Professional learning portfolios for argumentation in school science

Abstract

This paper reports on the use of portfolios in a continuing professional development programme to advance teachers' skills in their pedagogy of argumentation. The programme adopted a cyclical process of expert input- teacher practice- sharing practice, in order for professional learning to include reflective analysis of growing accomplishment. Accomplishment was initially defined according to previous research and development on the teaching of argumentation, but was redefined during the programme as teachers shared practice and discussed their achievements. Portfolios were used to help teachers apply their learning, collate evidence of their accomplishment and share reflective analysis of practice with other colleagues on the programme. The paper includes extracts of two teachers' portfolios; these provide evidence of each teacher's developing accomplishment in the teaching of argumentation. Portfolios are idiosyncratic and are constructed according to an individual teacher's motivations, interpretations and situations. Teachers need structure and guidance in creating purposeful portfolios that enhance reflective practice.

Introduction

School science teaching in the UK has traditionally been focused on the content of science – that established body of scientific knowledge that forms the bedrock of the curriculum and school science examinations. Yet recent debates about science education emphasise the importance of the nature of science and the processes of

critical reasoning and argument (Driver, Leach, Millar, & Scott, 1996; Driver, Newton, & Osborne, 2000; Millar & Osborne, 1998). As future citizens our students should be able to engage in decision-making about controversial issues in science, and to do so they will need to understand how evidence is used to construct explanations. They will also need to understand the criteria that are used in science to evaluate evidence. There is a growing need therefore to educate our students and citizens about why we believe in the scientific world-view – that is to see science as a distinctive and valuable way of knowing. Such a shift in emphasis requires that the teaching of science should focus more on the nature of science and on the evidence and arguments for scientific ideas, and help students develop skills of engaging in fruitful argumentation.

Research shows, however, that only if argumentation is specifically and explicitly addressed in the curriculum will students have the opportunity to explore its use in science (Khun, 1991; Hogan & Maglienti, 2001; Osborne, Erduran, & Simon, 2004a; Zohar & Nemet, 2002). Because science education has always been more concerned with students' understanding of scientific concepts, adopting different aims in the science classroom is notoriously difficult. The normative practice in science is predominantly that of transmission (Lyons 2006), the focus being on the delivery of science facts and concepts. Yet the teaching of argumentation through the use of appropriate activities and teaching strategies can provide a means of promoting a wider range of goals, including social skills, reasoning skills and the skills required to construct arguments using evidence (Osborne, Erduran, & Simon, 2004b; Simon, Erduran & Osborne, 2006). In order to change the emphasis in teaching science to incorporate argumentation, teachers need to adopt more dialogic approaches

(Mortimer & Scott, 2003; Alexander, 2005) that involve students in discussion, and to consider how they themselves interact with students to foster argumentation skills. The research reported here focuses on a programme designed to help teachers transform their practice and achieve such a change.

Transforming pedagogy requires teachers to share the values of an innovation and be prepared to take risks – a venture that is best supported by establishing the practice of collaborative reflection within a community of professional learning (Hoban, 2002; Loucks-Horsley et al., 2003). Early approaches to teacher development that had little sustained impact were underpinned by mistaken beliefs that teacher learning is a linear process where teachers' practice could be transformed by prescriptive approaches, whereas current knowledge would suggest that a more complex view of professional learning is required to bring about sustained change (Fullan, 2001; Hoban, 2002; Bell and Gilbert, 1996; Spillane, 1999; Loucks-Horsely, 2003; Adey, 2004). Hoban's work is particularly important in identifying a combination of conditions for teacher learning that complement each other in supporting change. These are a conception of teaching as a dynamic relationship with students and with other teachers where change involves uncertainty; room for reflection in order to understand the emerging patterns of change; a sense of purpose that fosters the desire to change; a community to share experiences; opportunities for action to test what works or does not work in their classrooms; conceptual inputs to extend teachers' knowledge and experience (in this case, ideas about the value of argumentation in teaching science); and finally sufficient time to adjust to the changes made. Moreover, as Fullan has established, any change is dependent on the introduction of new materials, approaches and a challenge to existing beliefs (Fullan 2001). Initiating the

kind of change that was attempted in this project was therefore reliant on teachers trying out new approaches, sharing their experiences and reflecting on their own practice.

Reflection can be viewed as 'a purposeful, systematic enquiry into practice' (Schön, 1983) with a view to its improvement and which allows for doubt and perplexity (Hatton & Smith 1995; Pedro 2005). According to Furlong et al (2000), it is a way of coming to know by capturing practical experience in order to learn from it. Reflection involves both doing and thinking, looking back and looking forward and is concerned with learning in order to be a better practitioner. Reflection, however, can occur at different levels, for example Hatton and Smith (1995) make a distinction between different kinds of reflection, including technical (decision-making about immediate behaviours or skills), descriptive (seeking what is seen as best practice), dialogic (weighing viewpoints and exploring alternatives) and critical (seeing goals and practices as problematic). The first three levels of reflection are characterised by recounts of personal experience that do not go beyond the self, or which focus on the effectiveness of skills without any broader critique, or which provide some reasons for action but which are limited to personal judgement. Critical reflection, by contrast, is a wider and longer term. It goes beyond the personal to review experiences in the light of other forms of professional knowledge such as the findings of research and theoretical insights. Lyons (1998) uses the metaphor of weaving and threading to illustrate how critical thinking can connect different experiences to bring into consciousness teachers' beliefs and values, in that way critical reflection can be 'transformational' (Barnett 1997).

