Getting Practical

Getting Practical – the evaluation

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ABSTRACT The findings from the Improving Practical Work in Science (IPWiS) evaluation suggest that the project can, and did, bring about noticeable improvements in the effectiveness of practical work in school science. However, the extent of these improvements varied widely and appeared to be dependent on the departmental seniority of the person undertaking the training, their commitment to the project and the extent of support from the school's senior management team. It was also found that the IPWiS project had a much less noticeable effect on the way primary teachers taught science, as much of what IPWiS set out to achieve was already taking place in primary science lessons.

The frequent and extensive use of practical work – activities in which the students manipulate and observe real objects and materials – in many countries (Bennett, 2003) is one of the characteristic features of school science in England. Yet, despite its widespread use, Lunetta, Hofstein and Clough (2007: 433) have suggested that '*Much more must be done to assist teachers in engaging their students in school science laboratory experiences in ways that optimize the potential of laboratory activities as a unique and crucial medium that promotes the learning of science concepts and procedures, the nature of science, and other important goals in science education*'. The Improving Practical Work in Science (IPWiS) project set out to contribute towards just such an improvement in the quality of practical work and this study was designed to evaluate its impact on the way in which practical work is used in English primary and secondary school science.

The project was led by the Association for Science Education (ASE), who created a package of continuing professional development (CPD) materials for the project (Figure 1). These materials were designed by a consortium that included the National Science Learning Centre, regional Science Learning Centres (SLCs), CLEAPSS, the University of York, the National Strategies and the Centre for Science Education at Sheffield Hallam University. The course materials were designed to help teachers reflect on and improve:

- the clarity of the learning outcomes associated with practical work;
- the effectiveness and impact of the practical work;
- the sustainability of this approach within their schools, allowing for ongoing improvements;
- the quality, rather than quantity, of practical work used.

The IPWiS project, which ran for two years and involved 200 trainers, trained over 2000 teachers from both primary and secondary schools. The initial 200 trainers attended 'train the trainer' events at their regional SLCs during the autumn terms of 2009 and 2010. The project then used a cascade model in which these 200 trainers then ran training sessions themselves for schoolteachers in their own local areas who, in turn, it was hoped would cascade down the training a further level within their own schools (primary) and departments (secondary). The course was designed for flexibility and the 6 hours of training could be delivered through a single (whole-day) 6 hour session, a pair of 3 hour sessions (two half-day courses) or three 2 hour sessions (twilight courses), with individual trainers deciding on which approach to use to best meet the needs of their local teachers. Some training courses

Figure 1 A CPD session at an ASE conference

were run only for primary or only for secondary teachers while others hosted mixed groups, and this again depended on the choice of the local trainer. Teachers working in both primary and secondary levels, and at all stages of their careers, attended the training sessions (Figure 2). All three secondary science main subject specialisms were represented by the secondary teachers. Technicians were also encouraged to undertake the training to enable them to better understand how practical work can be improved and to enhance the support they can offer teachers in practical lessons.

A framework for considering the effectiveness of practical work

Practical work encompasses a broad range of activities that can have widely differing aims and objectives (Lunetta and Tamir, 1979). As such, the effectiveness of *specific* practical tasks, rather than the effectiveness of practical work in general, is what needs to be considered. While the analytical framework used in this evaluation has been discussed in detail previously (Abrahams, 2011; Millar and Abrahams, 2009), it can be summarised relatively easily by thinking about practical work in terms of *doing* things with objects and ideas and/or *learning* about objects and ideas. For some activities, the teacher just wants the students to 'do things' with objects or materials in order to see a phenomenon or an event, and remember what they saw. Such activities, usually described as 'hands-on', are essentially just about 'doing' things. For others, the aim of the teacher is to help students understand some of the ideas that science uses to describe or to explain what they observe – and these only really make sense as activities if you look at them from the perspective (or 'through the spectacles') of a particular set of ideas. For such activities, thinking is as important as doing and such activities can be thought of as being both 'hands-on' *and* 'minds-on'.

Research strategy and methods

Permission was asked of 10 primary teachers (key stages 1 and 2) and 20 secondary teachers (key stages 3, 4 and 5), who had registered to undertake the IPWiS training, to observe two of their practical lessons: one before the training to provide a bench mark of their practice, and another after the training was completed to evaluate any changes in both their and their department's use of practical work. All three of the authors undertook observations which were audio-recorded interviews that were carried out with the teacher before and after the lesson. The pre-lesson interview was primarily used as a means of obtaining the teacher's account of the practical work to be observed and of his or her view of the learning objectives of the lesson. The post-lesson interview collected their reflections on the lesson and its success as a teaching and learning event. Furthermore, when the opportunities arose, other members of the department were questioned about their knowledge and understanding of the

Figure 2 Teachers receiving training in practical work

IPWiS project. In addition to audio-recording all teacher–whole-class discussions and instructions, conversations between groups of students, and between students and the researcher, were also recorded. These conversations, in addition to field notes that were made, provided insights into the students' thinking not only about the task(s) that they were observed undertaking but also with regard to their recollections of other previous practical tasks that they had undertaken.

