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**Abstract**

A collaborative curriculum development project was set up to address the lack of good examples of teaching about ideas and evidence and the nature of science encountered by student teachers training to teach in the age range 11-16 in schools in England. Student and teacher-mentor pairs devised, taught and evaluated novel lessons and approaches. The project design required increasing levels of critique through cycles of teaching, evaluation and revision of lessons. Data were gathered from interviews and students' reports to assess the impact of the project on student teachers and to what extent any influences survived when they gained their first teaching posts. A significant outcome was the perception of teaching shifting from the delivery of standard lessons in prescribed ways to endeavours demanding creativity and decision-making. Although school-based factors limited newly qualified teachers' chances to use new lessons and approaches and therefore act as change-agents in schools, the ability to critique curriculum materials and the recognition of the need to create space for professional dialogue were durable gains.

**Keywords:**

Curriculum development, ideas and evidence, nature of science, pre-service teacher education.

One year post graduate (PGCE) courses in Initial Teacher Education in England are traditionally comprised of two parts. One part is based in a training institution (typically a university department of education or a college of higher education) and deals with subject knowledge, pedagogical content knowledge (PCK) and knowledge of educational systems and processes. The other (larger) part is based in schools and provides opportunities for student teachers to observe experienced teachers' lessons, to plan and teach their own lessons and to reflect on their practice and that of other teachers (Fleming 2004; Teacher Training Agency 2003). Most teacher educators hope these two parts will be thoroughly integrated, representing inseparable and interdependent domains of knowledge and experience, though the reality and feasibility of this in practice has been challenged (Hopper 2001; Watkins & Whalley 1993). Teacher educators responsible for subject specific pedagogy naturally want to promote best practice in terms of current thinking in their subject to prepare their students to be 'at the cutting edge' of teaching. Teacher educators hope their students will observe experienced teachers in schools who are using methods that inspire and act as productive models on which they can build their own teaching and that reflect and relate well to what has been taught and promoted as good practice at the university. But what if an element, or whole area of the statutory school curriculum in the subject, is severely under-represented or even absent in schools in which student teachers practice? In such situations, the problem for a teacher educator is to support students so that they can acquire pedagogical understanding and teaching behaviours in an area where there are few examples of good practice from which the novice can learn. This situation currently exists in at least one area of science teaching in England: teaching about ideas and evidence and the nature of science.

As a consequence of the low occurrence of teaching in this area of science there is a national concern that, unless new generations of qualified teachers are confident to teach and have practised in this area of teaching, the situation in schools may not change much (Taber 2006). In other words, a cycle of inaction will exist that perpetuates current practice, limits the climate for change and therefore, the chance of progress in schools. Importantly, it restricts the experiences of those who might, as newly trained teachers, have the wherewithal to help initiate change. One way of breaking this cycle of inaction and improving the climate for acceptance of new teaching ideas is to engage student teachers and experienced teachers in collaborative curriculum development. In doing so, it is the hope that both will gain professionally and that student teachers will be in the vanguard of change when they have qualified and enter the teaching profession as beginning teachers. Using student teachers as change agents in this way, however, carries a number of risks, not least because of the inherent assumption that inexperienced novice teachers can cope with the demands of an aspect of teaching that experienced teachers find difficult. This is of concern both in the development of student teachers during their training year and when they enter their first teaching post (Taber 2006). An additional assumption, that determines the extent to which the cycle of inaction can, at least be addressed, if not completely broken, is the extent to which newly qualified teachers are in a position to influence the teaching behaviours and planning decisions taken by the more experienced colleagues that surround them when they take up their first posts (Cochran-Smith 1991; Jofli & Watts 1995). This article reports the outcomes of a development and research project that addressed these issues. Before a discussion of how the project was established and the research undertaken, it is necessary to provide some background on the specific area of the science curriculum that formed the focus for the project.

**Ideas and evidence in the school curriculum for science**

The science curriculum in England, as in other countries of the developed world, has been said to be out of date and irrelevant to the needs of young people in the 21st Century (Goodrum et al. 2001; Millar & Osborne 1998). In England, there has been pressure to change the science curriculum in schools so that 'ideas about science' feature in the curriculum in addition to 'ideas of science' (Millar 2006). These 'ideas about science' have commonalities with dimensions of the nature of science (NoS) identified, in a Delphi study of relevant experts (historians, philosophers, scientists and science educators), as being desirable to include as outcomes for school students (Osborne et al. 2003). Osborne et al.'s list has been simplified by Tao (2003) who used it to construct NoS 'stories' that explored: the idea that scientific discoveries help our understanding of nature; that there are questions that cannot be addressed by science and its methods; that scientists work in collaboration; that experiments are used to test ideas, hypotheses and theories; that scientists need to be systematic and creative; that scientific knowledge is tentative and; that scientific theories serve to explain phenomena. While not specifically mentioning the term ‘nature of science’, the revised statutory requirements for the science curriculum at Key Stage 4 (KS4: for pupils aged 14-16 years) in England included a new section entitled ‘How Science Works’ that embraces many of Tao’s NoS stories (Department for Education and Skills/Qualifications and Curriculum Authority 2004, p.37). In September 2008 an entirely new curriculum for science at Key Stage 3 (KS3: for pupils 11-14 years) will be introduced that places an even greater emphasis on ‘How Science Works’ and, in this version, almost all of Tao’s stories and Osborne et al.’s list can be recognised. In these revisions, the work of scientists and the ways in which data and evidence are used to construct and validate theories, is seen as being equally important as the facts of science and the practical methods used to generate data. Behind these revisions is a contention that a science education that does not recognise the intellectual efforts made by scientists, both in the present and in the past, to contribute to knowledge and provide explanations for scientific phenomena is, at best, only partially valid and, at worst, intellectually bereft. In the words of Osborne, Erduran and Simon:

> To ask school students to accept and memorise what the science teacher says without any concern for the justification of those beliefs is poor currency. Poor currency because it leaves them unable to explain those beliefs to anybody else but, more importantly, poor currency because it fails to lay bare the enormous intellectual achievement of those who first realised the scientific explanation and the struggle they had in winning the hearts and minds of a sceptical public….
>
> (Osborne *et a*l. 2004, p. iii)

In the version of the national curriculum for science introduced for England and Wales in 2000 (DfEE/QCA 1999), which was the version that teachers and students teachers in this project worked from, a section required teaching of ‘ideas and evidence in science’. In addition to concepts about data and evidence and their relevance to the construction and testing of ideas and theories, this section promotes science as a social enterprise with cultural and historic roots. At KS3 for example, pupils are required to be taught:

- about the interplay between empirical questions, evidence and scientific explanations using historical and contemporary examples (for example, Lavoisier's work on burning, the possible causes of global warming);
- that it is important to test explanations by using them to make predictions and by seeing if evidence matches the predictions;
- about the ways in which scientists work today and how they worked in the past, including the roles of experimentation, evidence and creative thought in the development of scientific ideas.

(DfEE/QCA 1999, p. 28)

It should be recognised that these curriculum statements constitute a rather restricted sub-set of outcomes in terms of the nature of science when compared with the 2004 and 2008 curriculum documents. This was the version that teachers in the schools supporting student teachers were required to work with. However, in our training, we took a wider view of NoS, more in line with the list of outcomes identified by Tao (2003), so that we could help prepare student teachers and their school colleagues for the new developments that had been signalled.

In 2002 the government in England, in response to criticisms of the quality of teaching, introduced a National Strategy to improve teaching at KS3 in the core subjects of mathematics, English and science (DfES 2002a). A mainstay of this strategy (or the Key Stage 3 Strategy as it came to be known) in science was the provision of in-service training for teachers in every school in England supported locally by KS3 consultants in science who were employed by Local Education Authorities (LEAs). These consultants carried out training and offered in-school support and advice. Since ideas and evidence in science was a significant change in the curriculum at this time, an entire in-service training block of the Key Stage 3 Strategy for science was dedicated to this area (DfES 2002b).

In spite of the efforts of the Key Stage 3 Strategy and the time that has elapsed since the introduction of the 2000 curriculum for teachers to get used to teaching this content, evaluations of the implementation of the strategy and reports from school inspections show that teaching about ideas and evidence remains an area that teachers find problematic or difficult and in which there are few reported examples of good teaching (Stoll et al. 2003; Office for Standards in Education 2004). In an editorial for a special edition of the *School Science Review* (volume 87 number 321) on ideas and evidence, Taber provides a number of reasons for the lack of development of teaching in this area (Taber 2006, p. 26). According to Taber, few science teachers received specific instruction on the nature of science in their degree studies or in their initial training as teachers. Additionally, teaching about ideas and evidence may often be seen by science teachers as an extra and unwanted demand on top of already onerous responsibilities to teach a content-heavy curriculum. Finally, the emphasis of teaching in the area currently entitled ‘ideas and evidence’ has been on what are termed ‘scientific investigations’. Taber sees science teachers in England as having a restricted view of ideas and evidence and the nature of science. This has been shaped by the needs of their students to show success in tests and examinations at understanding and using a ‘variables test model’. Preoccupation with variables testing and the limits it can place on the breadth and quality of practical work in science teaching has been commented on by Donnelly et al. (1996). As a consequence of these previously cited reasons, activities that encourage pupils to explore the social and cultural fabric within which scientists work, and through which data and theories are questioned and eventually validated or challenged, are very rare indeed.

**The xxx project as an example of collaborative curriculum development**

With the aim of improving the training of science teachers in England and in response to the issues of concern discussed previously, five one-year projects were initiated by the division of the Key Stage 3 Strategy concerned with Initial Teacher Training (Johnson 2004). The work of these projects, and in particular research arising from the one described here, obtained additional funding from the Science Enhancement Programme (SEP) of the Gatsby Trust. Each project had, at its core, an approach to training that involved experienced teachers (referred to as mentors when they have responsibility for initial education of student teachers in schools) working in close collaboration with student teachers to develop and evaluate materials to support learning and teaching about ideas and evidence in science. Methods were not defined centrally but were left to each project team to develop and implement.

The project described in this article was known as the xxx Project. It ran over the period 2003 to 2005 and focused on a group of student teachers following a PGCE course in 2003/2004. The model of training and development used in the xxx Project was designed to provide opportunities for trainees and experienced teachers to both learn and develop their practice through truly collaborative activities centred on the co-production and evaluation of novel teaching approaches. As such, it represents an example of what has been defined as 'Collaborative Continued Professional Development' (Cordingley et al. 2003).

The project was organised around the principle of a 'community of practice' (Lave & Wenger 1991; Wenger 1998). Wenger's concept of a community of practice has particular resonance for teacher educators because it locates the ways in which individuals and groups work together to solve a common problem. In this case, the problem was the lack of teaching and training opportunities in an important area of science teaching. For Wenger, individual actions and ways of working are "made meaningful only by the social learning and meaning making that takes place" (Wenger 1998, p. 45). Our research attempted to capture the significant outcomes for the members of our community and this "meaning making" and to comment on indicators of impact that might be useful for others who wish to develop similar programmes.

The xxx 'community' had a broad membership comprised of four groups: KS3 consultants who were experienced teachers working for two LEAs that have local, administrative responsibilities for schools in which student teachers train; 2) teachers and mentors involved in seven schools working in training partnerships with the university; 3) seven student teachers enrolled on the science PGCE course at the university and; 4) two academic staff from the Department of Educational Studies at the university (the authors) responsible for teaching and supervising student teachers and supporting mentors in partnership schools. Additional funding from the SEP allowed us to research the impact of the project by re-interviewing student teachers towards the end of their first full year in teaching.