To achieve the transformational goal of teachers' professional development thus requires an approach to teacher learning that is informed by Hoban's conditions and provides opportunities for reflection on practice. A vehicle for such reflection can be the building of a portfolio of evidence that can be shared and discussed between teachers. A portfolio is often defined as a 'collection of work' or a 'collection of evidence' (Paulson, Paulson & Meyer 1991; Snadden & Thomas 1998; Hoel & Haugalokken 2004). Just as the collection of any artefact is varied and built up gradually, implicit in the term 'collection' is the idea that the material presented shows change and development in different contexts over time and is not a product of the moment. In teacher education, portfolios have served two purposes: assessing performance and supporting professional learning. A learning portfolio allows teachers to 'engage in professional dialogue with colleagues', 'to collaborate and develop understanding and ideas on teaching and learning' (Klenowski 2002 p25). A learning portfolio involves thinking, talking and knowing about teaching; it is self-directed and involves a process of discovery (Grant & Huebner 1998). The process of coming to understand better the complexities of teaching involves asking questions, sometimes difficult ones which challenge the status quo and which query why things are the way they are. Sharing and discussing portfolio entries with colleagues in the program was perceived as a means of enhancing reflective practice through collaborative analysis of evidence (Davis & Honan 1998, Grant & Huebner 1998, Lyons 1998, Shulman 1992). The provision of feedback, questions and different perspectives by peers and mentors can strengthen the portfolio development process through broadening the process of reflection.

The research reported here focuses on the use of portfolios in a CPD programme to enhance the teaching of argumentation in science. The aim of the research was to see whether teachers would develop portfolios of evidence that demonstrated their growing accomplishment in the teaching of argumentation, and their reflective analysis of practice. Teachers were encouraged to gather evidence of how they interpreted the expert inputs of the CPD programme and put them into practice, and to share and document their reflections based on that evidence. It was anticipated that the portfolios would provide a source of data for demonstrating the efficacy of the CPD.

The CPD programme for argumentation

The CPD programme for teaching argumentation that was developed through the King's College Weizmann project grew out of previous research on teachers' use of argumentation in science classrooms (Simon *et al*, 2003, 2006) and from the in-service training materials called IDEAS (Ideas, Evidence and Argument in Science Education, Osborne, Erduran & Simon, 2004b). The CPD programme built in expert inputs from these materials and supplemented these with other professional learning conditions specified by Hoban, including sessions for sharing and reflecting on practice. A series of workshops was designed to incorporate these conditions and our research aimed to explore those features of the programme that would have an impact on professional learning in the context of teaching argumentation in science.

Earlier work on enhancing the quality of argument in school science had focused on ways in which such quality could be determined. A suitable analytic framework used

in the research was based on Toulmin's (1958) model (see Erduran, Simon & Osborne, 2004 for a fuller rationale), which had been used as a basis for characterising argumentation in science lessons (Russell, 1983) and in other coding schemes (e.g. Jiménex-Aleixandre, Rodríguez & Duschl, 2000). Features of a Toulmin analysis of argumentation include: the extent to which students and teachers make use of data, claims, warrants, backings, qualifiers and rebuttals; and the extent to which they engage in claiming, justifying and opposing the arguments of each other. The Toulmin framework was therefore a feature of the way in which we helped teachers to conceptualise and evaluate argumentation. Previous work had led to a distinction being made between *argument* and *argumentation*, argument referring to the substance of claims, data, warrants and backings that contribute to the content of an argument, whereas argumentation to the process of assembling these components, in other words, of arguing. Through providing students with tasks that require discussion and debate, teachers can support students in the construction of arguments through the process of argumentation.

A concept that was developed with this project was that of an accomplished teacher of argumentation. Though the idea of accomplishment was not new, what it meant to be accomplished with reference to the teaching of argumentation had to be established. Previous research with teachers (Simon *et al* 2006) identified how teachers' oral contributions demonstrated epistemic goals implicit in their interactions, both in whole class and small group settings. For example, the act of asking students to provide reasons for their claims reflected a teaching goal that students should show the process of justification. An analytical framework that focused on teachers' oral

contributions resulted in the formation of a tentative hierarchy of teaching goals that facilitate argumentation processes. These processes included:

- Talking and listening
- Knowing the meaning of argument
- Positioning
- Justifying with evidence
- Constructing arguments
- Evaluating arguments
- Counter-arguing/debating
- Reflecting on the argumentation process

It was envisaged that awareness of these argumentation processes would help teachers to incorporate them into classroom discourse. For example, that students needed to learn how to listen and talk, justify claims etc, before they could debate; and that teachers themselves needed to value and learn how to implement group discussion and prompt justification before they could orchestrate effective counter-argument within their teaching. Such a starting point, together with the IDEAS materials, enabled us to begin to define accomplishment in the teaching of argumentation as the following:

- Articulate argument goals and a rationale for teaching argument
- Model and communicate the meaning of argument
- Develop organisation strategies for group work
- Focus on the use of evidence

- Introduce writing frames to support argumentation
- Encourage counter-argument
- Evaluate arguments
- Become aware of their role as a facilitator in supporting argumentation
- Be reflective on their practice

The CPD programme thus focused on ways in which such accomplishments could be promoted, through a combination of expert input, workshop activities and episodes for sharing and reflection. The expert inputs began with sessions that helped teachers to become familiar with the rationale for teaching argumentation in science, in that for students to appreciate the origins of scientific belief and the nature of science, they must explore some of the reasons why theories have become established and why alternative theories are considered to be 'wrong'. Teachers discussed activities that invite students to evaluate the evidence that is used in such arguments, and became immersed (Loucks-Horsely et al 2003) in these activities themselves in order to appreciate their impact and extend their understanding of the possible teaching goals associated with argumentation. Many such activities were found in IDEAS (Osborne, Erduran & Simon, 2004b), but teachers were also encouraged to find other resources, or to develop activities themselves to suit their own curricular schemes. There was a distinct focus on the ways in which small group discussion could be organised, as the more dialogic approach needed for successful argumentation requires more careful grouping than simply allowing students to discuss. The teachers experienced several different group formats. Video materials and workshop sessions from IDEAS were incorporated that would help teachers to model argument and communicate its meaning to students. Video material was particularly focused on ways in which

teachers could introduce argumentation activities, and support argumentation using oral prompts to help students justify their arguments with evidence, including playing 'devil's advocate'.