The schools within the evaluation were selected by the ASE as 'typical' primary and comprehensive secondary schools in England in terms of size, and with a spread of geographical locations. It should, however, be noted that the selection process was not designed to meet the statistical sampling requirements associated with traditional, large-scale, quantitative research but rather with ensuring what Bell *et al*. (1984: 75) refer to as 'naturalistic coverage'. While we had no control over the subject matter or the age of the students in the lessons observed, a reasonably balanced coverage of subject material and age ranges was achieved (Table 1).

While two primary and eight secondary teachers were unable to take part in the second, post-training, observation, the fact that data saturation was achieved, in terms of the types of thing the students and teachers said and did, indicates that the second round of observations provided a reliable reflection of the impact of the IPWiS training.

Table 1 Lesson observations by student age range and subject

School type	Student age range (years)	Subject			
		Biology	Chemistry	Physics	Other (Earth Science)
Primary	5–7	2 (0)	1 (0)	5 (2)	0 (0)
	7–11	0 (2)	1 (1)	1 (3)	0 (0)
Secondary	11–14	4 (3)	3 (3)	6 (3)	1 (0)
	14–16	1 (0)	2 (1)	0 (0)	0 (0)
	16–18	1 (1)	1 (1)	1 (0)	0 (0)

Brackets indicate second-round observations. Primary school 'science lessons' have been classified as biology, chemistry or physics so as to present an overview of the range of subject areas observed across all age ranges.

Pre-training observations

Primary schools

What emerged from the first round of observations was how well-conceived, clear and productive practical science was in most of those primary schools visited. One possible explanation for this – an explanation that could strike some as paradoxical – might be that the lessons observed were, in all but one case, taught by teachers who were not science subject specialists in the sense that the term 'science subject specialists' is understood by secondary science teachers. Indeed, not only were the teachers not science specialists, but some of them spoke to us about their own difficulties with scientific ideas and the meanings of certain scientific terms (Harlen and Holroyd, 1997). As a consequence of the difficulties they themselves encountered with some aspects of science, they appeared better able to empathise with the problems that their students faced when learning about new ideas in science, and the meaning of new scientific terms, than were many secondary subject specialists.

The primary teachers used practical tasks that were tightly constrained, of the kind that have been termed 'recipe'-style (Clackson and Wright, 1992), as a means of ensuring that all of their students were able to see the desired phenomena in the time available. Furthermore, by using relatively short practical tasks embedded within a lesson rather than taking up the entire lesson, the teachers ensured that they had sufficient time to introduce students to, and fully discuss, new scientific terms and ideas in the way that it has been suggested (Abrahams, 2011) is necessary if teaching and learning are to be effective in developing conceptual understanding. Certainly, our observations suggest that primary teachers see practical work as both a 'hands-on' *and* 'minds-on' activity.

The findings of these baseline observations draw attention to characteristics of current good practice in the use of practical work in primary science teaching. They suggest an understanding of the need to ensure that practical work does not just involve 'doing' with observables but also requires students to think about, and engage with, scientific ideas and terms.

Secondary schools

The practical work that we observed throughout the 20 secondary schools was, generally speaking, effective in enabling most of the key stage 3, 4 and 5 (age range 11–19 years) students, irrespective of their academic ability, to do what the teacher wanted them to do with observables and, in so doing, produce the required phenomena. While various factors contributed towards this effectiveness, two of the most noticeable were the use of recipe-style tasks, designed to produce a particular phenomenon reliably if those undertaking it adhered to the recipe, and the allocation of more time to the presentation and clarification of procedural instructions than allocated by many of their primary colleagues.

Because a particular piece of practical work was likely to be considered as having 'failed' if the students were unable to produce the desired phenomena, teachers tended to focus their attention on ensuring that students were able to follow instructions in order to maximise the likelihood that they would all successfully produce the desired phenomena. Time constraints, and the fact that 'doing something with ideas' was not a prerequisite for the successful production of phenomena, meant that when using recipe-style tasks teachers devoted relatively little whole-class time to getting the students to do what they wanted them to do with ideas; that is, to think about the observables and phenomena they were seeing in a particular scientific way. Even when teachers did allocate time to getting the students to 'do things with ideas', the ideas were kept relatively simple to ensure that there was sufficient time not only to get the students to think about the observables and phenomena, using the intended ideas, but also to get them to produce the desired phenomena.