**Procedures**

According to Joyce and Showers (1995, pp. 108-125), programmes to bring about change in classroom teaching through the professional development of teachers, of which this project is an example, are most effective when they are planned around a sequence that has the following four elements as the outcomes for the participants:

- awareness and knowledge of theories, practice and curricula;
- change in attitudes to self or pupils or academic content of instruction;
- development and practice of newly learned skills, discrete behaviours and strategies, initially through more supportive means such as peer teaching before graduating to full classrooms;
- transfer of training through a community of practitioners (through peer coaching and collaborative designing of schemes of classroom work).

(Joyce & Showers 1995, pp. 108-125)

With Joyce and Showers' work in mind, we began the project with a planning meeting at which university tutors (the authors), KS3 consultants and two mentor teachers from the schools considered issues concerning teaching about ideas and evidence in science, how best to develop teaching in this area and best practice in supporting student teachers. We had hoped to involve at least some of the student teachers at this meeting but, since they had only just begun their teaching practice in a new school, this additional demand on them was felt to be counter-productive and rather disruptive at this sensitive stage of their training. The planning meeting was followed, four weeks later, by a one-day workshop attended by student teachers and mentors from the schools in which they were placed for teaching practice. The workshop consisted of:

- an exercise to elicit mentors' and student teachers' thoughts on teaching about ideas and evidence and the nature of science. Participants' ideas at the start of the day were collected by asking them to map out their knowledge and understanding of what might be required of teaching in this area. These maps were compared with a second set of maps collected at the end of the day to allow participants to see how their ideas had developed and changed;
- a PowerPoint slide-assisted lecture from one of the university tutors that reviewed what the national curriculum in England and the science education literature (for example from Osborne et al. 2003) say pupils should know about ideas and evidence and the nature of science;
- a PowerPoint slide-assisted input from a researcher on pupils' ideas about the nature of science based on research carried out in local schools (Driver et al. 1996) and a summary of the findings of a recent review of international research on effective group work in teaching science (Bennett et al. 2004). Associated documentation was used to stimulate subsequent discussions between mentors and student teachers, working together in small groups, to widen appreciation of the scope of teaching about ideas and evidence and the nature of science;
- workshop tasks focusing on classroom activities and approaches to teaching about ideas and evidence and the nature of science so that participants could see the style and content of (rather limited) examples published in schemes of work for teachers at KS3;
- a question and answer session with a KS3 consultant employed by a local LEA that challenged participants to think about how pupils' views of the validity and reliability of claims and evidence might be improved;
- a short input from one of the university tutors that provided a framework to guide trainees and teachers on how to plan, teach and evaluate the new lessons that were to be produced.

Following the workshop, each student teacher was asked to develop one or more lessons on a topic area incorporating ideas and evidence and the nature of science agreed with their mentor, and to teach and evaluate this lesson in the classroom on at least one occasion. In most cases, the lessons were original creations rather than adaptations of existing ones. Student teachers were issued with a framework so that they could systematically log evaluations of the lessons, adaptations and changes that were made if the lesson was taught more than once, successes and difficulties for pupils and discussions with mentors. Most student teachers received visits from a KS3 consultant who either, watched and commented on their teaching, helped develop ideas discussed at the workshop into lessons, or discussed outcomes and difficulties; advising them appropriately. After completion of this first round of teaching, student teachers and mentors attended a second workshop day at the university during which sets of lessons developed by each student teacher were presented, discussed and further evaluated. Suggestions were made for modifications and student teachers then taught these modified versions of their lessons to different classes (and in some cases in different schools) as part of an additional week of 'professional enrichment' in the summer term programme of their PGCE course. Student teachers were asked to submit a final version of their lesson in an agreed format that included a detailed lesson plan, teachers' notes, background science, answers to any questions and pupil materials.

Four student teachers chose to carry out additional, individual research studies on their lessons as part of the university's requirement for assessment of the PGCE course that involves extensive reading and a small scale research study based in school (see Bennett & Author 2 2001, for a description of this type of exercise). In most cases, the student teachers also gave presentations to teachers in the science departments in which they trained by way of disseminating approaches to a wider professional audience in schools.

In our example of collaborative curriculum development we deliberately planned stages requiring an increasing level of critique of practice. Each stage represented what can be regarded as an increased level of professional exposure and risk (see Table 1). Thus, at the lower levels 1-3, the degree of exposure and risk is limited because critique is within a personal frame of action and redress. At higher levels (4 and 5), the author/teacher is expected to critique the work of peers and others as well as to justify or defend actions and convince others of the efficacy of their lesson design, teaching effectiveness and pupils' learning. Thus, participants at these higher levels are working well outside the relative comfort of their personal professional spaces.

>insert Table 1 about here <

In the final phase of the project, training materials and lesson resources were written up in the form of a handbook for mentors and other teachers. This was presented to mentors in all partnership schools involved in training teachers with encouragement provided to utilise the materials to help further cohorts of student teachers in teaching about ideas and evidence and the nature of science.

**Research methods**

The research questions addressed by the study were:

RQ1: What are the professional and pedagogic gains for student teachers and mentors in a project developing materials in teaching about ideas and evidence and the nature of science?

RQ2: Which, if any, of these gains are carried forward by student teachers when they take up their first posts as newly qualified teachers (NQTs)?

With respect to RQ1, data were collected from the written materials and evaluations produced by student teachers towards the end of their training year and from semi-structured interviews with individuals (Interview 1). In this first interview, student teachers were asked to reflect on their teaching of the lessons they had created, perceptions of any influences on mentors and other teachers that might have resulted from involvement in planning and teaching these lessons and, professional and personal knowledge gained as a result of being involved with the project. Where it was relevant, student teachers were also asked to describe and reflect on involvement of the KS3 consultants. Additional data were available from unstructured interviews carried out with the KS3 consultants and with the mentors when they attended the final workshop of the project at the university. A KS3 consultant provided notes from observations of student teachers' lessons in two schools and a transcript of discussions that took place at the end of these lessons.