Exercises using Toulmin's framework were introduced with the aim of helping teachers to evaluate argument. Teachers were encouraged to develop criteria for assessing the quality of students' arguments focusing on how evidence was used to justify claims and how argumentation incorporated rebuttals. To encourage counter-argument, teachers were introduced to strategies that they could use to involve students in a conflict situation that can stimulate rebuttals (e.g. a pair taking one position in an argument works with a pair taking an opposing position). They were also introduced to writing frames that helped to support argumentation and provide a means for both students and teachers for evaluating argument outcomes. Teachers began their engagement with argumentation through attempting to teach science content in a way that includes an argumentation element. At each workshop, they shared these experiences before experiencing further inputs. The programme provided opportunities for the teachers to share evidence that could be included in their portfolios, and identify how such evidence demonstrated growing accomplishment.

Research

The research reported here focused on the contents of the final portfolios, addressing the following questions:

Do the portfolios show evidence of accomplishment?

Do teachers themselves identify that evidence as demonstrating accomplishment?

Do teachers annotate their reflections on the evidence in the portfolio, if so, how?

After an initial phase to establish the CPD contents, the programme was undertaken consecutively by two groups of teachers, the main aim of each phase being to refine the programme for future use. Though each group included four teachers at the outset of the programme, pressures of work and inability to be released from school meant that only two out of each group of four teachers eventually completed the programme and produced a final portfolio. The four portfolios (compiled by Martin, Nancy, Alice and Nick) were analysed by searching the documentation for examples of argumentation practice, reasons for selecting evidence and different kinds of reflective notes made immediately after practice and at a later stage. Evidence for accomplishment was identified according to the criteria for generated in the CPD programme (listed above), and evidence for reflective analysis was identified according to Hatton and Smith's (1995) descriptors of levels of reflection, that is technical, descriptive, dialogic and critical. The analysis of portfolios was followed up by interviews with the four teachers about the CPD experience.

The four portfolios were idiosyncratic and demonstrated accomplished practice and reflective analysis in different ways. The portfolios compiled by Martin and Nancy were considered by them to be good examples of their practice and to demonstrate their progress in the domain, whereas Alice and Nick considered their portfolios to be incomplete but a useful source of information about their teaching. To illustrate the potential of using portfolios as a vehicle for professional learning, in this case of teaching argumentation in science, this paper includes an analysis the final portfolios compiled by teachers Alice and Martin. The portfolios provide a record of how each

teacher practiced the skills acquired from the CPD, attempted to transfer these skills to different classroom contexts (Joyce and Showers, 1988), tracked their progress towards accomplishment and demonstrated their learning in the domain.

Portfolio: Alice

Alice was acting head of her science department, which was located in an inner London school with a high proportion of ethnic minority students. She joined the project in Phase 2, having had some previous experience of teaching argumentation. She attended all four workshops, which took place over a period of eight months, and experimented with different ideas for argument activities with students aged 11 to 15 years. She constructed her portfolio over this eight-month period, collecting examples of her practice that included lesson plans, resources she had created herself or acquired, students' work and her own reflections on many of her lessons. Alice's interpretation of her classroom practice was the focus of attention in the portfolio.

Initially, Alice had a rudimentary understanding of the argumentation process from a Masters course she had recently completed and had a limited appreciation of how to introduce it into her lesson systematically. She had some experience of reflecting on her teaching, but this was not very fully developed. After compiling her portfolio Alice constructed a table (Table 1) in which she reflected on the evidence she accumulated to demonstrate her work in this domain.

[Insert Table 1 here]

Table 1 shows how Alice focused on aspects of her teaching of argumentation that she believed provided evidence of her accomplishment. Within the portfolio there are more examples that show evidence of her professional learning, but the Table focuses on what she saw as her main achievements. The third column demonstrates an awareness of how she has achieved accomplishments including how to encourage students to use evidence.

During the second workshop of the programme Alice was introduced to the process of evaluating argumentation through expert input based on Toulmin's model. She subsequently promoted evaluation in her argumentation lessons, and shared her reflections on the process with colleagues. In constructing a section of her portfolio that showed how she developed her evaluation of students' argumentation, Alice drew from different lessons. Her aim was to explore ways in which students' arguments could be evaluated so that she could help students to progress to higher levels. Table 2 shows the Toulmin model Alice used and adapted to help her evaluate students' work.

[Insert Table 2 here]

Alice wrote the following note – a simplified version of Toulmin's model that she could use with students to explain what she was looking for:

- Make a claim
- What is your evidence? Present how you are substantiating your claim
- Warrant – explain HOW the evidence proves the point you are making

- Backing – present some information to BACK your claim
- Explore any shortcomings/where doesn't the evidence fit in?
- Anticipate/explore counterargument

Alice also drew on a model of the Levels of argument that had been derived from Toulmin's model (Osborne, Erduran & Simon 2004a):

[Insert Table 3 here]

She used a simplified version of these levels to help her assess students' work:

Level 1	Claim V claim
	Claim V counter claim
Level 2	Claim + data to back it
	+Warrant
Level 3	Claim +data to back it
	+Warrant
	+May have a weak rebuttal
Level 4	Claim + data
	+Warrant
	+Strong rebuttal
Level 5	Claim + data
	+ warrant
	+ more than one rebuttal

Alice transcribed students' spoken arguments and explained how she then applied these levels of argument as she analysed the discourse. Through discussing this analysis with colleagues she was able to consider how to improve their arguments in the future. Figure 1 shows her portfolio entry for this analysis.