We would emphasise here that 'recipe following' should not necessarily be seen as a patronising term. You do not, for example, need to understand why doing what you do produces the right sort of choux pastry if you want to make profiteroles, or need to have an underlying mental model about the behaviour of gluten, although, in science we do, generally speaking, want to develop such an understanding of the underpinning conceptual models.

Practical work was found to be more effective in getting students to learn what the teacher intended about observables and phenomena than it was in getting them to learn about ideas. A possible explanation for this is that to be effective in getting students to learn what the teacher intended about observables and phenomena requires only that they are able at some later time (such as in an examination) to describe qualitatively what they have seen, and/or be able to formulate simple relationships about observables. Given the observed effectiveness of practical work in enabling students to produce the desired phenomena, it seems reasonable to expect that most students will be able to achieve what are essentially intellectually undemanding learning objectives.

Yet, while some students were able to describe their observations and/or formulate simple relationships about the data during or immediately after the practical lesson, most were unable, without assistance, to recollect more than a few examples of the practical work that they had undertaken during their time at secondary school. Indeed, when asked, their recollections were found to relate primarily to practical tasks that were, in some sense, 'unusual'; furthermore, these recollections related almost exclusively to what had made that particular task – or something associated with it – unusual rather than to what the teacher might have intended them to learn and recollect. For example, students recollected the burning of magnesium ribbon in so far as they remembered that it had been visually spectacular, but there was no evidence that such 'memorable events' (White, 1979) provided any anchor point, or 'trigger', for associated scientific ideas that might have been learnt within the teaching sequence in which the practical lesson was embedded.

In terms of getting students to learn about the ideas intended by the teacher, all of the observed practical lessons were either wholly or to a large extent ineffective. One way of helping to understand the reason for this is to think of the 'learning about ideas' as being the last step in a process that depends necessarily on the students having succeeded not only in doing and learning what the teacher intended about observables and phenomena but also in doing what the teacher intended with ideas. A failure adequately to achieve any one, or more, of these prerequisites adversely affects the students' ability to learn about the ideas intended by the teacher within that particular practical lesson. Indeed, the strong emphasis placed by the teachers on getting the students to 'produce the phenomena' resulted in them not including in their lesson plans the need to devote teaching time specifically to providing the conceptual 'scaffold' that is required to help with the development of the students' conceptual understanding.

Post-training findings

Doing with objects, materials and ideas

The overall impression to emerge from the observations of lessons after the teachers had completed their IPWiS training was that primary and secondary teachers continued to see the production of the intended phenomena and/or collection of the intended data by the majority of students in their class as being central to the success of a practical lesson. In this respect, the continued widespread use of recipe-style tasks meant that in both primary and secondary schools practical work remained highly effective in enabling most of the students to successfully do what their teachers wanted them to, using the objects and materials provided.

While 'doing with objects and materials' is self-explanatory, 'doing with ideas' is less self-evident and refers to the process of using scientific terminology as well as thinking and talking about objects and materials, using theoretical entities or constructs that are not themselves directly observable. While the overwhelming majority of the practical work we observed in our post-training visits, in both primary and secondary schools, was effective in enabling students to do what their teacher wanted them to do with objects and materials, primary teachers were, compared with their secondary colleagues, more effective in getting their students to 'do with ideas'. This was essentially as a result of teachers devoting whole-class time to students learning the meaning of the new scientific words or concepts rather than the teachers being more effective in getting the students to talk about objects and materials in terms of theoretical entities or constructs that are not themselves directly observable.

Although IPWiS did bring about improvements in the effectiveness of practical work in some secondary schools, the extent of this depended upon *who* undertook the training, their commitment to the IPWiS project ideas and the extent to which the training and its implementation within the department or school had the explicit support of the school's senior management team. It also emerged that the IPWiS project had a much less noticeable effect on the way primary teachers used practical work since much of what IPWiS set out to achieve was already taking place in primary science lessons.

Owing to the differences between the impacts that IPWiS had on primary and secondary teachers, the findings will be presented separately.

Primary school impact

The most notable finding to emerge from the post-training observations of primary school teachers was the extent to which there was a feeling that the IPWiS 'message' was nothing new and that primary teachers had been doing just what IPWiS was suggesting teachers do, in some cases for many years. As one primary teacher explained:

A lot of the stuff we'd already had training on before … I just feel that a lot of the stuff that was covered [on the IPWiS training] *was things that on other science training* [courses] *I'd been on I'd already learnt.*

Yet, despite this, some of the primary teachers, as the following example illustrates, spoke of being more aware of the need to ensure that their practical lessons contained fewer learning objectives than might previously have been the case:

It made me focus more on specific objectives. I think before [the IPWiS training] *I would try to do too much in the whole lesson.*

Overall, the findings showed that, while the IPWiS training had been effective in getting primary teachers to think more critically about some of the issues relating to the effectiveness of practical work, it had had little impact on their actual practice in terms of doing with objects, materials and ideas. This should not be seen as a criticism of either the primary teachers themselves or the IPWiS training, but rather reflects the fact that much of what IPWiS set out to achieve, certainly in terms of 'doing with ideas', was already taking place in primary science lessons.