When student teachers moved into their first teaching posts, our main focus was on the extent to which knowledge and experience of teaching approaches gained from the project during the training (PGCE) year might have been sustained (RQ2). We were also interested in the extent to which mentors and other teachers in the schools might be influenced by these teaching approaches. In this way, we wished to explore the extent to which newly qualified teachers (NQTs) can be seen as 'change agents'. To do this we re-interviewed each student teacher (now NQTs) towards the end of their first full year in teaching (Interview 2). We used a semi-structured interview schedule including some questions referring back to responses made in the first interview at the end of the training year. In these second interviews we asked: 1) whether lessons from the project had been used again and if not, why this was so; 2) if any new lessons had been produced and taught; 3) if conversations with staff about teaching ideas and evidence and the nature of science had taken place and the outcomes of these conversations; 4) what new personal knowledge and professional gains had been added to those from the project in the first year of teaching and; 5) what were the targets for further professional development in teaching about ideas and evidence and the nature of science.

Final versions of the lessons (lesson plans, pupils' resources and teachers' notes) produced by student teachers and a CD-ROM containing teaching materials from the other four projects funded by the SEP (Author 1 et al. 2005) were used with new cohorts of student teachers in university-based training sessions on teaching about ideas and evidence and the nature of science. Towards the end of the training year, questionnaires were used with this new cohort of student teachers and with teachers from the schools in which they trained to establish the extent to which these materials had been used. The questionnaires contained items that elicited student teachers' opinions on the extent to which they thought teaching about ideas and evidence and the nature of science featured in schools' schemes of work and the support they may have received in this area of teaching from their mentors and other science teachers. This part of the research is not reported in detail here, but we draw on findings from it where it is felt they shed light on responses made in interviews with newly qualified teachers. We were thus able to explore the products and outcomes of the xxx Project in schools that have a partnership with the university for training teachers, but who were not involved in the project (Author 1 & Author 2 2005).

**Vignettes of practice**

We have used data sources to construct a series of *vignettes* for student teacher/mentor pairs. The vignettes were constructed on the basis of the key emergent themes arising from scrutiny of the data sources described above (interviews, written reports, and lesson observations). Emergent themes were identified independently by the authors and compared. Where there were disagreements (and these were rare) these were resolved through discussion and re-examination of all sources of data. Since our focus is principally on gains for student teachers, the vignettes are framed from their perspective but draw in information pertaining to the actions of and relationships with others, such as the KS3 consultants and, more importantly, their teacher mentors. Each vignette focuses on the principal professional development gains of the student teachers in terms of their knowledge, confidence and abilities to teach about ideas and evidence. The vignettes are structured consistently, in that they all describe; the context of their teaching practice (training) school, the nature of the lesson and associated teaching materials designed and taught by the student teacher, their reflections on learning outcomes for the pupils they taught in training, the context of the school in which they gained their first post, the impacts and influences of school-based factors in these schools on their teaching and, consequently, the extent to which teaching about ideas and evidence was able to be undertaken and develop. Thus, the vignettes show the extent to which gains from the project have been sustained into the first year of full-time teaching and how the NQTs may have influenced other teachers. As such, they explore a key issue – the extent to which initial teacher education can promote change in existing practice in schools.

We have included vignettes from three of the seven student teacher/mentor pairs involved in the project. The cases represented in the vignettes are ones where complete sets of data from the training year and from reflections at the end of the first year in a teaching post were available. It had been our intention to produce complete vignettes for all seven students involved in the first year of the project but this was not possible. In one case, the student teacher had decided not to take up a teaching post. In another, the student teacher had to repeat part of his practice and this was a case under external examination and therefore too sensitive to pursue. One student teacher was working abroad and the difficult personal circumstances of a further NQT prevented us from proceeding. The selection of cases featured here as vignettes was determined, therefore, by circumstances beyond our control and we do not claim that they are representative of the seven cases as a whole. They do, however, reveal different and interesting circumstances in the schools in which student teachers trained and in which they gained teaching posts. In the following vignettes the names of student teachers and teachers/teacher-mentors have been anonymised.

***Vignette 1: Jill*** (a chemistry specialist) worked in her training year with Gary, an experienced science mentor, at a large 11-19 city school. She worked with a class of 29 pupils aged 11 or 12 and devised a suite of five lessons, taught over a two-week period, to illustrate the historical development of ideas about the solar system. Jill and Gary developed original material encouraging and supporting pupils to research the work of selected scientists and explorations of space. Pupils used this information to script and enact interviews with the scientists and to construct a timeline showing the development of ideas about the solar system. The interviews were videotaped, shown to pupils and discussed. One of Jill's lessons was observed by a KS3 consultant. The consultant spoke with pupils during the lesson to identify learning outcomes and these were then matched against Jill's planned objectives for the lesson. Jill reported that pupils enjoyed the work and that motivation was very high. Pupils liked carrying out individual research, using the Internet and videotaping their interviews. The KS3 consultant, however, felt that pupils had gained more in the use of Information and Communications Technology (ICT) than in understanding changes in ideas about the solar system. Jill was asked about this in the first interview and she described how she would change the lesson to focus pupils more on the relationships between different scientific discoveries.

> Yes the discoveries of ideas bit did not really come out because they (the pupils) spent too much time researching on the Internet and they spent a lot of time watching other people

> present as scientists … they never really got like an overview … so I'm going to do a timeline at the end next time … so they can see how ideas have changed and will change again in the future … and I'll ask them questions about it.
>
> (Jill: interview 1)

The project had a significant impact on the science department of the school in which Jill trained resulting in all classes in Y9 (pupils aged 14) being engaged in lessons about ideas and evidence following the completion of national tests at the end of KS3.

