Teachers' experiences of teaching 'ideas-about-science' and socio-scientific issues

Pam Hanley & Mary Ratcliffe University of Southampton,
Jonathan Osborne King's College, London

Paper presented at ESERA Conference, Malmo, August 2007

Abstract

Teaching of socio-scientific issues encourages a focus on 'ideas-about-science' (the processes and practices of science) and consideration of scientific evidence and values. This paper reports an evaluation of teachers' practice and views as they taught an innovative pilot course (Twenty First Century Science) to pupils in their last two years of compulsory schooling. Using classroom observation, questionnaires and interviews of teachers, the evaluation explored the extent to which teachers were successful in handling 'ideas-about-science' and how the two components of the course ('ideas-about-science' and science explanations) were interrelated and recognised in the teaching. Teachers saw the course as very interesting but very challenging to teach. Despite declaring some confidence in their understanding of 'ideas-about-science', science explanations dominated over 'ideas-about-science' in teachers' perceptions of the focus of the course and in their teaching. There was gradual change in practice to incorporate more discursive pedagogies, suggesting that several cycles through the course are needed for teachers to appreciate its aims fully and support the teaching of socio-scientific issues effectively.

Background

Curriculum review in many countries has encouraged the development of courses which aim to develop 'scientific literacy' (Norris & Phillips, 2003). 'Scientific literacy' has become an increasingly important concept in the teaching of science over the past decade. In the *Beyond 2000* report (1998), Millar and Osborne argue that 'the [UK] science curriculum from 5 to 16 should be seen primarily as a course to enhance scientific literacy' (p. 9). A major pilot project in England, *Twenty First Century Science*, was devised to articulate a more flexible structure for the science curriculum for 15-16 year-olds (Millar, 2006). A central feature of this structure was a Core Science course designed explicitly to enhance students' understanding of a set of ideas *about* science[i]. The Core Science was thus composed of two components: 'science explanations' – key explanatory ideas, such as gene theory of inheritance; and 'ideas-about-science' – key features of the processes and practices of science, a grounding in which is important in evaluating scientific claims and viewpoints. Specific 'ideas-about-science' promoted in the course were: data and its limitations, correlation and cause, theories, the scientific community, risk, and making decisions about science and technology. Development of students' understanding of 'Ideas-about-science' is thus seen as an important strand in 'scientific literacy'. Many of the 'ideas-about-science' also feature in deliberation of socio-scientific issues – notably data and its limitations, the scientific community, risk and making decisions (Ratcliffe & Grace, 2003).

Previous research has suggested five dimensions of practice as characterising teachers' engagement of students in lessons *about* science (Figure 1, Bartholomew, Osborne and Ratcliffe, 2004). Teachers who were able to engage students in learning the processes and practices of science tended to be those who showed characteristics on the right hand side of the dimensions. Teachers in this previous research were volunteers who were able to introduce the teaching of aspects of 'ideas-about-science' into courses which enabled such teaching but did not demand it. The documentation for the Core Science course, in contrast, expected targeted teaching, outlined appropriate activities and resources and the development team provided support for the teaching of 'ideas-about-science'. Thus we wished to explore the extent to which teaching of Core Science modified teachers' practice in contrast with previous research suggesting that teachers' understanding of the nature of science is limited (Lederman, 1999) and that engaging in a discursive pedagogy is challenging when conditions are not fully supportive (Bartholomew, Osborne and Ratcliffe, 2004).

Figure 1 Dimensions of practice in teaching 'ideas-about-science'

1. Teachers' Knowledge and Understanding of the Nature of Science

Teacher is anxious about their understanding ⟷ Confident that they have a sufficient understanding

2. Teachers' Conceptions of Their Own Role

Dispenser of knowledge ⟷ Facilitator of learning

3. Teachers' Use of Discourse

Closed and authoritative ⟷ Open and dialogic

4. Teachers' Conception of Learning goals

Limited to knowledge gains ⟷ Includes the development of reasoning skills

5. The Nature of Classroom Activities

Student activities are contrived & inauthentic ⟷ Activities are owned by students and authentic

The pilot Twenty First Century Science GCSE course ran for three years from September 2003 and involved 78 schools across England (although in the majority only part of the year group - often the lower or middle bands - followed the new course). The project sponsors (the Nuffield Foundation, the Salters' Institute and the Wellcome Trust) commissioned three independent evaluations to assess different aspects of the pilot course. The one which forms the basis of this paper explored issues in implementing the course as regards classroom practice and teaching approach[ii].