[Insert Figure 1 here]

Alice also applied Toulmin's model when evaluating students' written arguments in other contexts. She used the IDEAS (Osborne, Erduran & Simon, 2004b) resource Snowman, which involves a concept cartoon showing one snowman with a coat (Fred) and one without a coat (Birt). Students are asked to decide which snowman would melt first. Alice included an example of one group's written argument in her portfolio and annotated it (in parentheses). Her analysis demonstrates that she had assimilated her understanding of Toulmin's model of argument and was able to apply it when assessing students' argumentation outcomes, so that she could judge whether students had achieved a high-level argument. The portfolio entry again shows her accomplishment in evaluating arguments (Figure 2).

[Insert Figure 2 here]

Alice also included other annotated entries of students' work to show how she was continuing to apply the analysis to other argumentation outcomes.

The portfolio, though incomplete in Alice's view, does demonstrate aspects of teaching argumentation that Alice tried to develop in her practice, particularly

evaluating students' arguments. The reflective annotations range from 'descriptive' where Alice is analysing her own performance and giving reasons for her actions, to more 'dialogic', as shown in Table 1, constructed after completing the portfolio. In Hatton and Smith's terms, Alice is 'hearing one's own voice' and exploring alternative ways of approaching argumentation. When interviewed, Alice stated that this CPD experience differed from others in that it centred more on the process of reflection and on the search for evidence from her own practice that demonstrated progress. She also valued the sharing of evidence with others on the programme; 'people look at things from a different perspective and help you see things that you would not necessarily see yourself'. The portfolio provided a vehicle for enhancing her reflective analysis.

Portfolio: Martin

Martin was head of a science department in an inner London community school for girls (aged 11 to 16 years) when he joined Phase 3 of the argumentation CPD programme. He constructed his portfolio over a period of 6 months by collecting several examples of his practice including lesson plans, resources he had used, students' work and his reflections on the lessons. Martin had a basic understanding of the argumentation process out the outset but was keen to improve his practice and to introduce argumentation into his lessons systematically. He also wanted to assist colleagues in his science department with their professional development. Portfolio evidence presented here is from two of Martin's argumentation lessons, one on the topic of genetics and variation (students aged 14 to 15 years) and the other focusing on volcanoes and earthquakes (students aged 12 to 13 years). Analysis of these

portfolio exemplars offers evidence of several accomplishments and of Martin's reflections on practice.

In the genetics and variation lesson Martin had clear scientific and argumentation goals. This was his second attempt at argumentation and he used a powerpoint presentation showing images of variation or mutation with a mixture of environmental and inherited elements to stimulate students' thinking about the role of evidence. The powerpoint was followed by discussion based on concept cartoons about living things and their environment in which Martin was able to implement small group discussion. Figures 3 and 4 are portfolio extracts that illustrate his planning and reflection on this lesson. The lesson plan demonstrates careful attention to the objectives, or teaching goals, of the lesson, and that these are content focused, though Martin clearly aimed to implement small group discussion that would encourage talking and listening.

[Insert Figures 3 and 4 here]

Martin's reflection suggests that he was not entirely happy with the content of the presentation and that in future he would include more images on environmental variation. His objective when compiling the slides may not have been very clear and student reaction caused him to rethink his objectives.

The second extract taken from Martin's portfolio focuses on his Year 8 class undertaking argumentation on the causes of earthquakes and volcanoes. In this lesson Martin organised group work in two different ways and asked the students to focus on the evidence they were given in the resources. He provided resources that could

support argumentation and were sufficiently diverse for students to judge the value of each piece of evidence. Martin's lesson plan is included here (Figure 5) as it demonstrates that he had progressed in his articulation of objectives as 'lesson outcomes' and that these included an identification of content goals, epistemological goals (the uncertain nature of scientific knowledge), social goals and reasoning goals.

[Insert Figure 5 here]

Martin's evaluation of this lesson was positive and focused on the students' homework, which he included in his portfolio. He added evaluative comments to some pieces of student work at a later date and his comments are shown in italics in Figure 6. The evaluation of students' work enabled him to focus on their use of evidence in answering questions and drawing conclusions.

[Insert Figure 6 here]

Throughout Martin's portfolio there were two levels of reflective comment; the first level included those comments made soon after the lesson, which simply reported success/problems or added some suggestions, and are therefore 'descriptive':

> *Technical issues marred start of lesson – powerpoint froze and sound track did not play so well.*
>
> *Could have given pupils more thinking time over paired activity to discuss causes of earthquakes and volcanoes.*
>
> *Forces of nature activity groups worked well – assigned on ability. Roles assigned by group. The pen rule for talking was partially effective in*

controlling the number of people talking. This would need to be worked on. In groups, discussion was good – and they could easily evaluate the evidence and draw conclusions to answer 3 questions.

The second level of reflective analysis comprised comments made after Martin's engagement with the project, when he reviewed his final portfolio. This level shows more specific reference to argumentation processes and how Martin facilitated these in his teaching, these reflections are more 'dialogic' in that they reflect his analysis of argumentation pedagogy:

The activities in feedback led to use of counter argument and speakers having to further justify their predictions and decisions. Pupils got into role well and discussions were heated and animated. Decisions were defended with zeal. The arguments used were complex in that evidence was used to support decisions.

Martin's evidence in his portfolio demonstrated his accomplishments in this domain. He used his portfolio to select, accumulate and analyse evidence, all of helped him to confirm the merits of using argumentation in science lessons.

In a follow-up interview Martin stated that he saw the portfolio as a means of having evidence that he was developing his own understanding of argument and that the pupils' understanding and ability to use argument was also developing. He added reflections to remind him of what he had learnt and what he could highlight from pupils' work. He began by including snippets of lessons using argumentation to whole lessons using argumentation: 'As long as I did my evaluations straightaway – they helped me analyse how much I understood about the process of argument and how

much the pupils understood. Evaluating helped me to go on to the next lesson.' He also commented that sharing his portfolio with other teachers was a useful experience as it helped him articulate his reflections.