After qualifying, Jill obtained a teaching post in a medium-sized independent, fee paying school for girls aged 11-18. The school's pupil intake has an ethnic mix, including a high proportion of Asian girls reflecting the cultural diversity of the area. The department consists of 10 teachers (4 Biology, 3 Chemistry, 3 Physics). When re-interviewed at the end of her first year of teaching, Jill admitted that she had not used the lessons she devised in training even though she had recently taught a similar topic, on the solar system, to the same age group. She intended, however, to use her lesson at "the end" (of the topic) and added the lesson to the department's teaching scheme (medium term plan). She provided a CD containing her lesson and others from the national project (SEP 2004) for other teachers in the department. The Head of Chemistry at her school identified some lessons on the CD that might be used, but again it was thought most appropriate to teach these after completion of the established teaching programme.

In the first interview at the end of her training year Jill said that she intended to write more lessons focussed on ideas and evidence. Her plans seemed to have been scaled down under the pressures of time and having to focus on the preparation of pupils for examinations, as the following extract from the interview towards the end of her first teaching year shows.

> I would say it's ongoing (teaching about ideas and evidence). I would say that there are little bits within my lessons that are tending towards that each time. But there is not a specific set of something that has been set out because I don't know how much time I've got when I'm

> teaching a new scheme of work. I want to make sure I've got everything they need to know for their exams. So I'm bringing in little bits where I feel that I can.
>
> (Jill: interview 2)

It appeared that Jill was trying hard to introduce new ideas on teaching into the school, including those about teaching ideas and evidence. There seemed to be opportunities for Jill to help the department make progress as the school is increasingly looking to bring itself in line with what it perceives to be best practice and front-line innovations in teaching approaches in science offered by schools in the state sector. It should be noted that independent schools in England are not required to follow the national curriculum for science or use national tests, though many of them choose to do so.

***Vignette 2: Hilary*** (a biology specialist) trained with Nigel, an experienced science mentor, at a medium sized 11-16 city school. A lesson, based on newspaper articles about genetically modified (GM) foods, was devised in conjunction with Nigel and the KS3 consultant. Hilary 'ghost wrote' the articles to avoid some of the language problems that it was felt pupils might have met in authentic texts and also to provide scenarios that would generate interesting discussion about the reliability of the claims being made. Pupils were asked to read each article and to discuss and reason in groups which ones might be legitimate. One article, in which scientists claimed to have developed a blue variety of strawberry, was bogus. The lesson was observed by a KS3 consultant who gave feedback and, after some modifications, took Hilary's lesson to share with other schools in the LEA. In her written accounts, and at the first interview, Hilary commented extensively on the professional benefits of devising, teaching and evaluating this lesson. In particular, she commented on being aware of pupils' misconceptions about GM foods, on how to improve the organisation of a class for debate and on producing high quality pupils' materials.

Hilary obtained her first teaching post in the school in which she trained. One of the main gains from the project that Hilary identified in the first interview was the chance to be creative and develop and produce her own lessons. At this first interview she said:

> ….. I mean it (my lesson) was from scratch totally. So you couldn't find a resource. It was totally from scratch. I don't think many other students have had that kind of experience in their training. At first I was a bit … oh now this sounds like a lot of work. I think it has been quite valuable for me on my own (to write lessons). I think it allowed me to be a bit more creative which I really enjoyed.
>
> (Hilary: interview 1)

This value placed on creativity was also evident a year later. In the second interview, at the end of her first full year in a teaching post, Hilary said:

> I think it (being involved in the project and having to write my own lessons) has helped me to be more creative I think, in planning my lessons, and knowing that you can use the curriculum but you can work from it and come up with your own ideas.
>
> (Hilary: interview 2)

The project seems to have had an influence on Hilary's approach in her first year of teaching. In addition to teaching the lesson (on GM foods) that she had prepared as part of the project with one Y8 and three Y11 classes, Hilary had also taken opportunities to include new approaches in some other lessons as the following sequence of dialogue from a second interview at the end of her first year in teaching interview shows (I = interviewer, H= Hilary):

> I Would you say that your lessons this year are now more focused on ideas and evidence and the nature of science, like the kind of thing that you were doing last year?
>
> H Yes. I haven't taught a whole (new) lesson but I have, kind of, thought more about ideas and using the word "evidence" and building on that particularly with my Year 7 and my Year 8 groups.

I OK. Can you think of some examples?

H I recently did - like a forensic kind of science lesson with my Year 7's, doing chromatography. We had a discussion about the quality of the evidence at the end of the lesson and like - is this evidence enough, and things like that. So I thought that was quite interesting and they all enjoyed the activity as well … and they came up with some really good ideas.

(Hilary: interview 2)

During the interview at the end of the training year, Hilary said she had plans to write other original lessons for teaching about electricity. This did not appear to have happened. The main constraints that Hilary listed were, lack of time and the demands of other priorities for development in the science department that compete for teachers' time at staff meetings and training sessions. The following sequence illustrates this:

H Yes, I think it is just the time and work with other people. At the minute we've got a different focus in the department and we are developing level ladders and level activities (these techniques are used in formative and diagnostic assessment) and things like that. So that's kind of the focus whenever we have departmental days and meetings and things.

I I see … so there are other priorities as well. So, when there is the chance to sit down and talk in a departmental meeting it's often about something else.

H Yes.

(Hilary: interview 2)

***Vignette 3: Anna*** (a physics specialist) trained with Cath at a medium sized 11-19 rural school. Cath was not Anna's regular mentor but Anna had been teaching Cath's Year 8 class for several weeks. Together they reviewed the scheme of work for a topic on light and decided to use one lesson to encourage pupils to use their existing knowledge and observations from a series of demonstrations to reflect on theories explaining the formation of rainbows. The lesson included, an elicitation of pupils' knowledge about rainbows and colour, a series of practical demonstrations of dispersion (*e.g.* soap bubbles, a water tank as a prism and a ray box shining light through a flask) and a plenary activity in which pupils had to choose between conflicting theories from the history of science (by *Theodoric* or *Aristotle*) on the formation of rainbows, saying how they thought these related to the evidence available. Anna and Cath both came to appreciate the difficulties that pupils have in substantiating their opinions and claims. They learned much about structuring groups of pupils and about the need to scaffold their discussions. Anna gained a significant amount of subject knowledge on the history of development of ideas about light and colour.