Research Aims

The objectives were to assess:

- how the two components of the course – science explanations and 'ideas-about-science' - were interrelated and recognised in the teaching of the course;
- the extent to which teachers were successful in handling 'ideas-about-science' and science-related issues;
- the views of students about Twenty First Century Science, particularly with respect to their experience of 'ideas-about-science'.

This paper reports predominantly on the first two objectives.

Research Methodology and Analysis

A combination of quantitative and qualitative approaches was used as follows:

- 28 lesson observations and 22 interviews with 12 teachers in 9 schools (across 2 years)
- 8 focus groups with students
- a survey of 121 teachers sampled from all participating schools
- a survey of students from all the pilot schools: 381 following core Twenty First Century Science, and 225 in the part-cohort schools doing 'traditional' GCSE

The quantitative data from the questionnaires were summarised in tabular form and statistical tests applied as appropriate. Qualitative feedback was explored using a grounded theory approach to identify emerging themes (Strauss & Corbin, 1994), and coding was assisted by use of NVivo software.

Our intention was to follow eight teachers in different schools across the two years of the course (5 visits per school), supporting observational data with interviews of teachers. In practice, a full set of observations, interviews and focus groups with pupils were undertaken across the two years in five of the schools. Some additional teachers were found to increase the sample of observations and perceptions of the course. An observation schedule based on the five dimensions of practice (Bartholomew, Osborne, & Ratcliffe, 2004) and that used by Adamson et al (2003) was developed by considering the elements contributing to each dimension in the context of teaching 'ideas-about-science' within Twenty First Century Science. The observation schedule was piloted by the three researchers on video-taped lessons to ensure consistency of use. Each element of each dimension was scored on a scale from 0 to 4 using descriptive or frequency *and* descriptive criteria. Zero related to the criterion - never occurred / very inaccurate description, running through to 4 – happens many times / very accurate description. Aggregates of scores on each dimension were obtained.

Research Findings

Classroom practice

There was little indication from the lesson observations that teachers modified their practice substantially over the 2 years of the evaluation. Changes in practice were gradual and subtle. Greater familiarity with the course did not automatically result in higher scores on the dimensions, although the scope of teachers' activities did widen. Looking at the overall averages (Table 1), the least developed practice was in 'use of discourse'. Teachers' generally low use of open questions and the dominance of whole class interaction where the teacher asked a question, the student responded and the teacher offered an evaluation led to some missed opportunities in developing students' critical reasoning. Classroom activities were generally focused towards pupils' active participation however. This may result from using the activities in the published materials.

The overall score on 'teacher's understanding of ideas-about-science' is modest and, judging by the standard deviation (SD), it incorporates the greatest variation across both teachers and lessons. Evidence from individual interviews also suggests that, in practice, understanding lacks the depth expected in order to explain these ideas with great confidence. This finding contrasts with the responses to the survey where teachers expressed confidence both in their comprehension of what the 'ideas-about-science' component demanded and how the ideas should be taught. However, classroom observations revealed that *explicit* treatment of an idea or ideas-about-science was unusual and the consequence is that these students may not have appreciated that a specific 'idea-about-science' was a core aim for the main outcomes of a lesson.

	Mean	SD
Teacher's understanding of ideas-about-science	2.0	1.1
Teacher's conception of their own role	2.2	0.8
The teacher's use of discourse	1.9	0.7
The teacher's conception of the learning goals	2.1	0.5
The nature of classroom activities	2.3	0.6

Scores on observations were in the range 0-4, 4 representing the most positive score on the dimension

Table 1 Summary of observations of teachers against each dimension

Analysis of the questionnaires, interviews and lesson observations suggests that 'science explanations' and 'ideas-about-science' are seen as interrelated rather than distinct and separate aspects of the course. This is to be expected as it is almost impossible to teach an 'idea-about-science' without drawing on a 'science explanation'.