Discussion

The two extracts from teachers engaged in Phase 2 and Phase 3 of the programme, where expertise in argumentation was to be developed with teachers who had little prior experience, shows how the portfolio process enriched reflective analysis by providing opportunities for annotation of portfolio entries, immediately after practice and at a later date. Moreover, the contents of the portfolio and the reflections were discussed with other members of the teacher group, so all eight teachers taking part in these two phases were able to contribute, share reflections and learn from their involvement. Interviews conducted with individual teachers indicated that the shared aspect of the work was the most highly valued component of the programme. Though this programme was conducted with a small number of teachers it served to refine the CPD for argumentation and enable teachers to co-construct the definition of accomplishment in the domain. In addition it enabled us as researchers to evaluate the role of the learning portfolio in professional development work. Critical to the process was the cyclical nature of expert input – teacher practice- sharing practice that was repeated in each Phase.

The value of portfolio development remains uncertain, as only half the teachers involved in the CPD produced a final portfolio; other teachers put argumentation activities into practice and collected student work but did not collate these documents

into a portfolio of evidence or write reflective comments. So why do some teachers undertake reflective analysis and others do not? What motivates a teacher to produce a portfolio, and how effective was it for those who engaged more fully in the process? During conversations in workshops teachers indicated that they needed to be motivated by personal goals in order to construct a portfolio. Teachers having different levels of experience and roles within their schools were motivated in different ways and hence their portfolios were very different. Martin was head of a science faculty and wanted to set up CPD within his school; he intended to use his portfolio to share his own learning experiences with colleagues, he also valued the portfolio from a personal learning perspective. Shared reflective analysis helped both him and less experienced teachers who used their portfolios to identify progress in their teaching. Our analysis of portfolios demonstrated that teachers made progress towards accomplishment in the teaching of argumentation, as evidenced in Alice's and Martin's extracts. However, these portfolios show that focus was different for each teacher in terms of selecting evidence for accomplishment. From documentary analysis and interview data alone, it is not possible to determine the extent to which the teachers progressed in their teaching of argumentation. To study their teaching was beyond the scope of this project, and the portfolio evidence can only be indicative of their practice. Our interpretations of accomplishment arising from the CPD are therefore limited to what can be seen in the portfolios. In addition, the portfolio extracts can only be indicators of how reflective these teachers were as practitioners. However, the portfolios do provide opportunities for reflection based on the documentation; it is possible that lower levels of reflection, such as descriptive reflection, are characteristic of immediate response to an event, whereas reflection becomes more dialogic when teachers have had time to think about their pedagogy, its

problems and possible solutions. The analysis of the portfolios of the four teachers who did complete the process (the two included in this paper are indicative of the four) showed evidence of dialogic reflection and each was positive about the role of the portfolio in their personal learning. One might ask why reflections do not reach the higher levels of criticality described by Hatton and Smith (1995). One possible explanation is that the portfolio, as conceived in this project, did not require teachers to look outwards beyond the analysis of their own practice, and to think about wider implications of their changes. A more wide-ranging analysis of levels of reflection was beyond the scope of this study, which focused specifically on recognition of growing accomplishment in teaching argumentation, and the choice of evidence to demonstrate that accomplishment. However, a combined set of analyses could serve to help develop the role of critical reflection in the wider use of learning portfolios, where these become part of accredited courses and professional development qualifications (Turner and Simon, 2007).

Our work with portfolios suggests that they can be used to develop the skills of reflection, self-evaluation and analysis, hence contribute to an individual's metacognitive development. The product cannot be separated from the processes involved in its development. If the main emphasis is on the quality of the product, then tasks may become reduced to a generic level and the intended processes of self-evaluation and reflection will give way to checklists of standards to be reached. The portfolio would be reduced to trivial and superficial purposes (Klenowski, 2002). However, there needs to be some structure to guide effective use of portfolios and a sense of purpose to motivate teachers. If the portfolio is to be shared with colleagues,

CPD providers and mentors, and is therefore ‘on show’, the selection and annotation of evidence becomes more purposeful.

References

Adey, P. with Hewitt,,G., Hewitt, J. and Landau, N. (2004) *The Professional Development of Teachers: Practice and Theory*. London, Kluwer Academic Publishers.

Alexander, R. (2005) Alexander, R. (2005) *Towards Dialogic Teaching*. York: Dialogos.

Barnett, R. (1997) *Higher Education: A critical business*. Buckingham: Open University Press.

Bell, B. & Gilbert, J. (1996). *Teacher Development: A Model from Science Education.* London: Routledge Falmer.

Davis and Honan (1998) Reflections on the Use of Teams to Support the Portfolio Process in N.Lyons (ed.) *With Portfolio in Hand: Validating the New Professionalism.* New York: Teachers College Press.

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

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

Erduran, S., Simon, S. & Osborne, J. (2004) TAPping into argumentation: Developments in the application of Toulmin’s argument pattern for studying science discourse. *Science Education*, 88(6), 915-933

Fullan, M. (2001) *The new meaning of educational change* (3rd ed). London: Routledge-Falmer.

Furlong, J., Barton, L., Miles, S., Whiting, C. & Whitty, G. (2000) *Teacher Education in Transition: Re-forming professionalism?* Buckingham: Open University Press.

Grant, G.E. and Heubner, T.A. (1998) The Portfolio Question: The Power of Self-Directed Inquiry, in N.Lyons (ed.) *With Portfolio in Hand: Validating the New Professionalism.* New York: Teachers College Press.

Hatton N & Smith D (1995): Reflection in Teacher Education: Towards Definition and Implementation. *Teaching and Teacher Education* 11(1) 33 - 49

Hoban, G. (2002) *Teacher learning for educational change*. Buckingham, Open University Press.