Anna obtained her first teaching post at an 11-18 school on the outskirts of a large city. The school is large (1206 pupils) and has a good reputation in the region. At the time of the second interview, Anna planned to accompany her partner to New Zealand and she hoped to obtain a teaching post there. Anna's stated intentions a year before, in terms of teaching about ideas and evidence and the nature of science, seemed to have been modified and constrained by the syllabus and schemes of work she was required to follow. In spite of this, there appeared to be opportunities afforded by the adoption of a new scheme of work by the science department in her school.

> Well we are teaching Salters' GCSE (an examination course for 14-16 year olds) that sort of thing. Obviously it's quite a packed GCSE so you don't get much chance to come off it. I have not had the chance to stray off the curriculum or do my own lessons because it's quite well structured here and you are obviously teaching to deadlines. We have also got the new *Catalyst* scheme of work in Year 7. This has got opportunities to teach about ideas and evidence built into it, which obviously I'm taking full advantage of.
>
> (Anna: interview 2)

At the time of the interview, Anna had not yet had a chance to use the lesson she devised in the project and opportunities for other teaching in this area seemed to have been restricted. Ideas and evidence seemed not to have been given priority in the department's teaching schemes.

> Yes, I've taught a couple of lessons here and there and I've actually talked (about ideas and evidence) to one Year 9 group in a lesson that I observed. I had to do an extra lesson at the end of a particular piece of the curriculum and so I taught a lesson on ideas and evidence.
>
> (Anna: interview 2)

Anna talked about opportunities there might be to develop teaching in the new scheme of work that the department might choose for their KS3 classes. This scheme seems to contain an 'ideas and evidence lesson' at the end of each topic. While the inclusion of this aspect of science is welcomed, its position in the teaching scheme reinforces the notion that teaching in this area is often seen as an addition to normal requirements. This was confirmed later in the interview as this sequence shows.

> I So, has there been lots of discussions about this (how to plan ideas and evidence into teaching the new scheme)?
>
> A There was before I arrived and there has been a lot of discussion since. A lot of teachers don't have the time to teach the lessons at the end of the topic because the Year 7s are quite slow with it being their first year (in the school).
>
> I So the picture we are getting from you is there's, let's call it … the contents lessons, and then on the end there are some lessons which are (about) ideas and evidence?
>
> A Exactly, they teach the content lessons first and then, if there is time at the end, then they will teach the lessons which are ideas and evidence.
>
> (Anna: interview 2)

Anna felt that being involved with the project had helped her to be ahead of some more experienced teachers as this sequence of dialogue shows.

I The impression I'm getting from you is that you may well be one step ahead of some of the more experienced teachers?

A Yes, definitely, definitely. I definitely feel that in terms of ideas and evidence, most of the experienced teachers don't know very much about it. They are less keen to get involved in it, because it's just an unknown thing and it's just another thing to learn about when they have already got a million and one things to do already. So obviously they don't have the time to put a few hours aside to learn about it properly until they come to meetings or a training session, they might not know very much about it.

(Anna: interview 2)

**Discussion**

From our analysis of data collected at the end of the training year, it was evident that one of the most significant outcomes reported by all student teachers was the satisfaction they gained in the generation of original ideas for lessons and the opportunity to progress these through the sequence of lesson planning, resource creation, teaching and evaluation that was a crucial part of the project. For some students, such as Anna, involvement with the project was seen as conferring a positive professional advantage over other student teachers/new entrants to teaching, one that might, for example, place them in a favourable light when applying for a teaching post. Student teachers considered that they had been given the opportunity to be creative and to establish ownership of their teaching. This was evidenced most strongly in the case of Hilary, but it was a feature mentioned by all seven student teachers. In many cases, this creativity was seen as a welcome contrast to the perceived rigidity and constraints of a scheme of work that they felt obliged to follow. For teachers and mentors too, the encouragement to experiment and be involved in something innovative was welcomed, particularly as it was sanctioned through a project supported by LEA consultant teachers and consistent with the latest approaches in science education nationally. Teaching was seen to move from being the delivery of standard lessons in a prescribed way to a more challenging and rewarding endeavour demanding creativity and decision-making. These were features we observed in all seven cases.

The dominance of published schemes of work in science, particularly at KS3, and the negative impact this has on teaching, and the ways in which this limits risk-taking and consequently innovation, was something we, as teacher educators, have experienced and others (House of Lords 2006) have commented on. However, we did not expect this to be a strong feature in this project. We observed this in four of the seven cases but in the vignettes it was Anna who communicated this most strongly. It was an issue for Jill too, particularly considering the pressure she was under to hit examination performance targets for her pupils. In Hilary's case, we know that the department in which she works relies mainly on school-generated teaching materials and so this is perhaps why this was not so much of a major issue for her as it was for Anna. It is perhaps a regrettable consequence of a school system dominated by target setting, testing and inspection, where teachers are constantly under pressure to reach imposed targets, that the chances to be creative and innovative are constrained. In this climate of coercion and (increasingly centralised) control, anything that steps 'outside the box' of schemes of work that slavishly (and safely) follow a prescribed curriculum, is seen as being risky behaviour, with possibly dire consequences when it comes to examinations, the results of which teachers in England are often judged by. A report on the state of science teaching in English schools points to the limited range of skills being tested in national tests and examinations as being a key factor stopping teachers using their own creativity to inspire students in science (House of Lords 2006, p. 27). Anxiety about examinations seems to be a general feature of teachers' experience, even in schools that are technically not bound to follow the national curriculum and use its testing regime – as in Jill's case.