This interleaving might not matter if both components of the course are given equal prominence in teaching. However, teachers' perceptions and actions indicate that 'science explanations' dominate over 'ideas-about-science'.

Table 2 shows that teachers spent almost twice as long teaching scientific content compared to 'ideas-about-science'. Given that the latter is the less familiar piece of the course which has as much emphasis in the aims and as much weight in the examination, these data would suggest that either the model of the course was not fully internalized; or that the teaching of content was seen as requiring more time; or that the complexities and difficulties of teaching 'ideas-about-science' and the time required were not recognised.

Course component	Average	Max	Minimum
Science explanations	62%	95%	30%
Ideas-about-Science	37%	70%	5%

Table 2: Teachers' estimation of proportion of time spent teaching each component

When interviewed, however, five of the 11 teachers admitted that, at a fairly early stage of teaching the course, they had little understanding of 'ideas-about-science' overall and how they fitted into the core course. Several teachers indicated that this lack of an overview of the elements of 'ideas-about-science' arose because the imperative of implementing lessons overrode reflection on the overall goals of the course:

> *I don't know (what ideas-about science is addressing). Because I haven't really gone into that. I was just given the scheme of work and told to get on with it.*
> Fiona[iii], Nov '05

It is only after teaching the course through that a full understanding of the expectation of the course was gained, as Lesley indicated:

> *In a way you work under pressure. You get the syllabus and you just go through the syllabus, so I have never even read those (ideas-about-science). I mean I followed their activities so I was incorporating them you know without really thinking about it…. I can see now where they fit in and why they are important and next time I teach them I would be able to make sure that I am actually teaching them in it more consciously, definitely.*
> Lesley, Apr '06

The teachers interviewed across the two years of teaching the course illustrated the length of time it took to appreciate the implications of the course for changing teaching methods. For example, Lesley acknowledged the changes the course had explicitly produced but recognised she was not always fully implementing them:

> *I suppose we have used Salters Science for a long while… We always ignored the discussion and role play in truth and now I would advise people to start bringing that in gradually, teaching them to discuss. I am saying that but I am not quite sure that I do that yet.*
> Lesley, Apr'06

Previous exploration of curriculum evaluation in science has suggested that teachers adapt the new curriculum to fit their teaching style rather than adapting their teaching style to fit the aims of the course (Atkin & Black, 1996). For the majority in this sample, some of whom who were willing advocates of Twenty First Century Science, there was a recognition of the changes needed in teaching methods and varying degrees of actual change in practice. The evidence suggests that these teachers did modify their practice to align somewhat with the intentions of the course but that the changes took place gradually and need a supportive environment in which to take risks.

Teachers were asked which strategies they felt they used more of, the same or less of (compared to the standard GCSE) on a 5 point scale. Table 3 shows their responses.

More Of **(Mean responses 2 or less)**	**Approximately the Same** **(Mean response between 2 & 3)**	**Less Of** **(Mean response 3 or greater)**
Whole Class Discussion Small Group Discussion Discussing Topical Scientific Issues Debating Pupil Initiated Issues Independent Study Accessing the Internet Pupil Presentation	Teacher Demonstrations Teacher Explaining Ideas Using Worksheets Note Taking from the Board Using Videos Role Play	Pupil Practical Practising Past Questions

Table 3: Teachers views of which strategies they are using more of, the same or less of.

The greater use of discussion in either small or large groups might be expected given that this is a course that requires more discursive exploration of topical scientific issues. Nonetheless, there was very little evidence that students were being taught essential elements of critical evaluation or collaborative working, despite being exposed to activities that required them to reason. While their active participation was encouraged, it was mainly in the form of individual contributions to structured written tasks and whole class questions and answers. Such a finding may be due a lack of experience or confidence with different approaches to teaching. Indeed, in interview several teachers made reference to the fact that the course encouraged students to share their opinions (a position which many actively supported) but felt they had some limitations in deploying appropriate strategies or that students were unable to engage in constructive discussion.