Hoel, T L. & Haugalokken, O K. (2004) 'Response Groups as Learning Resources When Working with Portfolios' Journal of Education for Teaching Vol. 30, No. 3, pp. 225 -241

Hogan, K., & Maglienti, M. (2001) Comparing the epistemological underpinnings of students' and scientists' reasoning about conclusions. *Journal of Research in Science Teaching*, 38(6), 663-687.

Jiménex-Aleixandre, M. P., Rodríguez, A. B., & Duschl, R. (2000) "Doing the Lesson" or "Doing Science": Argument in high school genetics. *Science Education, 84*(6), 757-792.

Joyce B. & Showers, B. (1988) *Student achievement through staff development.* White Plains, NY: Longman.

Klenowski, V. (2002) *Developing Portfolios for Learning and Assessment*. London: RoutledgeFalmer.

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

Loucks-Horsley, S., Love, N., Stiles, K, Mundry, S. & Hewson, P. (2003) *Designing Professional Development for Teachers of Science and Mathematics* (2nd Edition). Thousand Oaks, CA: Corwin Press Inc.

Lyons, N. (ed.) (1998) *With Portfolio in Hand: Validating the New Professionalism*. New York: Teachers College Press.

Lyons, T. (2006) Different countries, same science classes; Students' experiences of school science in their own words. *International Journal of Science Education,* 28(6) 591-613.

Millar, R., & Osborne, J. F. (Eds.) (1998) *Beyond 2000: science education for the future*. London: King's College London.

Mortimer, E. & Scott, P. (2003) *Meaning Making in Secondary Science Classrooms*. Maidenhead: Open University Press.

Osborne, J. Erduran, S. & Simon, S. (2004a) Enhancing the quality of argument in school science. *Journal of Research in Science Teaching*, 41(10), 994-1020.

Osborne, J., Erduran, S. & Simon, S. (2004b) *Ideas, Evidence and Argument in Science*. In-service Training Pack, Resource Pack and Video. London: Nuffield Foundation. Paulson, F L.

Paulson, P R. & Meyer, C A, (1991) What Makes a Portfolio a Portfolio? *Educational Leadership* Vol. 45, no. 5, pp. 60 – 63

Pedro, J. (2005)' Reflection in teacher education: exploring pre-service teachers' meaning of reflective practice', *Reflective Practice* vol. 6, no. 1, pp. 49 – 66

Schön, D. (1983) *The Reflective Practitioner: How Professionals Think in Action*, New York: Basic Books.

Simon, S., Osborne, J. & Erduran, S (2003) Systemic teacher development to enhance the use of argumentation in school science activities. In J.Wallace & J.Loughran

(Eds.) *Leadership and professional development in science education: New possibilities for enhancing teacher learning* (198-217). London & New York: RoutledgeFalmer.

Simon, S., Erduran, S. & Osborne, J. (2006). Learning to teach argumentation: Research and development in the science classroom. *International Journal of Science Education, 28*,(2-3), 235-260.

Spillane, J.S. (1999) External reform initiatives and teachers' efforts to reconstruct their practice: the mediating role of teachers' zones of enactment. *Journal of Curriculum Studies*, 31(2), 143-175.

Shulman, L. (1992) Portfolios in Teacher Education: A Component of Reflective Teacher Education, paper presented at the annual meeting of the American Educational Research Association, San Francisco.

Snadden, D. & Thomas, M. (1998) 'The use of portfolio learning in medical education' *Medical Teacher* Vol. 20, No. 3, pp. 192 – 199).

Toulmin, S. (1958) *The uses of argument*. Cambridge. Cambridge University Press.

Turner, K & Simon, S. (2007) Portfolios for learning; teachers' professional development through M-level portfolios. In J. Pickering, C Daly, & N Pachler (eds) *New Designs for Teachers' Professional Learning*. London, Institute of Education Bedford Way Papers.

Zohar, A., & Nemet, F. (2002) Fostering Students' Knowledge and Argumentation Skills Through Dilemmas in Human Genetics. *Journal of Research in Science Teaching,* 39(1), 35-62.

Table 1. Alice's tabulation of evidence for accomplishment.

Accomplishment being developed	**Activities through which accomplishment is practiced**	**Reflections on evidence for accomplishment**
Planning for achieving argumentation goals	IDEAs lesson on Euglena; Energy choice IDEAs lesson on Euglena with supporting prompts	The first lessons that I taught were simply based on the lesson plans provided in the resources without thinking of what I could do to develop their [students'] skills in writing arguments. Further on, other lessons show more careful planning and pre-thought. As a result of the prompts and the way I focused and taught the concept of argument, written outcomes are of better quality (even if they come from lower years).
Reflections on teaching argumentation	IDEAS lesson on Energy project How to introduce argument. PANGEA lesson	No written reflections were made, though my emphasis was on their scientific understanding rather than the development of their argument skills. Both recent lessons show that my reflections focus on how to develop effective arguments and pupils' engagement with the evidence.
Supporting argumentation	Where could Ideas and Evidence be taught? Resources to support	I'm now reflecting on sections of the curriculum where there are interesting, engaging opportunities to teach ideas and evidence. I'm now developing argument

	written arguments, evidence to frame arguments Assessing argument	prompts e.g. questioning, writing frames, key words to support pupils. I'm developing a bank of sites pupils can use to support their arguments with evidence – considering both sides of an argument. Assessing argument.
Pupil performance of argumentation	Snowman Euglena lesson	Pupils' written outcomes have improved.
The meaning of argument	Lesson on introducing the concept of argument	*No documented reflection*
Resources for argumentation lessons	Lesson plans Writing frames Plenary prompts	Lesson plans from the Net/CD-ROMs, Useful websites Animations/Presentations

Table 2 Toulmin's Model of Argument

Claims	These are assertions about what exists or values that people hold.
Data	These are statements that are used as evidence to support the assertion.
Warrants	These are statements that explain the relationship between the data to the claim.
Qualifiers	These are the specified conditions under which the claim holds true.
Backings	These are underlying assumptions, which are often not made explicit.
Rebuttals	These are statements, which contradict either the data, warrant, backing or qualifier of an argument.
Counter – Claims	These are simply opposing assertions.

