed students to negotiate a shared meaning of *theory*’; from the work of Howe with small groups who has shown how small group discussions can significantly improve conceptual learning of science concepts (HOWE, TOLMIE, DUCHAK-TANNER & RATTRAY, 2000; HOWE, TOLMIE & MACKENZIE, 1995); and from an extensive review conducted by Johnson and Johnson (1979). In summary there is a mounting body of evidence for the greater value for learning of such pedagogy.

Much of this work places an emphasis on developing students' ability to reason, to use higher order thinking strategies (ZOHAR, 2004) or meta-strategic knowledge in the belief that ‘learning to argue is learning to think’ (BILLIG, 1996). Evidence that the education system is weak at developing this kind of higher order capability comes from the work of Kuhn (1991) who explored the basic capacity of individuals to use reasoned argument. Her research 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) were very poor at co-ordinating and constructing a relationship between evidence (data) and theory (claim) that is essential to a valid argument. More recently, 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.

Kuhn's research is important because it highlights the fact that, for the overwhelming majority, the use of valid argument does not come naturally and is acquired through practice. The implication drawn 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. Similar conclusions were reached by Hogan and Maglienti (2001, p.683) who argued that “*students need to participate over*

time in explicit discussions in the norms and criteria that underlie scientific work". Such evidence would suggest that our education systems are not effective at developing students' general reasoning ability. The obvious inference is that such skills are not explicitly taught or emphasised. If so, how might this state of affairs be transformed?

Undoubtedly, general advice concerning how to structure successful discussion and argumentation can be found in the literature (e.g, DILLON, 1994) or in other disciplines (ANDREWS, 1995). However, only a little has been situated within the specific context of the science classroom. Indeed, throughout the literature the issue of how to transform teachers' pedagogy is constantly flagged. Mercer points to one of the major reasons why the use of dialogic teaching is rare arguing that because teachers lack a conception of its value or how to structure it effectively much of it is of doubtful quality as children are not offered:

"a clear conception of what they are expected to do, or what would constitute a good, effective discussion. This is not surprising, as many children may rarely encounter examples of such discussion in their lives out of school – and teachers rarely make their own expectations or criteria for effective discussion explicit to children."

Similarly conclusions were reached by Barron (2003, p. 354) who recognised:

"that it can be challenging even for expert teachers who have clear goals and deep understanding to develop new discourse norms. Given the many aspects of managing the dual-space requirements of collaboration are subtle, it is likely that teachers might benefit from the development of video cases that highlight contrasting cases and connect interaction to learning outcomes and to their own discourse practices." (BARRON, 2003)

And likewise, for Herrenkohl (1999, p.487) who argued

"Clearly, this form of instruction poses significant challenges to the teacher who is identifying the threads in the classroom discussions, engaging the students in evaluating their own and their peers' thinking, mirroring the ideas that are in play, and generally shaping the discourse." (HERRENKOHL, 1999)

The challenge of transforming practice is considerable and similar conclusions were reached when we were working on our own project of 'Enhancing the Quality of Argumentation in School Science' (OSBORNE, ERDURAN & SIMON, 2004).

Transforming Teacher Practice: The Role of Argumentation

How, then is the task of changing the way science is taught in school? My view and now, from many years of working in the field is that argument and argumentation offer the science teaching community a Trojan horse which can effect change in the culture of pedagogic practice to one which is more dialogic.

Why Argument rather than empirical inquiry? My answer to this comes from asking the epistemic question 'How do we know that day and night are caused by a spinning Earth? This almost trivial piece of knowledge is such a commonplace that it is taught to primary school pupils across the globe. The almost universal lack of a good response to the question reveals that the basis for belief is one of authority – most of us accepted the idea

because we told it by somebody whose knowledge we valued. However, 'Why', you might ask 'should it be believed? After all, there are good arguments against:

- The Sun appear to move
- If the Earth was spinning, you should not land on the same spot.
- If it is spinning, once a day, the speed at the equator is over 1000 miles an hour which should fling most people rapidly into space.
- And, surely, at that speed, there should be the most enormous wind as the earth runs ahead of the atmosphere which drags behind.