The written statements and evaluations produced by the student teachers and comments from their mentors showed that many of them (5 out of seven student teachers) reported increases in their pedagogic content knowledge (PCK) (Schulman 1987), particularly in terms of organising and scaffolding pupils' discussions. For example, in one case (not featured in the *vignettes*), a student teacher (Alan) claimed he had now become much more confident in organising pupils to debate in groups about controversial issues in science as a result of planning and teaching lessons on the origins of bioterrorism and the use of the smallpox virus in biological weapons that he developed in the project.

> As a trainee I have gained an awful lot from this project. It has enabled me to look at a topic and create a completely unique lesson …to look at an area of teaching that I have previously not seen (teaching about Ideas and Evidence). Using group work to set up a debate to examine different sides of an argument and seeing how pupils can draw evidence from a piece of text and use the same evidence to back up conflicting viewpoints has been very stimulating for me and something I had not had the courage to do before this project.
>
> (Alan: student teacher report)

We suspect this move to more student-focussed work promoting and using greater student-student dialogue and interactions was also true for some of the teacher-mentors, though this was not stated explicitly by them in responses collected via questionnaires in our other research (Author 1 & Author 2 2005). Dialogue, discussion and argumentation are crucial in validating scientific claims and data and so underpin teaching about ideas and evidence (Kelly 2005). Although there is research showing improved understanding of scientific evidence and process through discussion and argumentation (Simon et al. 2006; Webb & Treagust 2006) there are also concerns that few teachers have the necessary experience, training or confidence to use these strategies regularly in their teaching (Dawson 2006).

Involving experienced teachers and student teachers as creators rather than as recipients of curriculum has been found to yield similar successes in other contexts and countries (George & Lubben 2002; Hodges et al. 2004). These gains support the view of Schön (1987) that successful training is often the product of situations in which "coach" and novice engage in what he calls "reciprocal reflection-in-action". For participants in the xxx project, such reflections covered issues of managing and organising whole class activities and small group discussions, the appropriateness of different pedagogic approaches, the accessibility of learning resources and the practicalities of differentiation. Of course, it could be argued that these are skills of teaching developed through general professional activities, and so cannot be attributed just to the experience of teaching about ideas and evidence or the nature of science. Indeed, the majority of comments from student teachers' reflections in their written reports (about 80 percent) were about generic pedagogical issues but in over half of these (60 percent) there was evidence that the development and teaching of material about ideas and evidence and the nature of science helped the student teachers think more deeply not just about these areas but also about science teaching. As Hilary put it:

> One of my pupils was amazed and quite concerned that she had not heard about all these people suffering with blindness (due to beta-carotene deficiency – the subject of an example of GM food used by Hilary in her lesson materials) before and challenged its validity, this then resulted in somebody else saying, "of course its true" and that, "just because you've never heard of it doesn't mean it doesn't happen". The first pupil then responded, "well I've never met anyone who is blind because of this and neither have you". I felt this last point was very strong and it made me think about how much I trusted statistics, although I did know the original source of the data and knew it would not be published without the appropriate guidelines and peer reviews. I found the opinions of pupils to be fascinating and my feelings were that there should be more lessons like this in the national curriculum that encourage children to think about the way they see things … I feel that these types of lessons (on ideas and evidence and the nature of science) not only help teachers to teach other lessons but help pupils to ask more questions about the science that they are learning about by being more critical and wanting to know how people know these things.
>
> (Hilary: student teacher report)

In their logs, most student teachers (six out of seven) claimed that improved knowledge about the nature of science was an important outcome of having been involved with the project. However, as student teachers' knowledge about the nature of science at the outset and at the end of the project was not assessed, we are not able to verify these claims. The literature on student teachers' knowledge and understanding of the nature of science and its relationships with science teaching shows that the linkage is complex (Abd-El-Khalick et al. 1998). Teachers' appreciation of the content associated with the nature of science, for example, as in the list given by Osborne et al. (2003), or their abilities to reflect on this, is no guarantee that their teaching will consequently be changed or be any different to teachers with a less well developed view of the nature of science (Abd-El-Khalick et al. 1998; Brickhouse 1990; Lederman 1999; Lederman 1992). However, as discussed previously, there was evidence that student teachers in this study were disposed to using more group and discussion work. As Hasweh suggested, teachers who are open to student-centred epistemologies might also be more open to considering validity and reliability of scientific evidence through debate and discussion in science teaching (Hasweh 1996). According to Lederman (1999), these epistemological beliefs might be at least as strong, if not stronger than beliefs about the nature of science, and hence in influencing how teachers teach.

The comments of all the student teachers revealed that engagement in this project created a ‘professional space’ that encouraged developmental dialogue for both the student teacher and the experienced teacher acting as mentor. However, a recent evaluation of a project to change teachers’ behaviours away from didactic approaches towards more discursive, collaborative and pupil-centred teaching, shows that the time needed to foster and use this professional space to make long-term change should not be underestimated (Serret & Reiss 2006).

At the point of qualifying as teachers, these students had aspirations that the levels of creativity and the use of approaches experienced in the project during their training year might be continued in their first teaching post. It seems, from interview data gathered towards the end of their first year in teaching, that a number of school-based factors have limited fulfilment of these ambitions. At least one constraint was mentioned in each of the *vignettes*. These can be summarised as follows:

- ***Time constraints***. Newly qualified teachers in England typically teach an 85% timetable compared with a 50% load during their training period and so find it difficult to find time to write and plan new lessons (see for example Jill and Hilary).

- ***Curriculum constraints***. Newly qualified teachers may be expected to teach exclusively from a scheme of work that does not allow for lessons about ideas and evidence or the nature of science (see for example, Anna).
- ***Assessment constraints***. There may be a consensus view within a department or school that new approaches (as brought by the newly qualified teacher) detract from the practice that is perceived by teachers to underpin success in national tests and examinations (see for example, Jill).
- ***Development constraints.*** Schools and departments may have priorities for professional development and learning and teaching that focus the attention of staff on matters that are different and so compete for available training time (see for example, Hilary).