Secondary school impact

The impact of the IPWiS training on secondary teachers varied considerably and this variation was seen to depend on not only who undertook the training, their role/seniority within the department and their enthusiasm for the project, but also the extent to which the aims of the project had active support from members of the school's senior management team.

Upland Community College (their head teacher gave permission to mention them by name) clearly shows what can be achieved when conditions are close to 'ideal'. In this case, it was the head of science who undertook the training, saw tremendous value in the material being delivered, and returned to the school keen to implement the IPWiS project ideas across the department as a whole. The senior management team within the school was fully committed to supporting the full-scale implementation of the required changes in the Science Department's schemes of work in order to bring them more into line with the ideas about the use of practical work as suggested by the IPWiS training. The senior management team also provided time to enable a full and effective cascade of ideas to occur not only for the members of the school's own Science Department but also for the teachers of science in the school's feeder primary schools. A very noticeable change in classroom practice was evident as, compared with the first (pre-training) observation, the second lesson now only focused on a few, clearly identified, learning objectives, and was very much a 'hands-on' *and* 'minds-on' lesson. The structure of the lesson had also changed so that rather than the practical task taking up a large proportion of the lesson it was, in the post-training lesson, relatively short and embedded within the lesson and was only started *after* the students had engaged with the ideas that would enable them to understand their observations. Other members of the department showed in discussions that they too, as a result of the training being cascaded down to them, were familiar with the ideas of the IPWiS project. Not only did they talk positively about changes to the way that they now used practical work but they also said that they had begun to undertake regular peer observations of each other's use of practical work that were designed to help reinforce the IPWiS message within the department.

While Uplands shows what can be achieved, the impact in the other secondary schools was much less evident. There were various reasons for this, including the seniority and role of the person undertaking the training. Another particularly noticeable problem in getting the IPWiS 'message' heard in schools was the evident weakness of the cascade model of training used within the IPWiS project.

Conclusions and implications

Two main findings have emerged from this evaluation. First and foremost is the fact that the IPWiS project can, and did, bring about substantial change in both the use and effectiveness of practical work. However, the extent of that change varied widely and, while many secondary teachers appeared to understand the IPWiS project 'message' and *claimed* that it had changed their practice, our evaluation would suggest that for most secondary teachers we observed their actual use of practical work remained relatively unchanged as a result of the training. The primary teachers also appeared to be aware of the IPWiS 'message', but their own pre-training practice was already exhibiting many of the good characteristics about the need to 'do with ideas' that the project was intended to develop and, as such, very little change was observed in the way they used practical work. However, despite the fact that many primary and secondary teachers included the learning of scientific ideas among their learning objectives for practical lessons, in addition to which many primary teachers devoted an appreciable proportion of their practical lessons to 'doing with ideas', there was little evidence to show that primary or secondary teachers recognised the need to plan *explicitly* how they wanted to get their students to learn about ideas. This was in marked contrast to the way in which their lesson plans, and recipe-style tasks, typically made explicit what they wanted their students to do with objects.

Second, the impact of the IPWiS project within a particular school was seen to depend upon who undertook the training, that is, whether they were a head of department or a newly qualified teacher (NQT), and the extent to which the school's senior management team was supportive and proactive in wanting the IPWiS project ideas to be implemented.

The principal implications of these findings are that, while the IPWiS project was successful in raising primary and secondary teachers' *awareness* of how to improve the quality of the practical science work, *extended* and *sustained* continuing professional development (CPD) in this area is needed if lasting change to teachers' practice is to be achieved (Figure 3). Indeed, the CPD literature attests to the need for coaching and ongoing support if substantial changes are permanently to be made to practice (Joyce and Showers, 2002; Loucks-Horsley *et al*., 2003). We would suggest that the valuable work of the IPWiS project could be sustained beyond the lifetime of the project by integrating the IPWiS training into all Initial Teacher Education PGCE secondary science training programmes. We also feel that it is important to provide further sustained IPWiS-related CPD, particularly to secondary teachers, in order to consolidate and further develop the effective use of practical work within school science departments (Figure 4). We would suggest, given that the cascading of any such additional training is more likely to occur if the person attending the CPD is a senior member of the science department, that such CPD should be made available, in the first instance, only to heads of department. Recognising the importance that sustained CPD can play in terms of improving the quality of practical work, we would also suggest the need to develop centres of training

Figure 3 CPD at a specialist school in technology for 11- to 18-year-olds

Figure 4 Science department CPD

excellence and that, in the UK, the most suitable vehicle for doing so would seem to be the national and regional Science Learning Centres.

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