The need to be in control as a teacher and a concern that students would not be able to sustain activities in small group discussion has featured in previous research (Ratcliffe & Grace, 2003 chapter 7) and was present with several teachers in the observed classes:

> *I haven't done discussion between pupils working in small groups very much. I find it quite hard to do with these groups because they are so easily off task. I think it would be a nice idea and may be something to develop. So the discussion tends to be more whole class discussion.*
> Lesley, Oct '04

The student comments would suggest that the default pedagogy is still one of transmission and 'bookwork' which students find unengaging. However, evidence that some movement has occurred in this approach comes from a number of positive views about the opportunity for expression and debate:

> *This course is good because it is a lot of discussion based, whereas a lot of the other ones it was sort of textbook theory and you copy down. Whereas this one we can discuss it and the teacher can say 'Oh you're right or you are wrong,' and 'what do you think about it?'.*
> Student focus group

Pat, in a school where less than 50% of the cohort was doing Twenty First Century Science, recognised the potential for peer group discussion in clarifying understanding and sharing opinion but felt the need for more training in using the technique effectively:

> *I think [the course] has made me think about - more about having discussion group based classroom activities. But I do think I need retraining or a bit of help in knowing good techniques really. In understanding what techniques work.*
> Pat, July '05

Teachers were very appreciative of the high quality IT resources provided, particularly where they were easy to introduce into lessons (such as PowerPoint presentations and video clips). There are suggestions in the data that use of such IT resources helped teachers to make the connections between 'school science' and contemporary science. However, there is a danger that such resources might reinforce teaching by transmission where students are expected to absorb yet more information, albeit attractively presented. Hence, to encourage a more interactive pedagogy, IT resources which have an in-built need to involve students in collaborative working would be helpful.

Both students and teachers expect practical work to be a prominent feature of a science course. In the survey, 27% of Twenty First Century Science students (and 24% of standard GCSE students) commented that they would like more practicals. This demand is clearly a double-edged sword. On the one hand, the evidence is that practical work is motivating and engages students – a point which is seen in this comment:

> *Student: You learn more when you are doing practical, because you are like having fun and learning something at the same time.*

On the other hand, research has consistently failed to show that students learn more from practical experiences (see, for instance, Watson et al (2004)) despite students' perceptions.

Students' engagement

The analysis of focus groups and questionnaire data gave little indication of whether students' achievement levels were related to their views of the course. There was however significant comment emerging from most of the teacher interviews that lower achieving students in particular gained more from Twenty First Century Science than from traditional courses:

I don't know if you picked up on that vibe in the lesson, but the majority of them were on task and motivated and interested. It's the discussion, it's the independence, it's using video, using different strategies that are keeping them where they are. Because I have taught foundation groups before with [other exam board] and it wasn't reaching them in the way that this one has been.
Yasmin, Nov '04

Teachers felt that lower achieving students were more engaged by Twenty First Century Science than traditional courses. However, the struggle to manage discussion with less articulate students and for those with a limited attention span, meant teachers did retreat to worksheets as a device to maintain control and some momentum in classroom activities. The management and support of lower achieving students in peer group discussions was seen as problematic:

I think they find linking concepts and ideas together quite difficult. (Pause) Yes, maybe with the other higher ability groups they would find something like that [application of science] really interesting and they would debate but here to get them to debate like you have to really be you know feeding them information and then they would start, maybe thinking one or two things here and there.
Nadia, Nov '04

The extent to which higher achieving students were seen as advantaged in taking Twenty First Century Science depended on how teachers viewed the two components – science explanations and 'ideas-about-science' – in the balance of these students' experiences. For example Peter was one of several teachers seeing the course as making rigorous demands on the higher achieving students because of the challenge of dealing with both elements:

The core they are actually finding quite challenging because it makes them think. And actually when they are challenged I think they respond rather well.
Peter, Jan '05

Pat, however, and some other teachers in informal discussion, felt that the skew towards 'ideas-about-science' or their inadequate realisation could disadvantage potential A-level students:

I can see that in some aspects the course did help to make it more relevant for them, but at the same time there are a lot of kids who go on to do A level science, that just get wowed by the whole scientific approach and scientific theory and somehow it didn't bring that through.
Pat, May '06

In this respect it should be noted that one of the other evaluations conducted of Twenty First Century Science by Scott et al (2007) found no difference in conceptual attainment between students taking the standard double award GCSE and those students who did the Twenty First Century Science course.