There was an indication, shown in the vignettes described (see for example, Anna), that if 'new' teaching is to take place then it can only be accommodated as an add-on to 'normal' teaching rather than being integrated with existing practice as was intended by the project. Analysis of data from questionnaires, issued to teachers in schools that had not been involved in the project but that had been provided with the curriculum and training materials from it, supports this view (Author 1 & Author 2 2005).

Newly qualified teachers enter their first post in a position of little power to make inroads into curriculum development, even when they are willing, able and confident to do so (Cochran-Smith 1991). They may enter a markedly different pedagogic culture from the one experienced in their training environment and may have little option but to absorb what they experience around them and adapt their teaching accordingly. Indeed, research shows that the influences and practices experienced and valued in training are often 'washed out in the process of enculturation' that takes place when new entrants find themselves in a school where pedagogy is markedly different from what they had experienced in their training (Cochran Smith 1991; Kelly 2000). Cochran-Smith calls this learning to 'teach against the grain' of the student teachers'/NQTs' previously preferred and valued pedagogies.

Our project has focused on teaching a particular aspect of science. This has served as a vehicle to evidence the wider benefits to teacher development that can be derived from a professional partnership conceived as collaborative professional development using a community of practice and centred on initial teacher education. While teacher education theory is often seen as the province of the university and practice that of the school (Blake et al. 1998) we have not made such a distinction. We feel that we have successfully challenged the entrenched views of roles and embraced the true notion of partnership in teacher education, in which all partners extract benefit especially in relation to specific curriculum innovation such as the one described (Author 1 2001).

Findings from surveys of teacher recruitment and retention in the UK (House of Commons 2004; Smithers & Robinson 2004) show that a common reason for leaving the profession, quoted by teachers moving out after 4/5 years, is that their talents and abilities, as they perceive them, are infrequently used and submerged by increasingly heavy workloads. The chance to be creative comes high on the list of things that teachers aspire to do but often have little chance to realise (Jeffrey & Woods 2003). This project and others like it may serve to whet the appetites of teachers as they enter the profession, as far as this opportunity to be creative is concerned. The question remains as to whether the diet that full-time teaching eventually serves up will be satisfying enough to prevent unnecessary and harmful wastage after a few years by undervaluing and failing to capitalise on the aspirations and talents of new recruits.

We recognise, however, that not every teacher has the ability or inclination to be truly innovative or creative. Neither is there the need or time for every lesson to be an original creation. Earlier we described ‘levels of critique’ (Table 1) to describe how student teachers and their mentors can be critically reflective of the materials they use to support learning. These levels have been fundamental in our approach to training and professional and curriculum development. Whilst we believe that it is not necessary for every teacher to ‘hold the pen’ (in the sense of individual authorship and original creation of lessons) there is, for us, a bottom line. We see this as an enabling function, giving teachers the tools to, at least, make better use of what published materials and peer produced resources already exist (*i.e.* at least to level 3 of our scheme). As far as improved appreciation of the nature of science is concerned, this may go some way towards meeting Lederman's plea that teachers should be helped to, "internalise the instructional importance of the nature of science … to avoid the lack of attention … in teachers' instructional decisions" (Lederman 1999, p. 927).

**Conclusion**

Curriculum innovation and change are complex issues in schools and rely on an interaction of personal, organisational, pedagogical and, sometimes, political beliefs (Hopkins et al 1994). At the classroom level, of those who have to grapple with day-to-day curriculum change embodied in legislation, there are perhaps two ways of changing hearts and minds. One is through individuals who can successfully proselytise and influence practice, the other is through in-service training and Continuing Professional Development (CPD). Our research shows that, in this particular case in science education, and, as far as the individuals described here were concerned, relying on new entrants to teaching and their abilities to proselytise and therefore act as 'change agents' might be overly optimistic. Various school-based factors and the realities of moving from being a student teacher to a 'full-time' NQT have made this difficult.

According to a recent study, the world's top performing school systems (Alberta, Australia, Belgium, Finland, Hong Kong, Japan, Netherlands, New Zealand, Ontario, Singapore and South Korea) share three essential features. These are: 1) teachers are recruited from the pool of the highest qualified graduates: 2) there is high quality sustained professional development and: 3) there is high quality instruction for all learners (Barber & Mourshed 2007). According to Barber and Mourshed all three must interact and be concurrent. Thus, high quality CPD has a pay-off in good instruction and so raises standards of pupil performance. We believe that projects such as the one discussed here, based on communities of practice with a broad membership and focussed on collaborative curriculum development, should play a part in providing high quality and sustained CPD.

Some outcomes for members of the xxx community were common, such as the experience of critiquing learning materials and the insights into teaching gained from this. Other outcomes were unique to different members of the community such as the improved understanding of the different needs of novice and experienced practitioners gained by the KS3 consultants, who had not previously worked with student teachers. One key outcome, valued equally by all participants, was the opportunity to have professional space through which one problematic area in science teaching could be explored at length. It is to be hoped that the professional dialogue and the skills of critiquing that occupied this space are features that will live with members of the community and will enrich their professional lives for some time to come. Providing these tools and this professional space might go some way towards retaining the many talented and creative individuals that enter teaching and that are essential to a society seeking to maintain and develop its scientific knowledge base.

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**Table 1: Levels of 'critiquing' in the xxx Project**

| Level | Requirement |
|---|---|
| **Level 1** | Constructively critiquing existing published and school-produced materials. |
| **Level 2** | Constructively critiquing changed or adapted materials. |
| **Level 3** | Constructively critiquing one's own novel materials. |
| **Level 4** | Constructively critiquing novel materials created by peers. |
| **Level 5** | Persuading others to adopt the newly created materials, methods or approaches. |