The empirical evidence for our beliefs was first demonstrated by Foucault in 1851 in the Pantheon in Paris. Other evidence comes from long exposure photographs of the night sky showing all the stars appearing to rotate around the pole star (though it is worth noting that the explanation was believed long before any empirical evidence was available which is a story in itself). Thus, the scientific explanation stands because (a) it is impossible to refute such evidence and (b) we can justify why the arguments for a moving Sun are wrong. Secure scientific knowledge depends as much on the ability to refute and recognise poor scientific arguments as much as it does on the ability to reproduce the correct scientific view. Argument is, therefore, a core feature of science and, as a corollary, should be a distinctive feature of any science education (DRIVER, NEWTON & OSBORNE, 2000; NEWTON, DRIVER & OSBORNE, 1999). What is more, teachers of science implicitly recognise this argument – particularly as I have found – when they are troubled by the difficulty they have in providing the evidence, when asked, to convince their students that matter is made of atoms; that we live at the bottom of a sea of air; or that matter is conserved in a chemical reaction. Such ideas are, after all, not self-evident. Even a passing knowledge of the history of science will show that their achievement was in many cases a product of many years of intellectual deliberation (MATTHEWS, 1994). More importantly, the epistemic basis of science is a commitment to evidence as the basis of belief and not authority (MATTHEWS, 1994; SIEGEL, 1989). Confronted with evidence that their practice may lack opportunities to consider why we believe what we do, many teachers are sufficiently perturbed or dissatisfied to be prepared to trial activities that expose the concept that ideas in science are the product of competing theories.

However, such opportunities need to be well-structured and clearly defined as they are inherently challenging for any teacher. Why? Because the rhetorical project of the teacher is to persuade his or her students of the validity of the scientific world view. In such a context even student experiments are really 'autodemonstrations' that 'carry the even stronger implicit message that our understanding and consequent control of materials and events, is so good that I (the teacher) don't even have to do it for you but you can do it yourself.' (MILLAR, 1998) The effect is that a successful outcome persuades the teacher's students to place 'more confidence in the chain of reasoning which led to prediction of the expected outcome' – in short, the scientific world view. This explains why teachers go to considerable efforts to 'rig' or 'conjure' their experiments and demonstrations to achieve the necessary desired effect (NOTT & SMITH, 1995). Note, that in such processes, no alternatives are considered – experiments and demonstrations are carefully chosen because they serve the teacher's arguments well. The teacher's rhetoric is a kind of pseudo-dialogue for alternative views, counter-claims or challenges are rarely permitted, let alone considered. In contrast, engaging in a process of argumentation to deliberate about scientific theories, ideas and their supporting evidence requires a gestalt shift. In addition, time is precious in schools, opportunities for dialogue and deliberation

are time consuming and may seem to lacking in clear goals and outcomes. Finally, trying new practices for teachers is risky – it places them into a zone where they move from a state of comfort to one of discomfort, from being in control to uncertainty, and from competence to incompetence.

Our work on argumentation in school science begun to address this issue. First it has shown that it is possible to develop students' skills at reasoning in a context where dialogue is structured and supported. To undertake this work, we first developed a Toulmin-based schema for analysing the quality of argument (ERDURAN, OSBORNE & SIMON, 2004). Working initially with 12 teachers to develop their skills and expertise in the first year, we then used the students of the six teachers who had made the greatest progress to collect baseline data from two groups of children in each class about the quality of argument attained in an exercise involving socio-scientific argument (whether to build a new zoo) and in a range of scientific contexts. Teachers then used a minimum of eight argument-based, dialogic activities across the course of a year. We then repeated the exercise a year later to find that their skills had improved compared to a control group who had not used such activities. The skills of the intervention group had improved compared to the control but not significantly. Our hypothesis here is that acquiring such skills is a long-term process that takes significantly more time than a year. However, our evidence along with others provides credibility helping to convince teachers that such approaches may, if adopted, be effective