Students' views

This evaluation has not been able to explore fully the extent to which the course is differentiated in practice for students of different achievement levels nor the impact on their subsequent study of science. Nonetheless, there are some indications that students who have been switched off science through 'standard' GCSE courses are more motivated. Twenty First Century Science students perceived the course as significantly easier than those students who were taking the standard GCSE. They also found it significantly more topical, and it seems reasonable to conclude that the topicality of the content allows Twenty First Century Science to provide a more accessible, and therefore 'easier', experience of science concepts and ideas.

Whilst the perception of Twenty First Century Science students of the enjoyment and relevance of the course was more positive than those taking the standard GCSE, the difference was not significant. Nevertheless, the students' comments obtained from focus groups would suggest that the course was achieving one of its primary goals of relating science to the everyday life of at least some of the students with many remarking that the relevance and value of school science was now more self-evident than it had been previously. Many comments were made about the contemporary nature of science – comments that would suggest that the course is achieving one of its primary aims of relating the science of the classroom to the students' life-world. The link to contemporary practices in science is now transparent, for instance:

Student A: *Like you can use it in everyday life, like, if you like talking to someone and they say ' what do you think about this?' or something like that.*
Student B: *You actually know what they are talking about.*
Student A: *Yes. Like watch the news and understand.*

A course which has an emphasis on 'scientific literacy' is necessarily going to make more demands on students to read and interpret information. This leads to some problems with the literacy demands of the text being quite high, one student arguing:

The books are quite hard to extract the information. They are quite long paragraphs.

For some teachers this is an issue. However, being able to engage with science in a range of forms, from academic texts to popular journalistic accounts, is an essential skill of a scientifically literate person (Osborne, 2002).

Teacher development and support

Undertaking any new course makes considerable demands on teachers to read and assimilate a wide range of curriculum support materials, plan new lessons and adapt the materials to their context. In addition, the goals of any activity sometimes only become clear after the event. Thus, the pressures that it places on teachers are significant. For this reason, it is perhaps not surprising that in the survey, 72% of teachers rated Twenty First Century Science as either much harder or harder to teach than other courses. Few teachers used the space available to explain their responses but comments such as 'you need to be absolutely up-to-date on current issues – difficult but a challenge I enjoy' and the requirement to 'be more ready to discuss contentious issues' explained at least part of the challenge provided by the course. Some evidence for the additional demands of such a course emerged in the interview with Elaine (22 years teaching experience) who commented:

> *Also, you actually do have to prepare. I know this sounds ridiculous, but quite a lot of lessons I don't prepare for, I just walk in and make it up because I know the subject knowledge. But quite a lot of this I actually have to prepare it, which is good, because I am learning all sorts of new things and learning new ways to do things. It's made me plan.*

Interview and questionnaire data suggest teachers perceive that they learnt most about teaching the course from sharing their views and experiences with others piloting the course. Sharing with colleagues emerged from the survey as the most common, and the most highly valued, form of support they received. An example of this was seen at Hinchcliffe, the one school where there was consistent high use of discursive discussion in the lessons observed. Here, there was considerable sharing amongst teachers as to how to implement the course. Elaine, for instance, had a background in humanities and drama, and her resultant expertise proved useful in supporting the students and teachers in this school:

> *Well with our kids in particular, they love discussion, and they are very good. They are very good at doing it. What I would think our teachers need is strategies on how to actually do discussions. A lot of people in this department keep saying to me 'how do you do a discussion?' I would have thought that they would have done that by now, but a lot of teachers are too scared to kind of let go and just let the kids talk about stuff, and then sort of bring them back together to find out what they think.*
> Elaine, Nov '05

Conclusions

The change in focus of the new science course provided a conceptual and practical challenge for teachers. Change, even in these schools who had volunteered for the pilot, was slow and hard-won. There was evidence that after one complete cycle of teaching the course, teachers were developing a better appreciation of its objectives and an improved grasp of how they might be realised.