Table 3 Levels of argument from Osborne et al 2004a

Level 1:	Level 1 arguments are arguments that are a simple claim versus a counter-claim or a claim versus a claim.
Level 2:	Level 2 arguments consist of claims with either data, warrants or backings but do not contain any rebuttals.
Level 3:	Level 3 arguments consist of a series of claims or counter-claims with either data, warrants or backings with the occasional weak rebuttal.
Level 4:	Level 4 arguments consist of a claim with a clearly identifiable rebuttal. Such an argument may have several claims and counter-claims.
Level 5:	This is an extended argument with claims supported by data and warrants with more than one rebuttal.

Figure 1. Alice's analysis of students' transcribed spoken arguments

In this lesson the focus has been 'Evaluating argument'. I am looking at how argument can be assessed. I have chosen to focus on spoken argument during class discussions. The 'Level of argument' sheet was used to identify claim, data, warrants and rebuttals in pupils' conversations. What follows is an attempt to analyse particular parts of the lesson that I recorded in writing.

Level 1	*Fateha*	*I agree with it*
	John	*No, it's bad*
	Fahmida	*I don't know*
	John	*It's bad, I know*

This shows a claim from Fateha. John just disagrees - a counter claim. Fahmida doesn't help. John repeats what he had said before, but still doesn't explain why.

Vincent	*I eat GM food and you do too*
Sabena	*Don't say that, it's not true. Anyway how do you know what I eat?*
Vincent	*……said it's in loads of food, like veg.*
Sabena	*I don't like veg.*

Vincent seems interested in discussing a social implication of the presence of GM but Sabena took offence and defended herself. This is another example of a low level argument as it is simply claim versus claim.

Level 2 Jake responded to Vincent

Jake	*So this means it is bad for health because we are eating it*
Vincent	*Well, I haven't died*
Jake	*But you don't know if it's doing something inside.*

This conversation shows a claim by Jake followed by Vincent backing his claim with 'weak' data – 'Well, I haven't died'.

Level 3	*Fateha*	*We can have more food and people need it.*
	John	*But it's bad because it's not natural*
	Fatena	*What, plants or genes?*
	John	*No changing it like that*
	Fatena	*And it grows quicker*
	John	*Because you can't change it back*

John has included a rebuttal – 'changing genes' is not 'natural' and implies danger when he adds the data 'because you can't change it back'. However, it doesn't carry much weight. John does not explain fully how his evidence related to his argument, so I assume it to be a Level 3.

Level 4 Luke steps into the conversation between Fateha and John, in support of John.

Luke *Yeh, its like sometimes the changes can do a bad thing, like getting it to be bad for the soil, or it makes it dangerous and if that happens it spreads and you can't stop it.*

Luke reiterates what John said but makes a stronger rebuttal this time.

Level 5	*John*	*GM food is not good*
	Fateha	*I don't think so*
	Fahmida	*It affects wildlife like insects so it has to be bad because of the food chain, so it will have an effect on the environment like more or less animals. It depends .*

Fateha talks to Rima to get her on side –

Rima	*Look, it says that more people can eat because it grows better, I don't know, so then the land will be less*

damaged because you have to grow less. And this is done so it doesn't get diseases and that.

The discussion starts with a simple claim 'it's not good' vs counter claim by Fateha. Fahmida offers data – it affects the environment, and also a warrant – because it affects the food chain causing an imbalance. Rima supports Fateha with a rebuttal – it will affect the land less because you have to grow less and there is less chance of the plant being diseased.

The challenge presented in an argumentation lesson is to make an effective argument – where all its components are present. It is important for pupils to offer reasons – data – to support their claim and, if they do not agree with the counter claim they should be able to work through the other's thinking to find out exactly why it is they don't agree with it.

A good argument is valid and connects the claim and conclusion by using evidence. To evaluate argument I have focused on pupils' conversations during a class discussion.

Figure 2. Alice's annotated student work, and commentary

I think that Birt will melt 1st because….

The sun is hitting Birt directly so he will melt quicker as the sun carries heat energy [claim and data], *which means the heat from the sun can be passed through the molecules quicker if the sun is hitting him directly* [warrant].

Another reason is that….

Birt is not wearing a coat so when the snow melts to water it can melt and drip off whereas if he was wearing a coat the coat will absorb the water, and water is not a good conductor of heat [backing].

One reason why Fred's argument was wrong in the first place is because….

He says that his coat will trap all the sun's energy [counter-claim], *however he doesn't say that the sun's hitting him directly* [rebuttal], *so it will take more time to trap the sun's energy* [backing]. *And also when the water melts the coat will absorb it, and water is not a good conductor of heat* [rebuttal].

Finally, I think that….

Birt will melt first the main reason is that the sun will hit him directly. Fred will melt last as the sun isn't going to hit him directly even though he's wearing a coat [considering counter-claim].

The argument is introduced with a claim followed by data. The link between the data and the claim is being stated by the warrant, thus making this a strong argument.
The pupils have carefully considered the counter-argument (rebuttal) by stating why it is that the opposing argument does not hold true.
This is a high-level argument – it is and extended argument – the group has considered both sides of the argument, and there is more than one rebuttal present. Also, they have carefully backed up their ideas with evidence and have explored where the data does not fit into the claim made.

Figure 3 Martin's Lesson plan for Lesson 1 Genetics and variation

Context

A new topic: in the previous lesson we looked at the PowerPoint show and discussed the role of evidence in making decisions.