More fundamentally, we recognised that argument is a process that needs to be explicitly taught through the provision of suitable activity, support, and modeling (SIMON, ERDURAN & OSBORNE 2006). Other researchers have reached similar conclusions (HOGAN & MAGLIENTI, 2001; ZOHAR & NEMET, 2002). Translating the research findings from our work on argumentation, and our work on teaching 'ideas-about-science', into a form which is accessible to teachers was, however, a non-trivial task. The debate that exists in the literature on the professional development of teachers is essentially between those who would first seek to transform teachers' values which, in turn, would then lead to a change in their practice (PUTNAM & BORKO, 2000) and those who would seek to transform practice whose positive outcomes on engagement and learning would then lead teachers to reconsider their values (GUSKEY, 2002).

Moreover, research on teacher professional development (GUSKEY, 2002; JOYCE & SHOWERS, 2002) has shown that an essential element, amongst others, of effective professional development is coaching where teachers have an opportunity to see novel or different practices. Thus, drawing on the work of Joyce and Showers (2002), we were led to believe that what was needed were video exemplars of the kind of practice we sought to establish. Therefore, working with our original group of 6 committed teachers, we developed the IDEAS (Ideas, Evidence and Argument in Science Education) materials, based on a DVD of 28 video clips and workshops for teachers' continuing professional development in this domain (OSBORNE, ERDURAN & S. SIMON, 2004). This pack was based around these video exemplars of the practices and strategies that experienced classroom teachers use. In addition, it incorporated a set of innovative and simple lesson materials for use by teachers to support their teaching of ideas, evidence and argument in science. These materials were produced as part of a cycle of development that included a period of trialling with a group of teachers. Feedback from these teachers was then used to modify and improve both the printed materials and the training video.

The materials we have developed have essentially 6 themes:

1. *Introducing Argument:* Teachers require some theoretical knowledge and a meta-language for talking about argument. For many, the language of ideas, evidence, data, warrants, reasons and justifications are an unfamiliar discourse and simple exercises are required to develop their knowledge and to help them perceive scientific explanations as a form of argument.
2. *Managing Small Group Discussions:* The history of the use of small group discussion is that it is a minimal feature of most science classrooms (NEWTON, DRIVER, & OSBORNE, 1999; SANDS, 1981). Teachers lack the repertoire of basic strategies such as pairs; pairs to fours; envoys; or listening triads that can be used to structure group discussions that have been developed and used in other curriculum areas (JOHNSON, JOHNSON, & JOHNSON-HOULBEC, 2002). In addition, they need to consider how large the groups should be and whether they should be heterogeneous or homogeneous. Such knowledge is critical to successful pedagogy.
3. *Teaching Argumentation:* Teachers require a knowledge of the skills necessary to scaffold argumentation in their students. For instance, how to encourage students to listen – a skill which many students lack; how to recognise the elements of an argument and use an appropriate meta-language with students; how to exemplify instances of good and poor arguments; how to take a contrary position and challenge students ideas to encourage counter-argument; and the ability to demonstrate how arguments are justified.
4. *Resources for Argumentation:* In the first instance, teachers need a set of ready-made resources for argumentation activities. These are the culinary equivalent of the ready-made meal – an off-the-shelf activity whose instructions can be followed to the letter and the outcomes then considered. The IDEAS pack contains 15 of these activities developed by teachers which exemplify the frameworks for argumentation discussed in Osborne et al. (2004).
5. *Evaluating Argument:* As students are engaged in dialogic and argumentative deliberation, the teacher has to make rapid judgements about the quality of argument. If it is weak, their responsibility is to intervene and challenge the group to enhance the quality of their argument. Argumentation based activities are challenging for any teacher of science who require a secure knowledge of the discipline to evaluate the salience of the many points students will raise.
6. *Modelling Argument:* This is the process of representing to a student what an argument consists of; what are its components parts; and what makes one argument better than another. An example of this process can be found from our work in Simon et al (2006) where the teacher modeled the process of producing a good argument:

Sarah: *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. So what sorts of things do you think you need to do to make a good argument? How are you going to make your argument strong?*

Student: *By backing them up.*

Sarah: By backing them up, what do you mean by that, Emma? How can, what do you mean by backing them up?