What these findings do point to yet again is the significance and value of the surrounding professional community to teachers' learning. Not only is this the form of professional development that most teachers have experienced, but it is also the form that they value most. Forming 'communities of practice', in which experienced and less experienced teachers of Twenty First Century Science can share and refine their teaching techniques in a supportive atmosphere, seems an important priority.

The findings also suggest some practical methods of assisting the teaching of Twenty First Century Science such as:

- providing more resources which focus on 'ideas-about-science' and promote collaborative working
- developing more interactive techniques which encourage student contributions

- teaching students more explicitly about understanding and interpreting texts
- opportunities for professional development on specific approaches e.g. effective peer group discussion

The evaluation found that the teachers considered the course more interesting to teach than a standard GCSE. Generally, students were engaged and overall the lessons seen had relevance and rigour. Any new course is inevitably very demanding of teachers' time, requiring a lot of reading, planning and trialling of new materials without a clear sense of the goals or how any one lesson might contribute to the overall objectives. However, if teachers enjoy teaching a course - if it makes more sense to them –then it is likely that they will teach it with more enthusiasm and passion and the experience will be more engaging for their students. The findings suggest that, for many participants in the pilot, the introduction of Twenty First Century Science has achieved this important goal.

References

Adamson, S. L., Banks, D., Burtch, M., Cox III, F., Judson, E., Turley, J. B., et al. (2003). Reformed Undergraduate Instruction and Its Subsequent Impact on Secondary School Teaching Practice and Student Achievement. *Journal of Research in Science Teaching,* 40(10), 939-957.

Atkin, M. & Black, P. (1996). *Changing the subject: Innovations in science, mathematics and technology education.* Routledge: London

Bartholomew, H., Osborne, J. and Ratcliffe, M. (2004). Teaching students 'ideas-about-science': five dimensions of effective practice. *Science Education* 88, 655-682.

Lederman, N. G. (1999). Teachers' understanding of the nature of science and classroom practice: Factors that facilitate or impede the relationship. *Journal of Research in Science Teaching*, 36, 916-929.

Millar, R., & Osborne, J. (1998). *Beyond 2000. Science education for the future.* London: Nuffield Foundation.

Millar, R. (2006) Twenty First Century Science: Insights from design and implementation of a scientific literacy approach in school science. *International Journal of Science Education* 28, 13 1499-1521

Norris, S & Phillips, L. (2003) How literacy in its fundamental sense is central to scientific literacy. *Science Education* 87, 2, 224-240

Osborne, J. (2002). Science without Literacy: a ship without a sail? *Cambridge Journal of Education* 32 (2) 203-215

Ratcliffe, M & Grace, M. (2003). *Science Education for Citizenship*. Maidenhead: Open University Press

Scott. P., Ametller, J., Hall, K., Leach, J., Lewis, J., & Ryder, J. (2007) in Twenty First Century Science Evaluation Report at http://www.21stcenturyscience.org/rationale/pilot-evaluation,1493,NA.html (Accessed 2 August 2007)

Strauss, A., & Corbin, J. (1994). Grounded Theory Methodology: An Overview. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of Qualitative Research* (pp. 273-285). London, Sage.

Watson, R., Swain, J., & McRobbie, C. (2004). Students' discussions in practical scientific enquiries. *International Journal of Science Education*, 26(1), 25-46.

---

[i] The Qualifications and Curriculum Authority (QCA) commissioned the University of York Science Education Group to devise and develop the Twenty First Century Science GCSE specifications

[ii] The other two evaluations compared students studying Twenty First Century Science to those following other GCSE Science specifications in terms of (a) their learning of science explanations and ideas about science and (b) their attitudes to school science and science more generally.

[iii] Pseudonyms are used throughout