Objectives

Explain that variation can be caused by genetic and environmental factors

Explain that genetic variation can be caused by:

- Mutations (as caused by radiation, chemicals, spontaneous)
- Fertilisation

Explain that mutations are usually harmful but may be beneficial.

Recognise that there is a debate over the relative importance of genetic and environmental factors in determining some human attributes.

Intelligence

Sporting ability

Health

Success criteria

1. Using examples and evidence I can decide if the difference in living organisms is caused by genetic or environmental factors;
2. I will be able to explain how human appearance and performance is affected by Genetics and the Environment

Resources

PowerPoint slideshow, Concept cartoons 7.11, 7.2 and 6.8

Time	Pupils	Teacher
10 minutes	Starter activity: pupils are given cards with questions on about differences in animals and plants. They need to try to give reasons for this (pair work)	Register
10 minutes	Pupils observe powerpoint and decide on the outcomes of the lesson	

20 minutes	In groups of 4: they look at the concept cartoon The roles are 2 listeners, 1 scribe and 1 questioner – speaker. The speakers give their thoughts on each suggestion with reasons as to why they think they could be correct or not. They must give ideas on how to provide evidence for their choices.	Teacher displays groups on Whiteboard
5 minutes	Scribes feedback to different groups	Teacher gives scribes permission to move.
10 minutes	Whole class discussion on the outcomes	Teacher invites comments
30 minutes	In pairs pupils will research changes in humans. Criteria: genetic – are the benefits for all or a few? Give examples of the changes being made. Focus on health, sport and intelligence. Environmental: focus on health, sport, intelligence	Teacher sets the scene. Humans are changing: the causes are the environment and genetics
10 minutes	Pupils feed back to other pairs: in feedback one pair listens the others talk	
5 minutes	Review success criteria	

Figure 4 Martin's reflection on this lesson.

Powerpoint and audio [discussion] was good – pupils identified different types of variation and contributed concepts heard of and displayed good prior knowledge. The soundtrack provided good discussion about genetics and its possible effect on the planet.

The lesson worked well, in that groups actively involved themselves in the activity. There were 3 different activities linked to variation. The groups were arranged by me and displayed via power point. As not in friendship groups – but random with mixed ability within them this caused initial problems. However the activity went well. Each person had a clear role. At the end the scribes went to a group with their worksheet. The group had time to look at the sheet and then listen to the scribe. Groups then asked the scribe questions.

The argument activity worked well however it should improve as the pupils are not used to this sort of activity. In supporting the groups the underlying problems revolved around getting them to think of evidence that they know of or experiments they could do to disprove their ideas.

To restructure: get pupils to find evidence of human modification by looking at papers, press sites, then looking for arguments to support these changes through their own beliefs, personal experiences and evidence from press and internet.

Figure 5 Martin's Lesson Plan onVolcanoes and Earthquakes

Lesson Outcomes:

Science content

Explain why scientists cannot yet accurately predict when earthquakes and volcanic eruptions will occur.

Ideas and evidence

Uncertainties in scientific knowledge. These are especially likely in complex situations [I&E (d)].

Key skills/thinking skills

- Communication: contribute to discussion
- Reasoning: make deductions, and judgements informed by evidence
- Enquiry skills: predict outcomes.

Context:

The class has been studying rocks and in the previous lesson we looked at volcanoes, earthquakes and plate tectonics.

Resources

Prepare for learning – scrolling power point of volcanoes and earthquakes with music – *You make the earth move under my feet*.

Class set of earthquake-volcano worksheets

Time	Pupil	Teacher
5mins	Pupils to watch slide show (on entry)	Register
5mins	Discuss in pairs what they think could be the causes of earthquakes and volcanoes. Come to agreement on the causes	
5mins	Pupils will put forward ideas – have to decide if it can be backed by evidence	Ask pupils for ideas – record on white board
15mins	In each group one person is to read the text for the group. Followed by the questions.	Introduce the activity – set up rules. For forces of

	They are to discuss the answers as a group following the talking rule. The scribe writes down the answers. The scribe moves to a second group to read the answers to them. The group can ask the new scribe questions but must have pen in hand. Pupils get into expert groups	Nature. When talking only the penholder can talk. Ask for comments from groups on questions
5mins	Pupils read through agenda in silence	
2mins		Go through main activity and the agenda and set the rules
15mins	Pupils are to discuss the expert cards – one speaker at a time – they can highlight and/or make notes. Pupils then work through the agenda in the order set. Penholder to speak and pass on pen	Assign roles for group activity
30mins	To complete table and answer questions	Call meeting groups together
10mins	Pupils respond and make contributions to class	Bring class together to discuss questions and answers
		Set homework which is to complete predication question
	Plenary – pupils give way in which scientists make predications	

Figure 6 Martin's Examples of student work from the volcanoes lesson

Student 1

1. Scientists can only say there might be a eruption
2. Scientists can only collect indirect evidence of changes in earth's surface magma near the surface – small eruption of magma inside the volcano – big eruption.
3. Predication can lead to false alarms – rising magma can freeze and stop
4. Volcanoes can erupt without warning

This [is a] good example of using evidence to back up an answer/response to questions

Student 2

We should spend money on preparing the town so it can survive the disaster.
It is better to protect the town because you'll be saving money as if you spend it making predictions you won't have more money to take any action.

This student has made a suggestion but not actually considered and included evidence.

Student 3 Forces of nature

Because they have no warning
Because they can't escape quickly
People would flee the country – evacuation
Death can be prevented in earthquakes by putting more support on houses by making it heavier so the vibrations can't tip it over.
Conclusion
Our conclusion [they would spend money in the following proportions] 15% predicting earthquakes, 15% predicting volcanoes 60% stronger homes

This [is a] good example of using evidence to back up an answer/response to [the] question.