Student: You say how and why.

Sarah: Alan, I just heard a word from you, what did you say?

Student: Evidence.

Sarah: Evidence. Giving evidence to support, what, your ideas? Your views? Evidence and ideas to back it. Should it just be opinions and feelings or should it be ...?

Student: Facts.

The ability to model argument to students is dependent on a meta-level of knowledge – that is knowledge about argument and its role in science. In many ways, it is equivalent to subject knowledge and is a body of knowledge which teachers must possess if they are to be able to model the practice of argument to their students. Such practice is essential as it exemplifies, with concrete examples, the kind of reasoning and dialogue the teacher wishes to develop.

The next stage in our work is to ask how such practice can be more effectively embedded in the regular everyday practice of teachers? Current knowledge would suggest that a more complex view of professional learning is required to bring about sustained change (BELL & GILBERT, 1996; FULLAN, 2001; HOBAN, 2002; SPILLANE, 1999). Hoban's work is particularly important here as it identifies a combination of conditions for teacher learning that complement each other in supporting change. These are a conception of teaching as a dynamic relationship with students *and* with other teachers where change involves: uncertainty; room for reflection in order to understand the emerging patterns of change; a sense of purpose that fosters the desire to change; a community to share experiences; opportunities for action to test what works or does not work in their classrooms; conceptual inputs to extend teachers' knowledge and experience (in this case, ideas about the value of argumentation in teaching science); and finally sufficient time to adjust to the changes made.

Additionally, the work of Spillane (1999) offers a model termed 'zones of enactment' which he uses explain why some teachers change and others do not by examining the limits and constraints imposed on any teacher within a professional community. Zones of enactment model the distance between teachers' current practice and their understanding of practice, and the levels of understanding and practice that can be accomplished through collaboration with others using material resources. These studies and theoretical perspectives of teacher change suggest that to embed a new approach in the teaching of science as a normative practice, changes in pedagogy need to be adopted not just by individuals in isolation but, rather, by whole departments across the 11-19 curriculum working collaboratively. Working with departments in this manner will, we hope, in the new research project we are about to begin enable a transformation of the 'cultural *habitus*' in which much of teachers' daily discourse, and its associated and embedded values about 'successful' pedagogy reside.

Taken together, all this research would suggest, therefore, that it is the tightly knit community of a school science department which can provide the professional learning system in which teachers can support each other through collaboration and reflection. In

such a context, any change in practice is less reliant on the enthusiasm of critical individuals who may move to new posts. Hence, we seek to work with whole school science departments to see if a critical mass of willing teachers can support and sustain change that, over time, would lead to a more committed and enduring change in practice. Furthermore, we seek to build a professional learning community that transcends the boundaries of the school by bringing two lead teachers from each school together to share their experiences, knowledge and understanding of effective practice at regular intervals. Collaborative CPD requires reflective analysis that helps sustain change through the development of a shared language (LOUGHRAN, 2003), in this case that of argumentation and dialogic teaching.

What will be key to this work will be to shift teachers from seeing student utterances as responses to be evaluated to a situation where the points they make are to be treated as 'thinking devices' (WERTSCH, 1991) – that is as a contribution to the process of knowledge construction where the teachers' use, and response to, the student utterance is critical in determining the value of the dialogue. Argumentation transforms the common monologic discourse of the school science classroom because it demands the use of small group work; the consideration of plural alternatives and enables a discourse which is generates student questions and counter-argument. In this way, not only will students come to a deeper understanding of the concepts of science but also acquire a sense of why we know what we know and the intellectual struggle necessary for its production. Only then, not only will they have an understanding of what the scientific idea is but also how it came to be and why it matters. At the very least, what school science will then offer is something which is more engaging and perhaps, most importantly, more enduring. School science then will have justified its rightful place on the curriculum.

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